Chapter 20

INNOVATION AND ECONOMIC DEVELOPMENT

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Abstract

Innovation is often seen as carried out by highly educated labor in R&D intensive companies with strong ties to leading centers of excellence in the scientific world. Seen from this angle innovation is a typical "first world" activity. There is, however, another way to look at innovation that goes significantly beyond this high-tech picture. In this broader perspective, innovation—the attempt to try out new or improved products, processes, or ways to do things—is an aspect of most if not all economic activities. In this sense, Section 1 puts forward the idea that innovation may be as relevant in the developing part of the world as elsewhere. Section 2 discusses the existing theoretical and empirical literature on the subject. An important conclusion is that to be able to exploit technology to their own advantage, developing countries need to develop the necessary capabilities for doing so. But what are these capabilities and how can they be measured? Section 3 surveys attempts to identify and measure capabilities at the national level. However, the development of such capabilities, it is argued, depends in important ways on what firms do. Section 4, therefore, focuses on recent attempts to survey innovation activity in firms in developing countries and what can be learnt from that. Section 5 discusses the role of domestic versus foreign sources in fostering innovation in the developing part of the world. The final section summarizes the main lessons.

Keywords

development, innovation, innovation surveys, measurement, openness

JEL classification: O14, O19, O31, O33, O40

1. Introduction

Is innovation important for development? And if so, how? The answers to these questions depend, we will argue, on what is meant by the term innovation. One popular perception of innovation, that one meets in media every day, is that it has to do with developing brand new, advanced solutions for sophisticated, well-off customers, through exploitation of the most recent advances in knowledge. Such innovation is normally seen as carried out by highly educated labor in research and development (R&D) intensive companies, being large or small, with strong ties to leading centers of excellence in the scientific world. Hence innovation in this sense is a typical "first world" activity.

There is, however, another way to look at innovation that goes significantly beyond the high-tech picture just described. In this broader perspective, innovation—the attempt to try out new or improved products, processes, or ways to do things—is an aspect of most if not all economic activities (Bell and Pavitt, 1993; Kline and Rosenberg, 1986). It includes not only technologically new products and processes but also improvements in areas such as logistics, distribution, and marketing. Even in so-called low-tech industries, there may be a lot of innovation going on, and the economic effects may be very large (von Tunzelmann and Acha, 2004). Moreover, the term innovation may also be used for changes that are new to the local context, even if the contribution to the global knowledge frontier is negligible. In this broader sense, innovation may be as relevant in the developing part of the world as elsewhere. Although many of the outcomes are less glamorous than celebrated breakthroughs in the high-tech world, there is no reason to believe that their cumulative social and economic impact is smaller (Fagerberg et al., 2004). In this broader perspective, innovation becomes as important for developing countries as for the rich part of the world, an argument which is also strongly supported by evidence from the surveys of innovation activities in firms referred to below.

It is fair to say that the question of how technology and innovation influence economic development is a controversial issue, and has been so for a long time (Fagerberg and Godinho, 2004). In Section 2 of this chapter we trace the discussions back to Torstein Veblen's writings about Germany's industrialization nearly a century ago. Here Veblen pointed to some of the issues, such as the nature of technology, the conditions for technological catch-up, etc., that have been central to the discussion to the present day. In fact, he was very optimistic about the possibilities for technological and economic catch-up by poorer economies. This optimistic mood came to be shared by neoclassical economists when they, nearly half a century later, turned their attention to the same issues. In this conception of reality, technology was assumed to be a so-called "public good," freely available for everyone everywhere. Hence, a common interpretation of neoclassical growth theory (Solow, 1956) has been that catch-up and convergence in the global economy will occur automatically (and quickly) as long as market forces are allowed to "do their job."

However, writers from several other strands, such as economic historians, with Alexander Gerschenkron (1962) as the prime example, or economists inspired by the revival of interest in Joseph Schumpeter's works that took place from the 1960s onwards, have been much less optimistic in this regard. According to these writers, there is nothing automatic about technological catch-up. It requires considerable effort and organizational and institutional change to succeed (Ames and Rosenberg, 1963). A central theme in the literature on the subject concerns the various "capabilities" that firms, industries, and countries need to generate in order to escape the low development trap. Following this perspective, countries that do not succeed in developing appropriate technological capabilities and other complementary conditions should be expected to continue to lag behind. Concepts such as "social capability" (Abramovitz, 1986; Ohkawa and Rostovsky, 1974), "technological capability" (Kim, 1980, 1997), "absorptive capacity" (Cohen and Levinthal, 1990), and "innovation system" (Edquist, 1997; Lundvall, 1992; Nelson, 1993) have been suggested and a burgeoning empirical literature has emerged focusing on these aspects of development (see Archibugi and Coco, 2005; Fagerberg and Godinho, 2004 for overviews). In Section 2 of this chapter we explore the different suggestions and consider the relevance for development.

Having dealt with what the literature on catch-up and economic growth has to say, we move in Section 3 closer to the empirical evidence on the subject matter. Until relatively recently there has not been much data available that could be exploited to explore the relationship between innovation and diffusion of technology on the one hand, and economic development on the other. But during the last few decades, national governments and international organizations started to devote more efforts to collect statistics on factors relevant for innovation and diffusion, and various attempts have been made to capitalize on these investments to produce indicators of the technological capabilities (or competitiveness) of countries, including the developing ones.

Although many of the data sources used to illustrate country-level technological capabilities reflect activities at the firm level, direct information on innovation activities of firms has been scarce. However, from the early 1990s, some countries, mainly in Europe, started to survey innovation activities in firms, and more recently such surveys have also been conducted in the developing part of the world. These surveys are based on a broad notion of innovation, including not only those that are "new to the world," and therefore have the potential to reveal important insights about innovation activities in such economies. We explore this ongoing work in Section 4 of this chapter.

Finally, in Section 5 we turn to another controversial issue, namely the extent to which technological activities in developing countries depend mainly on "spillovers" from the outer world. Much economic theorizing and applied work (see, e.g., Coe and Helpman, 1995; Grossman and Helpman, 1991) suggest that for all but the largest countries of the world, foreign sources dominate and much policy advice to developing countries has been based on this presumption. Critics contend that this is not only a question of access to technology but also about the ability to absorb it in a way conducive to development. We examine the evidence that has been brought to the table on this issue. Section 6 sums up our current knowledge about innovation and development.

2. Innovation, catching-up, and falling behind: Taking stock of the literature

This section provides an introduction to the main strands of literature of relevance for our topic. The so-called "old" neoclassical growth theory of the 1950s provides a useful starting point. As mentioned above this theory was based on the idea of technology as a public good, freely available to everybody anywhere and hence a powerful equilibrating force in the global economy. However, as we show, applied work based on this perspective soon confirmed that the optimistic scenario of this theory did not really fit the evidence, and this led to a search for alternative ways to understand the role of technology and innovation for economic development.

Another strand, which particularly gained currency during the 1980s and 1990s, although some contributions were older, was based on the work of several prominent historians (and other social scientists) who argued that in practice the successful exploitation of technology for development depends on the ability of a country to generate the necessary "capabilities" for doing so. What these capabilities are and how (and why) they matter are among the central questions addressed in the voluminous literature that has emerged and which we survey in the following. Some of the topics addressed in the "capability" literature, such as, for example, the role of institutions and policy for technological and economic development, are also central to the so-called "new growth theory" that developed from the mid-1980s onwards, and we discuss the implications of this approach for our topic towards the end of this section.

2.1. "Old" neoclassical growth theory: An optimistic scenario

Intuitively, most people easily accept the idea that knowledge and economic development are intimately related, and hence that access to knowledge should be regarded as a vital factor for developing countries. However, this is not the way development used to be explained by economists. From the birth of the so-called "classical political economy" more than 200 years ago, economists have focused on accumulated capital per worker when trying to explain differences in income or productivity. Similarly, differences in economic growth have been seen as reflecting different rates of capital accumulation. This perspective arguably reflects the important role played by "mechanization" as a mean for productivity advance during the so-called (first) Industrial Revolution, the period during which the frame of reference for much economic reasoning was formed.

Closer to our own age, Robert Solow adopted this perspective in his so-called "neoclassical growth theory" (Solow, 1956). Solow's model was based on standard neoclassical assumptions, such as perfect competition (and information), maximizing behavior, no externalities, positive and decreasing marginal products, absence of scale economies, etc. In this model, productivity growth results from increases in the amount of capital that each worker is set to operate. But as capital per worker increases the marginal productivity of capital declines, and with it the scope for further increases in the capital–labor ratio. Ultimately, the capital–labor ratio approaches a constant, and productivity growth ceases. In this long-run equilibrium gross domestic product, the capital stock and the labor force all grow at the same, exogenously determined rate.

However, to allow for long-run growth in GDP per capita, Solow (1956) added an exogenous term, labeled "technological progress." In this interpretation, technology—or knowledge—is a "public" good, that is, something that is accessible for everybody free of charge. Solow did not discuss the implications of this for a multicountry world but subsequent research based on the neoclassical perspective took it for granted that if technology—or knowledge—is freely available in, say, the United States, it will be so at the global level as well. The following remark by one of the leading empirical researchers in the field is typical in this respect: "Because knowledge is an international commodity, I should expect the contribution of advances of knowledge (...) to be of about the same size in all the countries... " (Denison, 1967, p. 282). On this assumption the neoclassical model of economic growth predicts that, in the long run, GDP per capita in all countries will grow at the same, exogenously determined rate of global technological progress.

The only factor left within this framework that could possibly explain differences in per capita growth across countries is so-called "transitional dynamics": since initial conditions generally differ, countries may grow at different rates in the process towards long-run equilibrium. A case can be made, then, for poor countries growing faster than the richer ones because countries where capital is scarce compared to labor (i.e., where the capital–labor ratio is low) should be expected to have a higher rate of return on capital, a higher rate of capital accumulation and higher per capita growth. To the extent that capital is internationally mobile and moves to the countries where the prospects for profits are highest, this tendency should be considerably strengthened. Hence, the gaps in income levels between rich and poor countries should be expected to narrow (so-called "convergence") and—ultimately—disappear.

It soon became clear, however, that this could not be the whole story. From the late 1950s onwards empirical research on factors affecting long-run growth grew steadily. Much in the same way as the postwar work on national accounts decomposed GDP into its constituent parts, the empirical research on growth attempted to decompose growth of GDP (so-called "growth accounting"). One of the first calculations of this kind was carried out by Moses Abramovitz (1956) in a historical study of US growth. His results indicated that only a small part of US productivity growth could be explained by factor growth. Thus, the major part of US productivity growth remained unexplained (the "residual") and had to be classified as so-called total factor productivity growth. Abramovitz's comment was: "This result is surprising (. . .) Since we know little about the causes of productivity increase, the indicated importance of this element may be taken to be some sort of measure of our ignorance about the causes of economic growth." (Abramovitz, 1956, p. 11). This result was soon corroborated by other studies (Denison, 1962; Kendrick, 1961; Solow, 1957) and has since been repeated many times for different data sets (see Easterly and Levine, 2001 for a good overview of the more recent evidence on the subject). Although several attempts have been made to "squeeze down the residual" as Nelson (1981) put it,[1] the result—that a theory that only focuses on factor growth is unlikely to explain long-run growth very well—is now generally accepted.

Moreover, what came to be seen as the central prediction of theory—that convergence between rich and poor countries should be expected—was shown not to be consistent with the facts either (Islam, 2003). In fact, the long-run trend since the Industrial Revolution has been towards divergence, not convergence in productivity and income. For example, according to the economic historian David Landes, the difference in income or productivity per head between the richest and poorest country in the world has substantially increased over the last 250 years (Landes, 1998). Although different sources may give different estimates for this increase, the qualitative interpretation remains the same.

2.2. *Knowledge and development*

This leads us back to where we started, namely the role of knowledge in growth. "Knowledge," or "knowing things," may take many forms. It may be theoretical, based on an elaborate understanding of the phenomena under scrutiny. But it may also be practical, based on, say, cause–effect relationships that have been shown to hold in practice, although a total understanding of the underlying causes may be

[1] Two avenues were followed "to squeeze down the residual." One has been to embody, as much as possible, technological progress into the factors themselves by adjusting for shifts in quality, composition, etc. (Denison, 1962; Jorgenson and Griliches, 1967; Madison, 1987). Another approach in this literature, originally developed by Denison (1962), has been to add other possible explanatory variables, such as structural change, economies of scale, etc. The list may in some cases be quite long. The reader is referred to the surveys by Madison (1987) and Fagerberg (1994) for more detailed accounts.

lacking. It may be created through search or learning but it may also be acquired through education or training or simply by observing what others do and trying to imitate it. The creation (or acquisition) of knowledge does not require an economic motive (or effect), although this is quite common. The subset of knowledge that deals with how to produce and distribute goods and services, which is what interest economists most, is usually labeled "Technology." An open question is whether the concept of technology only refers to knowledge about physical processes ("hardware"), or if it also includes knowledge about, say, how to organize/manage these ("software"). For the purpose of economic analysis, the latter, broad interpretation of the term is clearly the most meaningful. Arguably, mastery of physical processes is of dubious value if one doesn't know how to embed these in a well-organized production and distribution system.

As mentioned in the introduction the role of technology—and hence innovation—for catch-up processes has been a highly controversial topic for at least a century. Torstein Veblen, who is often credited with being the first to provide an analytical framework for the analysis of catch-up processes, provides a useful starting point for our discussion. In his analysis of Germany's catch-up *vis-à-vis* the then economically leading country, the United Kingdom, Veblen (1915) put forward the argument that recent technological changes had altered the conditions for industrialization in latecomer economies. In earlier times, he argued, the diffusion of technology had been hampered by the fact that technology was mostly embodied in persons, so that migration of skilled workers was a necessary prerequisite for its spread across different locations. However, with the advent of "machine technology," as he put it, this logic had changed (Veblen, 1915, p. 191). In contrast to the conditions that had prevailed previously, Veblen argued, this new type of knowledge "can be held and transmitted in definite and unequivocal shape, and the acquisition of it by such transfer is no laborious or uncertain matter" (Veblen, 1915).

Although Veblen did not use the terminology that is now commonly applied to the process he described, it is pretty clear what he had in mind. Effectively, what he was arguing is that while technology was previously "tacit" and embodied in persons, it later became more "codified" and easily transmittable. Hence, catch-up should be expected to be relatively easy, and was, under "otherwise suitable circumstances," largely "a question of the pecuniary inducement and (. . .) opportunities offered by this new industry" (Veblen, 1915, p. 192). Since the latecomers could take over the new technology "ready-made," without having to share the costs of its development, this might be expected to be a very profitable affair (Veblen, 1915, p. 249). This being the case, Veblen predicted that other European countries, for example, France, Italy, and Russia, would soon follow suit (he also mentioned the case of Japan).

As noted this perspective of technology was later wholeheartedly adopted by standard neoclassical economics. Following that approach, knowledge should be seen as a body of information, freely available to all interested, that could be used over and over again (without being depleted). Obviously, if this is what knowledge is about, it should be expected to benefit everybody all over the globe to the same extent, and cannot be used to explain differences in growth and development. It is understandable, therefore, that the first systematic attempts to use knowledge to explain differences in economic development did not come from economics proper but from economic historians (many of whom came to look at knowledge or technology in a rather different way from the prevailing view in economics). Rather than something that exists in the public domain and can be exploited by anybody everywhere free of charge, technological knowledge, whether created through learning or organized R&D, is in this tradition seen as deeply rooted in the specific capabilities of private firms and their networks/environments, and hence not easily transferable. Compared with the traditional neoclassical growth theory discussed earlier these writers painted a much bleaker picture of the prospects for catch-up. According to this latter view there is nothing automatic about catch-up: it requires a lot of effort and capability building on the part of the backward country.

2.3. What it takes to catch-up: The need for "new institutional instruments"

The economic historian Alexander Gerschenkron set the stage for much of the subsequent literature (Gerschenkron, 1962). Some countries are at the technological frontier, he pointed out, while others lag behind. Although the technological gap between a frontier country and a laggard represents "a great promise" for the latter, a potential for high growth through imitating frontier technologies, there are also various problems that may prevent backward countries from reaping the potential benefits to the full extent. His favorite example was the German attempt to catch-up with the United Kingdom more than a century ago. When the United Kingdom industrialized, technology was relatively labor intensive and small scale. But in the course of time technology became much more capital and scale intensive, so when Germany entered the scene, the conditions for entry had changed considerably. Because of this, Gerschenkron argued, Germany had to develop new institutional instruments for overcoming these obstacles, above all in the financial sector, "instruments for which there was little or no counterpart in an established industrial country" (Gerschenkron, 1962, p. 7). He held these experiences to be valid also for other technologically lagging countries.

Gerschenkron's work is often associated with his focus on investment banks, which he saw as critical in mobilizing resources for development. However, as pointed out by Shin (1996), it is possible to see his writings as an attempt to arrive at a more general understanding of the conditions for catch-up, focusing on the instruments—or capabilities to use a more recent term—that need to be in place for successful catch-up to take place and the roles that public and private sector actors may play in generating these capabilities. Shin also emphasizes the historically contingent nature of the capabilities needed for catch-up. For example, the factors that constrained German catch-up towards the end of the nineteenth century are not necessarily the same as those experienced by Japan in the early post World War II period or other Asian countries more recently. Hence, while the need for such capabilities may be a quite general phenomenon, their precise nature may well differ between historical time periods, industries/sectors, and levels of development.

2.4. Social capability and absorptive capacity

Moses Abramovitz, arguing along similar lines as Gerschenkron, also placed emphasis on the potential for catch-up[2] by latecomers. He suggested that differences in countries' abilities to exploit this potential might to some extent be explained with the help of two concepts, technological congruence and social capability.[3] The first concept refers to the degree to which leader and follower country characteristics

[2] He defined it as follows: "This is a potential that reflects these countries' greater opportunity to advance by borrowing and adapting the best practice technology and organization of more productive economies" (Abramovitz, 1994b, p. 87).

[3] The term "social capability" comes from Ohkawa and Rostovsky (1974).

are congruent in areas such as market size, factor supply, etc. For example, the technological system that emerged in the United States towards the end of the nineteenth century was highly dependent on access to a large, homogenous market, something that hardly existed in Europe at the time, which may help to explain its slow diffusion there. The second concept points to the capabilities that developing countries have to develop in order to catch-up, such as improving education (particularly technical) and the business infrastructure (including the financial system). Abramovitz explained the successful catch-up of Western Europe in relation to the United States in the first half of the post World War II period as the result of both increasing technological congruence and improved social capabilities. As an example of the former he mentioned how European economic integration led to the creation of larger and more homogenous markets in Europe, facilitating the transfer of scale-intensive technologies initially developed for US conditions. Regarding the latter, he pointed among other things to such factors as the general increases in educational levels and how effective the financial system had become in mobilizing resources for change.

The concept "social capability" soon became very popular in applied work. Nevertheless it is, as Abramovitz himself admitted, quite "vaguely" defined (Abramovitz, 1994a, p. 25) and this has left a wide scope for different interpretations. But although Abramovitz found it hard to measure, it is not true that he lacked clear ideas about what the concept was intended to cover. These are some of the aspects that he considered to be particularly relevant (Abramovitz, 1986, 1994a,b):

- technical competence (level of education)
- experience in the organization and management of large scale enterprises
- financial institutions and markets capable of mobilizing capital on a large scale
- honesty and trust
- the stability of government and its effectiveness in defining (enforcing) rules and supporting economic growth

A related concept that has become popular in the applied literature on growth and development is "absorptive capacity." The term itself is not new. In development economics it has been used for a long time, as the ability of a developing country to absorb new investments more generally (Adler, 1965; Eckaus, 1973). However, as the role of knowledge for growth and development became more widely recognized, it came to be associated with the ability to absorb knowledge. Rostow (1980, pp. 267–277) summarized this new perspective well: "economic growth depends on the rate of absorption of the existing and unfolding stock of relevant knowledge; the rate of absorption depends on the availability of both trained men and capital; the reason for the accelerated growth among (...) middle-income countries is that they have built up the stock of trained man-power (including entrepreneurs) to a position where they can accelerate the rate of absorption of the existing stock of knowledge."

Wesley Cohen and Daniel Levinthal, in an influential contribution (Cohen and Levinthal, 1990), applied the concept to the firm level. They defined it as "the ability of a firm to recognize the value of new, external information, assimilate it and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). In this meaning of the term it became widely used in analyses of international technology spillovers, which we discuss below (Section 5). Cohen and Levinthal saw absorptive capacity as dependent on the firm's prior related knowledge, which in turn was assumed to reflect its cumulative R&D. However, they also noted that the path-dependent nature of cumulative learning might make it difficult for a firm to acquire new knowledge created outside its own specialized field, and that it therefore was important for firms to retain a certain degree of diversity in its knowledge base through, among other things, nurturing linkages with holders of knowledge outside its own organization.

Although the focus of Cohen and Levinthal was on firms, many of the same considerations apply, as emphasized above, at more aggregate levels, such as regions or countries (Eaton and Kortum, 1999; Griffith et al., 2004; Keller, 1996), and the term has continued to be used at these levels as well. It should be noted, however, that the concept as used by Cohen and Levinthal combines three different processes into one, namely (1) search, (2) assimilation (or absorption) of what is found, and (3) its commercial application. Hence, it refers not only to "absorption" in the received meaning of the term, but also on the ability to exploit and create knowledge more generally. The authors defend this by arguing—with reference to relevant psychological literature—that the ability to assimilate existing and the ability to create new knowledge are so similar so there is no point in distinguishing between them (Cohen and Levinthal, 1990, p. 130). In contrast, Zahra and George (2002), in a review of the literature, argue that the skills required for creating and managing knowledge differ from those related to its exploitation and that the two therefore deserve to be treated and measured separately. They term the latter "transformative capacity." In a similar vein Fagerberg (1988) and Fagerberg et al. (2007), in an analysis of capabilities at the country level, distinguish between a country's ability to compete on technology (what they term "technology competitiveness") and its ability to exploit technology commercially independently of where it was first created (so-called "capacity competitiveness").

2.5. Technological capability

Gerschenkron and Abramovitz focused mainly on evidence from Europe and the United States. But from the 1970s onwards several studies of catch-up (or lack of such) in other parts of the world emerged. For example, there is by now an ample literature demonstrating that the catch-up of not only Japan (Johnson, 1982) but also other so-called "newly industrializing countries" in Asia (Amsden, 1989; Hobday, 1995; Kim, 1997; Kim and Nelson, 2000; Nelson and Pack, 1999; Wade, 1990) was associated with conscious capability building. One case which received much attention was the rise of Korea from being one of the poorest countries in the world to a first world technological powerhouse in just three decades. Linsu Kim, who made the authoritative study on the subject, used the concept "technological capability" (Kim, 1980) as an analytical device to interpret the Korean evidence. He defined it as "the ability to make effective use of technological knowledge in efforts to assimilate, use, adapt, and change existing technologies. It also enables one to create new technologies and to develop new products and processes. . ." (Kim, 1997, p. 4). Hence, the concept includes not only organized R&D, which arguably is a small activity in many developing countries, but also other capabilities needed for the commercial exploitation of technology.[4]

Kim's analyses were based on lessons from how Korean electronics firms, such as Samsung, gradually upgraded from a passive role of implementing imported technology, to a more active role of introducing incremental improvements, and eventually ventured into the forefront of innovation-based competition in the industry (the so-called implementation–assimilation–improvement sequence).

[4] In fact, the definition of technological capabilities by Kim is quite similar to that of absorptive capacity by Cohen and Levinthal (1990) and Kim (1997) uses the two concepts interchangeably.

He expected the requirements to become more stringent, in particular with respect to innovation capabilities, as countries climb up the development ladder. Thus, following this view, for a firm or country in the process of catching-up, the appropriate level of technological capability would be a moving target, in constant need of improvement (Bell and Pavitt, 1993).

It has become common in the literature (see, e.g., Dahlman et al., 1987; Kim, 1997; Romijn, 1999) to consider three aspects of technological capability: production capability, investment capability, and innovation capability. Production capability is needed to operate productive facilities efficiently and to adapt production to changing market circumstances. Investment capability is needed to establish new productive facilities and adjust project designs to suit the circumstances of the investment. Finally, innovation capability is required to create new technology, for example, develop new products or services that better meet the specific requirements of the market.

The origin of the technological capability concept can be traced back to a project on "The Acquisition of Technological Capability" organized by Larry Westphal at the World Bank in the late 1970s, involving among others Alice Amsden, Jorge Katz, Linsu Kim, and Sanjaya Lall. The concept has since been used in a large number of studies at various levels of aggregation. Initially many studies following this approach concentrated on understanding the rapid technological catching-up in East Asia (Amsden, 1989; Fransman, 1982; Hobday, 1995; Kim, 1980, 1997) and the lack of it elsewhere, such as in Latin America (Fransman and King, 1984; Katz, 1984; Teitel, 1981), India (Lall, 1987), or the former centrally planned economies (Hanson and Pavitt, 1987). Similar concepts that were proposed at the time, but did not receive the same recognition, include "technological mastery" (Dahlman and Westphal, 1981; Fransman, 1982) and "technological effort" (Dahlman and Westphal, 1982).[5]

Although initially developed for analysis of firms, the concept has also been applied to whole industries or countries. Sanjaya Lall, in a survey (Lall, 1992), emphasized three aspects of "national technological capability" as he phrased it: the ability to muster the necessary (financial) resources and use them efficiently; skills, including not only general education but also specialized managerial and technical competence; and what he called "national technological effort," which he associated with measures such as R&D, patents, and technical personnel. He noted that national technological capability does not only depend on domestic technological efforts but also foreign technology acquired through imports of machinery or foreign direct investments (FDIs). Lall also made a distinction between technological capabilities proper and their economic effects. These effects, he noted, did also depend on the incentives that economic agents face whether resulting from political decision making (e.g., governance) or embedded in more long-lasting institutions (e.g., the legal framework). This reasoning is of course very similar to that of Abramovitz. Hence, potentially there is a considerable overlap between the concepts of technological and social capabilities: both include aspects related to skill formation and finance. We consider the implications of this in more detail in the next section.

The successful catch-up of a number of "newly industrializing" countries in the 1970s and 1980s also served as inspiration for the development of new perspectives on the dynamics of the global economy that placed the development of appropriate technological activities (or capabilities) at the core of the

[5] For good overviews of this literature see Dahlman and Westphal (1982), Dutrénit (2000), Evenson and Westphal (1995), Figueiredo (2001), Fransman and King (1984), and Romijn (1999). For the early literature see also the special issues of World Development (no. 5–6, 1984) and *Journal of Development Economics*, (no. 1–2, 1984). For a more recent account see the special issues of *Oxford Development Studies* (no. 3, 2004) and *International Journal of Technology Management* (no. 1/2/3, 2006).

analysis (Dosi et al., 1990; Fagerberg, 1987, 1988; Verspagen, 1991; for an overview see Fagerberg and Godinho, 2004). Fagerberg (1987, 1988) has suggested an empirical model based on Schumpeterian logic that includes innovation, imitation, and other efforts related to the commercial exploitation of technology as driving forces of growth. Following this approach, catch-up or convergence is by no means guaranteed. It depends on the balance of innovation and imitation, how challenging these activities are and the extent to which countries are equipped with the necessary capabilities. According to Verspagen (1991), who implemented similar ideas into a nonlinear setting that allows for both catch-up and a "low-growth trap," poor countries with a low "social capability" are the ones at risk of being "trapped." Moreover, evidence presented in Fagerberg and Verspagen (2002) suggests that the importance of innovation for development is increasing with time, highlighting the urgency of the matter for policy makers in the developing world.

2.6. National innovation systems

The observation that technological and social factors interact in the process of economic development might also be taken as supporting the view that a broader, more systemic approach that takes such interactions into account is required.[6] Such concerns led during the 1980s and 1990s to the development of a new systemic approach to the study of countries' abilities to generate and profit from technology, the so-called "national innovation system" approach. The concept, first used in public by Christopher Freeman in an analysis of Japan (Freeman, 1987), soon became a popular analytical tool for researchers who wanted to get a firmer grasp on the interaction processes underlying a country's technological and economic development (Lundvall, 1992; Nelson, 1993; see Edquist, 2004 for an overview). Organizations such as the OECD, the EU and the UN intensified their efforts to provide relevant statistics with which performance along these lines could be assessed. But the adoption of the innovation system approach to developing countries is a relatively recent phenomenon (Lundvall et al., 2006; Muchie et al., 2003; Viotti, 2002) and arguably still in its infancy.

Moreover, there is currently no agreement in the literature on how innovation systems should be defined and studied empirically. Some researchers in this area emphasize a need for developing a common methodology, based on the functions and activities of the system, to guide empirical work (Edquist, 2004; Johnson and Jacobsson, 2003; Liu and White, 2001), while others advocate the advantage of keeping the approach open and flexible (Lundvall, 2007).

2.7. New growth theory

During the 1980s and 1990s economists' interest in the possible role of knowledge (technology) for growth and development increased. On the theoretical front an important development was the emergence of the so-called "new growth theory" (Aghion and Howitt, 1992, 1998; Romer, 1986, 1990) according to which differences in economic development across countries should be understood as the outcome of differences in endogenous knowledge accumulation within (largely national) borders.

[6] Edquist (2004, p. 182), in a survey, argues that national systems of innovation should include "all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations."

Although some newly created technological knowledge may spill over from one country to another, there are according to this approach sufficient impediments to this process (being legal, such as intellectual property rights (IPRs), or more informal in nature) to secure that in most cases the lion's share of the benefits will accrue to the innovator. Hence, following this approach, long-run economic growth should to a large extent be expected to depend on appropriability conditions and the enforcement of IPRs. The increasing attention to IPRs in both developed and developing countries and their mutual relationship (e.g., the TRIPS agreement; see Granstrand, 2004) may to some extent reflect this shift of emphasis in economic theorizing. Moreover, the theory predicts that large countries should be expected to be more innovative, and benefit more from innovation, than small countries. According to the theory, the latter may to some extent overcome the disadvantages of scale by practicing free trade and taking a liberal stance towards international capital flows. Hence, following this approach, openness to trade and foreign investment is essential for countries that wish to catch-up (Coe and Helpman, 1995; Coe et al., 1997; Grossman and Helpman, 1991).

Although it is widespread view that openness to trade is a positive factor for growth, the evidence supporting this conclusion is quite weak (Fagerberg and Srholec, 2008; Rodríguez and Rodrik, 1999; Rodrik et al., 2004). In fact, it appears to be a fairly robust result in the literature that the degree of openness to international transactions, given by imports, inward FDI or royalty and license payments abroad, does not discriminate well between countries that manage to escape the low development trap and those that continue to be poor. However, this does not mean knowledge flows across borders are not important for growth and development. We discuss this in more detail in Section 5 of this chapter.

2.8. Capabilities and beyond

As our survey so far shows, there is by now a relatively large conceptual and applied literature on the role of capabilities in development. However, as should be evident from the discussion, scholars in this area have suggested alternative concepts that are to some extent overlapping and often difficult to operationalize. How can measures for concepts such as technological and social capability be defined or constructed? And how should the close relationship between technological capability proper and the broader social, institutional, and political framework, for example, "social capability," be taken into account in empirical work? The importance of these matters can hardly be questioned. Abramovitz, who pioneered much of this work, was, as noted above, quite pessimistic about the prospects for examining these questions empirically in a rigorous manner, but as we shall see, the availability of indicators has improved a lot in recent years, not the least for "noneconomic" aspects of development, and recent research has made real progress in dealing with these important and challenging issues.

3. Measuring national capabilities

As is evident from the preceding section, conceptual work on the role of "capabilities" and "innovation systems" for development has flourished during the last few decades. But to what extent can these concepts be operationalized empirically? Trying to put numbers on such concepts may be a difficult exercise, as Archibugi and Coco (2005) point out. Still there have been some attempts in that direction and in this section we will discuss this possibility in more detail. For example, Furman et al. (2002) and Furman and Hayes (2004) have suggested measuring a country's innovation system (or its "innovative capacity" as they put it) through the number of patents and find that there are large differences in this respect across countries at similar levels of income. However, patents refer to inventions, not innovations, and are used much more intensively in some industries than others. In fact, the global novelty requirement associated with patents implies that minor innovations/adaptations, which arguably make up the bulk of innovative activity worldwide, will not be counted since these are simply not patentable. Moreover, costs, both financial and opportunity, and the fact that in any case, their domestic IP systems may not function very well, may also lead to their low usage by inventors in developing countries. Thus, for countries below the technology frontier, and developing countries in particular, most of their innovative activities would get unrecognized by this approach. Most attempts to measure national technological capabilities or innovation systems in developing countries therefore try to take into account more information than just patents.

While commendable, and consistent with suggestions in the literature, taking into account more information also represents a challenge, both with respect to data availability and in terms of method. Such exercises easily run into problems because, typically, most developed market economies figure prominently among those with good coverage, while developing countries and former socialist economies often lack data on many potentially useful indicators. Based on the preceding discussion, Table 1, adapted from Fagerberg and Srholec (2008), presents an overview of various factors that has been identified in the relevant literature as being particularly relevant for the measurement of technological and social capabilities along with examples of possible empirical indicators.

As discussed earlier, the concept of technological capability refers to the ability to develop, search for, absorb, and exploit knowledge commercially. An important element of this is what Kim (1997) termed "innovation capability." There are several data sources that capture different aspects of this. For example, the quality of a country's science base, on which invention and innovation activities to some extent depend, may be reflected in articles published in scientific and technical journals. R&D expenditures measure some (but not all) resources that are used for developing new products or

Table 1
Measuring capabilities

Dimension	Measure
Science, research and innovation	Scientific publications, patents, R&D (total/business), innovation counts
Openness	Openness to trade, foreign direct investment, research cooperation/alliances with foreign partners, technology licensing, immigration
Production quality/standards	International (ISO) standards, total quality management (TQM), lean production, just-in-time
ICT infrastructure	Telecommunications, internet, computers
Finance	Access to bank credit, stock-market, venture capital
Skills	Primary, secondary and tertiary education, managerial, and technical skills
Quality of governance	Corruption, law and order, independence of courts, property rights, business friendly regulation
Social values	Civic activities, trust, tolerance, religious ethics, attitudes towards technology and science

processes, while patents count (patentable) inventions coming out of that process. However, R&D data are not available for many developing countries. Patent data, on the other hand, are available for all countries but as noted above many if not most innovations are never patented. So, as for many other indicators, this gives only a partial view of what we wish to measure. Firms' own judgments about their innovativeness (innovation counts) is another possible source of information but such data are only available for a relatively small number of countries and a limited time span (see, however, Section 4, and the chapter by Mairesse and Mohnen, this volume).

Openness (or interaction) across country borders may facilitate technology transfer (spillovers) and stimulate innovation. This issue is as mentioned above particularly emphasized in work inspired by the "new growth theories." The applied literature on the subject has mostly focused on four channels of technology transfer across country borders: trade, FDI, migration, and licensing (for overviews see Cincera and van Pottelsberghe, 2001; Keller, 2004, and this volume). Some of these data sources are in scarce supply for developing countries, especially the latter two, with predictable consequences for the research that has been carried out on this subject. We discuss this issue in more detail in Section 5 of this chapter.

Another important aspect of technological capability mentioned by Kim (1997) is "production capability." A possible indicator of this might be the adoption of quality standards (ISO 9000). Although ISO certification is mainly procedural in nature, it is increasingly seen as a requirement for firms supplying high quality markets, and is therefore likely to reflect a high emphasis on quality in production. Moreover, although earlier studies such as Lall (1992) did not place much emphasis on capabilities in information and communications technology (ICT), nowadays a well-developed ICT infrastructure must be regarded as a critical factor for a country that wishes to catch-up. Arguably this holds not only for production capability but for the ability to innovate as well. Possible indicators reflecting ICT use may be number of personal computers, internet users, and fixed/mobile phone subscribers. These indicators are available for most countries.

The important role that a country's financial system may play in mobilizing resources for catching-up was pointed out already by Gerschenkron, Abramovitz, and Lall. Kim included this in his definition of "investment capability." It is also emphasized by a host of recent research (see, e.g., King and Levine, 1993; Levine, 1997; Levine and Zervos, 1998). Authors in the capability literature attached a qualitative dimension to this that is difficult to measure with the available data. What we can measure is the (quantitative) development of the financial sector of a country, for example as reflected in the amount of credit (to the private sector) or by capitalization of companies listed in domestic capital markets.

A different set of factors, emphasized by for example Abramovitz and Lall, and for which there is solid support in the literature, relates to education and skills (Barro, 1991; Benhabib and Spiegel, 1994; Nelson and Phelps, 1966; Verspagen, 1991; for an overview see Krueger and Lindahl, 2001). Both Abramovitz and Lall were especially concerned about specialized managerial and technical skills but this is again an example of information that is hard to come by, especially for a broad sample of countries on different levels of development. What is available for most countries are more basic education statistics such as the literacy rate, the teacher–pupil ratio in primary schools and the rates of enrolment in secondary and tertiary education.

The importance of governance and institutions, furnishing economic agents with incentives for creation and diffusion of knowledge, is generally acknowledged in the literature. Although such factors often defy "hard" measurement, especially in a broad cross-country comparison, there exist some survey-based measures, often collected by international organizations, that may throw some light on these issues. For example, there now exists survey data reflecting how easy it is to set up and operate a business, the extent to which law and order prevails, independence of courts, whether (intellectual) property rights are enforced, political stability or how widespread corruption is conceived to be (Botero et al., 2004; Djankov, 2009; Djankov et al., 2002, 2003; Kaufmann et al., 2003; La Porta et al., 2004; Park, 2008; World Bank, 2009). All these aspects are potentially important for innovation and may, to some extent at least, be achieved within quite different political systems.[7]

However, the impact of government's actions on innovation activities and development outcomes may as pointed out by Abramovitz also depend on the prevailing social values in society such as, for example, tolerance, honesty, trust, and civic engagement. Such values, facilitating socially beneficial, cooperative activities, are often seen as expressions of so-called "social capital" (Putnam, 1993; for an overview see Woolcock and Narayan, 2000). The fact that the type of factors taken up by the literature on social capital may matter for economic development is widely accepted. For instance, Kenneth Arrow pointed out more than three decades ago that "It can plausibly be argued that much of the economic backwardness in the world can be explained by lack of mutual confidence" (Arrow, 1972, p. 357). The problem is rather how to measure it. One possible source of information that has been exploited to throw some light on the issue is the "World Value Survey." Knack and Keefer (1997) used such data to analyze the relationship between trust, norms of civic behavior, and membership in groups on the one hand and economic growth on the other for a sample of 29 (mostly developed) countries. However, the limited time and country coverage of these data has, until recently at least, precluded its extension to a sizeable part of the developing world.

Given the relatively large number of potentially useful indicators there is obviously a lot of information to exploit when attempting to use these data to measure the various capabilities identified in the literature. One of the key challenges is how to combine this rich information into a smaller number of dimensions (e.g., capabilities) with a clear-cut economic interpretation. The most widely used approach to construct composite variables is to select relevant indicators and weigh them together using predetermined (usually equal) weights (Archibugi and Coco, 2005). The problem in this case is that the choice of weights tends to be quite arbitrary. An alternative approach, pioneered by Adelman and Morris (1965, 1967), uses so-called "factor analysis" (Basilevsky, 1994) to advise on questions like these. This method is based on the very simple idea that indicators referring to the same dimension are likely to be strongly correlated, and that we may use this insight to reduce the complexity of a large data set (consisting of many indicators) into a small number of composite variables, each reflecting a specific dimension of variance in the data.

Fagerberg and Srholec (2008) used factor analysis on data for 115 countries and 25 indicators between 1992 and 2004. The analysis led to the selection of four principal factors jointly explaining about three quarter of the total variance of the set of indicators. The first (and quantitatively most important) of these loaded highly on several indicators associated with "technological capability" such as patenting, scientific publications, ICT infrastructure, ISO 9000 certifications, and access to finance. However, it also correlated highly with education, so it cut across the distinction in the literature

[7] Thus we find it useful to draw a distinction between, on the one hand, the "quality of governance" with respect to innovation and economic life more generally and the character of the political system on the other. The measures we discuss here concern mainly the former aspect (quality of governance).

between "technological" (Kim, 1997) and "social" capabilities (Abramovitz, 1986). They suggested to interpret it as a synthetic measure of the capabilities (or "factors") influencing the "development, diffusion, and use of innovations," quoting Edquist's (2004) definition of an innovation system, hence the name "innovation system" for this factor. Their findings are reproduced in Figure 1, which plots the innovation system factor score against GDP per capita for the countries covered by their investigation.

As is evident from the graph there is very close correlation between the "innovation system variable" and economic development as reflected in GDP per capita. To the extent that there are deviations from the regression line this primarily comes from a group of resource rich economies (OPEC countries for instance), having slightly higher GDP per capita levels than the quality of their innovation systems would indicate, and some of the former centrally planned economies for which it is the other way around. Fagerberg and Srholec's study indicates that the most advanced innovation systems are to be found in smaller countries (in terms of population) such as Australia, Denmark, and Norway.[8] These three countries, it may be noted, are low by international standards not only on patents but also on R&D, still they excel economically. Fagerberg and Srholec (2008) suggest that the explanation for this difference may be that these countries have well-developed capabilities for exploiting knowledge.

Table 2 presents a comparison of different composite variables aiming at measuring (national) technological and/or social capabilities (activities). The ArCo measure, developed by Archibugi and Coco (2004), was constructed as the average of eight different indicators reflecting various aspects of technological capability (patents, publications, ICT, electricity consumption, and education) for 162 countries in the late 1980s and 1990s. Hence it is by design a relatively broad measure. The technology and capacity competitiveness indexes developed by Fagerberg et al. (2007) were developed with similarly broad purpose in mind, as reflecting capabilities necessary for exploration and exploitation of technology, respectively. The SOCDEV variable, initially developed by Adelman and Morris (1965) and later updated by Temple and Johnson (1998), is an amalgam of structural indicators (share of agriculture, urbanization, etc.), socioeconomic characteristics (role of middle class, social mobility, literacy, etc.) and the development of mass communication (measured through the spread of newspapers and radios in the population). Temple and Johnson (1998) suggest using this as a measure of "social capability" or, alternatively, "social capital." Finally, the Human Development Index is assumed to reflect the level of "social" development (e.g., welfare) as reflected in statistics on health and education (UNDP, 2004).

The main lesson to be drawn from Table 2 is the very close correlation between these measures. For example, the correlation coefficient between the ArCo and the "innovation system" measures is 0.90. Hence the ranking implied by these measures appears robust. Second, there is a very close correlation between these measures and the Human Development Index, which to some extent is to be expected due to their overlapping nature. It is also consistent with the finding in the literature of a close relationship between technological and social capabilities (Fagerberg and Srholec, 2008).

The finding that economic development and capability building go hand in hand is suggestive. But correlation, it may be noted, is in itself no proof of causation. Fagerberg and Srholec (2008) provided

[8] This result differs from those reported by Furman et al. (2002) and Furman and Hayes (2004) which, based on evidence from patent statistics, emphasize large economies such as the United States, Japan, and Germany as being among the global leaders.

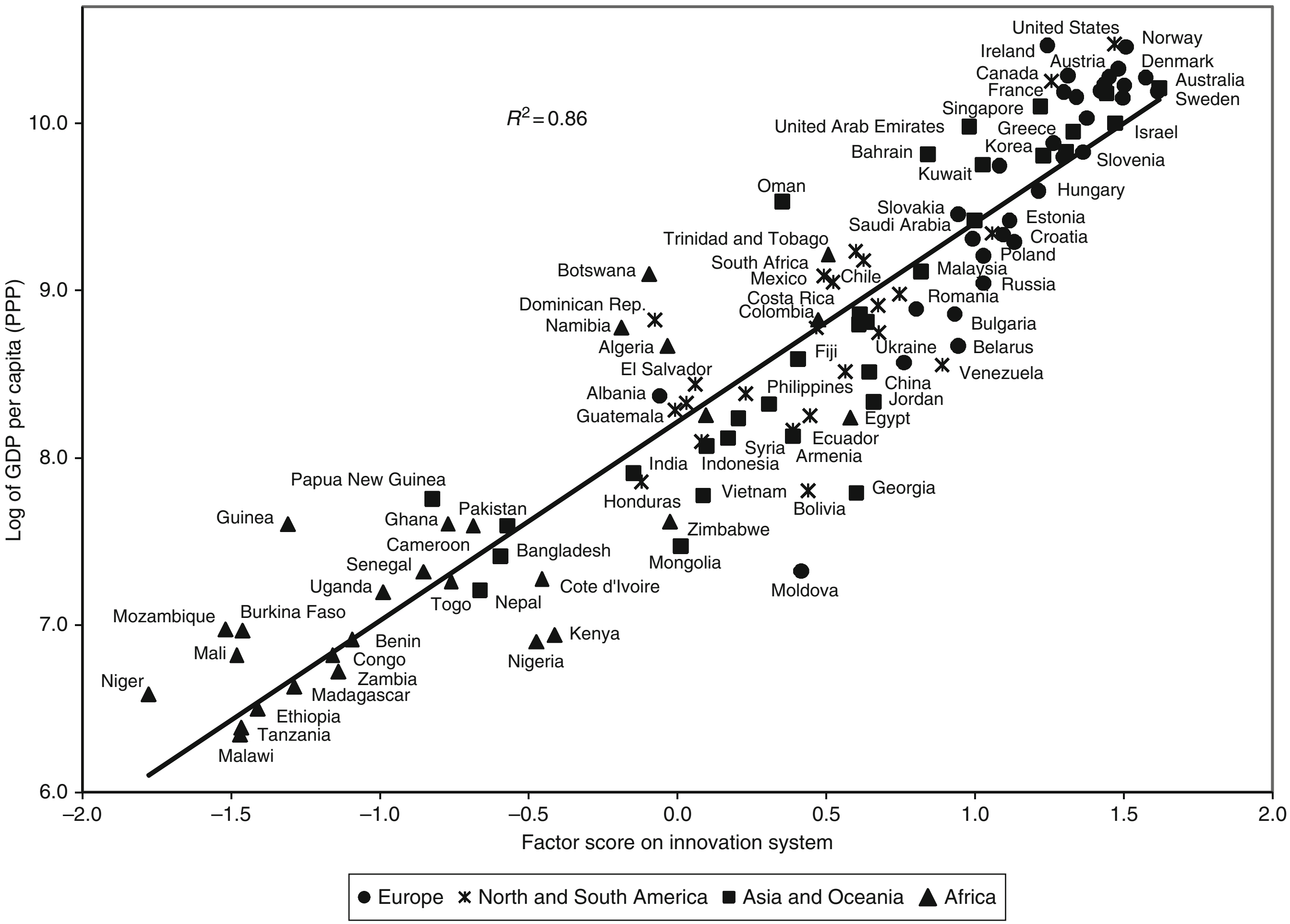

Figure 1. GDP per capita and innovation system (average level over 2002–2004). Source: Fagerberg and Srholec (2008).

Table 2
Correlation between measures of national capabilities

	Indicator	Reference	Reference period	(1)	(2)	(3)	(4)	(5)	(6)
(1)	ArCo	Archibugi and Coco (2004)	2000		0.90	0.93	0.92	0.85	0.89
(2)	Innovation system	Fagerberg and Srholec (2008)	2000–2004	115		0.74	0.85	0.89	0.96
(3)	Technology competitiveness	Fagerberg et al. (2007)	2002	90	79		0.84	0.53	0.72
(4)	Capacity competitiveness	Fagerberg et al. (2007)	2002	90	79	90		0.69	0.87
(5)	SOCDEV	Temple and Johnson (1998)	1957–1962	73	57	53	53		0.88
(6)	Human Development Index	UNDP (2004)	2004	154	114	89	89	68	

Note: Above the diagonal is the correlation coefficient between pairs of measures and below the diagonal is for each of these pairs the number of (common) observations.

some evidence (in the form of econometric tests) supporting the proposition that capability building affects development positively. However, since many of the relevant data sources used to measure capability building exist only for a few years (and in some cases for a single year only), there is very limited scope for causality testing. Hence the possibility that economic development in some sense affects capability building (or some aspects of it) positively cannot be excluded. As longer time series become available for many relevant data sources, it will be possible to learn more about these relationships and this is an important topic for future research.

Capability building may also be influenced by long-run factors related to the history of the country (Acemoglu et al., 2001, 2002), its geography, or nature (Alesina et al., 2003; Bloom et al., 2003; Gallup et al., 1999; Masters and McMillan, 2001; Sachs et al., 2004). Failing to take this into account may lead to biased inferences (with respect to policy, for instance). Fagerberg and Srholec (2008) found that unfavorable factors related to history, geography, and nature did indeed influence the possibility of developing a well-working innovation system negatively. They saw this as an additional argument for developing aid because it confirmed that some countries are much worse placed than others for reasons beyond the control of people living today (or their politicians).

4. Firm-level innovation in developing countries

In this section we move from the macro to the micro level; from the technological capabilities of countries to the innovation activities in firms. Traditionally, indigenous firms in developing countries have been portrayed as passive adopters of foreign technologies. However, as emphasized in Section 2, from the late 1970s insights about how firms operate started to reveal that technological catching-up required more than just import of capital goods. As the research has shown, even basic production capabilities cannot be taken for granted in the developing part of the world, and hence need to be created (Dahlman and Westphal, 1982; Fransman, 1982; Kim, 1980; Katz, 1984; Teitel, 1981 among others). Moreover, conditions in developing countries often turn out to be quite different from those in which the technology was originally developed, so that to be able to put it into efficient use, local firms need to adapt the imported technology to differences in inputs, tastes, customs, and cultures (Evenson and Westphal, 1995). In the process of doing so, creation of new knowledge and innovation may occur.

Arguably, a very sharp distinction between innovation and diffusion (or imitation), may not be very useful in the context of developing countries (Bell and Pavitt, 1993). Typically what happens, also in developed country settings, is that innovation tends to continue during the diffusion phase (Metcalfe, 1988; Rosenberg, 1972). So, even though firms in developing countries do depend heavily on diffusion of technology developed elsewhere, there may still be substantial scope for innovation and growth by improving the imported technology (Fransman, 1982; Hobday, 1995; Kim, 1997; Voss, 1988). Such incremental or minor innovations consist of context-specific improvements along the prevailing technological trajectories. However, although minor in a technological sense, these improvements can be of major economic significance (Hall, 2004).

It also needs to be emphasized that technological capability in developing country firms is much more than R&D. As Bell and Pavitt (1993) have pointed out, most firms in developing countries innovate on the basis of a broad range of capabilities. These are, they argue, typically concentrated in the departments of maintenance, engineering, or quality control (rather than in, say, a R&D department). This does not mean, however, that R&D is unimportant. For example, Kim (1980) emphasized the role of R&D efforts for firms' ability to assimilate foreign technology, especially at more advanced stages of development. Of great importance according to Kim (1980) is also dense interaction with other firms or organizations in the local environment—so-called "linkage" capabilities in the terms of Lall (1992)—which may help to unlock the internal constraints for innovation that often hinder firms in developing countries with insufficient internal technological capabilities to succeed in their endeavors. This, of course, concurs with the emphasis in recent literature (see Section 2) on seeing firms' innovation activities from a systemic perspective.

Figueiredo (2006), in a recent survey, points out that our knowledge about innovation in developing country firms has been constrained by the fact that the available evidence has been overwhelmingly qualitative in character. In general, these studies seldom comprise more than a small number of case studies, mainly of large firms, in a single industry or country. Definitions, typologies, and ways of measurement tend to vary from one study to another, creating problems for comparative work and efforts to generalize the findings. This state of affairs has also made it difficult to carry out statistical tests of the various hypotheses that have been asserted in the literature about innovation processes in developing countries.

It should be noted, though, that until recently, this situation applied to advanced countries as well. But from the early 1990s onwards efforts were made to collect more information on innovation activities of firms through surveys based on the so-called Oslo Manual (Smith, 2004). In the beginning these surveys were mostly confined to member states of the European Community, hence the label "Community Innovation Surveys" (CIS), but more recently a number of non-European countries, including some developing ones, have started to collect the same type of information (Blankley et al. 2006; Jaramillo et al., 2001; UNU-INTECH, 2004). These efforts resulted among other things in a manual (the so-called Bogota Manual, see Jaramillo et al., 2001) for how to carry out innovation surveys in developing countries. The authors of the Bogota Manual argued that the original Oslo-approach to innovation was too narrow and needed to be broadened to take into account factors such as organizational change, training, use of ICTs, etc. in a better way. These concerns subsequently led to revisions of the Oslo Manual, the third edition of which include a separate appendix on measurement of innovation in developing countries (OECD, 2005) based to a large extent on the Bogota Manual.

According to the third edition of the Oslo Manual (OECD, 2005, p. 46), "an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations." Arguably, this broad definition of innovation is close to the one originally offered by Schumpeter (1934). However, in the CIS survey it suffices for the innovation to be new to the firm, it does not necessarily have to be new to the market or to the world as a whole. Thus innovation in this sense includes activities that Schumpeter would have classified as imitation.[9] This departs somewhat from the Schumpeterian perspective, based on a relatively sharp distinction between innovation and imitation, but is consistent with the emphasis on incremental innovation and the close relationship between innovation and diffusion emphasized in the recent literature. However, from a comparative perspective this entirely subjective definition of innovation may also create problems, because something that would qualify as an innovation in one context may not do so in another.

4.1. Stylized facts

In Europe, several innovation surveys have been already conducted, from the early 1990s onwards. The results indicate a clear correlation between innovative activity and the level of development: the higher the level of GDP per capita the higher the share of firms reporting to take part in innovation activities. However, although innovation, especially of the product type, tends to be more frequent in more economically advanced settings, the figures also reveal that innovation is a quite widely dispersed phenomenon, not limited to the most developed parts of the EU.

Table 3 presents some main results from innovation surveys in countries in the process of development. We have chosen to include some countries that a few decades were rather backward but which since have managed to substantially reduce the difference *vis-à-vis* the developed part of the world, hence the term "catching-up economies." In cases where several surveys have been conducted we chose the most recent (which tend to be of higher quality).[10] It should be emphasized, however, that the figures need be treated with some caution, because there are differences in formulation of the questions, length of the reference period, and sampling methods (UNU-INTECH, 2004). To take just one example, some of these surveys have been limited to the manufacturing sector, for which the frequency of innovation is known to be higher than in the rest of the economy. Nevertheless, the result that innovation is quite frequent also in developing economies seems to be supported. About one fourth of firms reported to have innovated in China, where the survey conformed to high quality standards, and the results from Brazil or Turkey were not very different. In other cases, such as Thailand and Russia, the figures are markedly lower, though. This may have to do with the fact that the reference period was confined to a

[9] See Fagerberg (2003, 2004) for an extended discussion of the Schumpeterian contribution and different definitions of innovation.

[10] Several other developing countries, including Columbia, Cuba, Ecuador, Panama, Paraguay, Peru, Singapore, Trinidad-Tobago, and Venezuela, have also made attempts to collect similar data. Due to comparability concerns we have chosen not to include the results from these exercises here.

Table 3
Innovation surveys in catching-up economies

	GDP per capita (PPP)	Response rate (%)	Number of respondents	Reference period	% of firms with new or significantly improved	
					Product	Process
Slovenia	18,405	88	2960	02–04	20	22
Korea[a]	18,271	61	–	02–04	36	23
Taiwan	18,247	34	3356	98–00	28	33
Czech Republic	17,634	74	6188	03–05	27	30
Hungary	14,836	77	3950	02–04	14	13
Slovakia	12,803	73	2195	02–04	15	17
Estonia	11,892	79	2201	02–04	37	33
Croatia	11,639	77	3094	04–06	17	24
Poland	11,608	87	–	02–04	15	19
Argentina[a]	11,421	76	1627	02–04	39	37
Lithuania	11,042	94	1639	02–04	17	20
Latvia	10,101	–	2990	02–04	9	10
South Africa	9290	37	979	02–04	42	35
Chile[a]	9103	15	706	99–01	43	40
Russia	9101	–	–	04	Less than 10%	
Mexico[a]	9038	69	1515	99–00	27	24
Malaysia[a]	8496	19	749	00–01	32	27
Uruguay[a]	7981	98	814	01–03	23	26
Turkey	7460	–	–	04–06	22	23
Bulgaria	7212	80	13,710	02–04	14	8
Brazil	7196	–	10,600	01–03	20	27
Romania	7193	78	9180	02–04	15	18
Thailand	7091	43	2582	03	6	5
Tunisia	6812	79	586	02–04	51	49
China[a]	6043	82	31,436	04–06	25	25

[a] Manufacturing firms only.
Source: National statistical offices and other sources.

single year, which has implications for the propensity of firms to provide a positive answer. In the Russian case, however, several innovation surveys have been conducted with broadly similar results, indicating that the low level of innovation activity reported there may be a real phenomenon.

Another source of information on innovation in developing countries that deserves mentioning here is the Productivity and Investment Climate Survey (PICS) of the World Bank. In this survey, which covers around 50,000 firms in more than 100 (mostly) developing countries, firms were asked about various aspects of their business activities, including innovation and learning (World Bank, 2003). Table 4 summarizes some of the results with respect to innovation and development (GDP per capita in PPP, constant 2000 US$). Since we are concerned about the representativeness of the data, we include only datasets of around one thousand (or more) observations, which reduces the evidence to about two dozen surveys. Another concern is that despite the fact that these surveys are coordinated by the World Bank,

Table 4
Evidence on innovation from Productivity and Investment Climate Surveys organized by the World Bank

Country	GDP per capita (PPP)	Number of respondents	Reference period	% of firms that innovated	
				Product	Process
Questionnaire version 1					
China	2496	1498	1998–2000	21	30
China	2787	2375	1999–2002	24	33
Questionnaire version 2					
Poland	12,488	968	2002–2004	35	34
Turkey [a]	9302	1323	2003–2004	36	42
Brazil[a]	7883	1640	1997–2002	68	68
Thailand [a]	7224	1042	2005–2006	48	46
Thailand [a]	5933	1385	2001–2002	50	52
Egypt [a]	4332	977	2002–2003	15	11
Egypt[a]	4687	995	2004–2005	19	–
Morocco[a]	3107	831	2000–2002	25	35
India [a]	2004	2240	2003–2004	40	16
Vietnam[a]	1942	1149	2003–2004	44	45
Questionnaire version 3					
Mexico [a]	11,142	1119	2003–2005	35	34
Ukraine	6048	848	2005–2007	57	–
Nigeria [a]	1736	945	2004–2006	54	53
Bangladesh [a]	1071	1201	2004–2006	33	45
Turkey	10,870	1148	2005–2007	45	–

[a] Manufacturing firms only.
Source: World Bank (2003, 2008).

the questions about innovation have changed between different vintages of the questionnaire, which may have an impact on the reported results. To control for these differences, we group together countries with similar questionnaires.[11]

The overall impression from these data is, as before, that innovation is a quite frequent phenomenon in developing countries.[12] Similar to the CIS surveys, innovations in the PICS survey are new to the

[11] For example, in China, the first entry in the table, firms were asked whether they "entered new business line" and "introduced new process improvements." Firms in Brazil and other countries in the second group of countries in the table were asked variations around questions whether they "developed (successfully) a major new product line" and "acquired new technology that either substantially changed the way the main products are produced or allowed the production of new products." Much broader definitions were used in the most recent wave of the surveys, included at the bottom of the table, referring to "any new or significantly improved products" and "any new or significantly improved production processes including methods of supplying services and ways of delivering products."

[12] An intriguing finding is that, with an exception for China, the propensity to answer positively is much higher in the PICS than in the CIS surveys. We are not aware of any attempt to explain this result, which occurs in spite of the fact that the definitions are not all that different. The major difference between the two surveys is that in the CIS the questionnaire is more elaborate and the term "innovation" is used.

firm, not necessarily new to the market or to the world as a whole. However, since firms in developing countries can benefit from imitation of technologies already in use in the developed part of the world, they may—everything else equal—be more likely to introduce the "new to the firm" innovations than their counterparts in Europe or elsewhere. Probably much of this is related to diffusion of advanced technology from abroad—"innovation through imitation" as Kim (1997) puts it—rather than major "new to the world" technological breakthroughs. But as pointed out above this does not at all make these innovations less relevant economically.

4.2. Econometric studies based on CIS and PICS data

Stylized facts on the propensity of firms to innovate are informative but do not reveal much about factors that explain innovation in firms and about its effect on performance. To delve deeper into such issues researchers have attempted to use econometric models, and we discuss aspects of this work in the following. Tables 5 and 6 provide an overview of the studies taken into account here.[13]

A natural starting point is to look for variables explaining innovation, which is the question addressed by the first set of papers considered here (Table 5). The column to the far right lists the key explanatory variables taken into account. In spite of the fact that the models, samples, and methods differ, the results seem to be quite robust. First of all, as in developed countries, large firms are more likely to innovate than smaller ones but the latter tend to report relatively higher proportion of sales of innovative products. The age of the firm, on the other hand, is not a conducive factor for innovation. Firms with more well-developed technological capabilities, broadly defined (e.g., not only internal R&D but also capabilities in design, engineering, quality standards, adoption of ICT, marketing, management, and skills) are clearly more innovative. The same goes for firms that use external sources of knowledge intensively and interact actively with customers, suppliers, and other parts of the innovation system. These positive results do not carry over to measures of foreign ownership, which did not come out as significantly correlated with innovation in almost half of the cases considered, and this also holds for the relationship between exports and innovation.[14]

Another important question considered in the literature concerns the impact of innovation on firm performance (Table 6). A widely used econometric approach for assessing this effect is the so-called Crépon–Duguet–Mairesse (CDM) structural model (Crépon et al., 1998), which in a sequential way considers links between R&D, innovation, and labor productivity. Using CIS type data this framework

[13] It should be pointed out that the list is unlikely to be exhaustive, because there is a lot of work in progress along these lines. Moreover, studies based on other sources of data than innovation, such as for example the traditional R&D surveys (or various surveys occasionally organized by research project), are not included.

[14] Surprisingly, perhaps, the effect of (openness to) imports has been rarely taken into account by these studies. Nevertheless, when included, the effect of import openness has often turned out be positive and statistically significant, in sharp contrast to the mixed results of foreign ownership and exports. Another set of studies, not included in the table because they focused on exports as the dependent variable, considered the possibility of a reverse causality from innovation to exports. Chudnovsky et al. (2007), Correa et al. (2007), Damijan et al. (2008b), de Araújo (2007), and Özçelik and Taymaz (2004) found positive and statistically significant correlations between innovation and exports in Argentina, Brazil, Slovenia, and Turkey, but not in Ecuador.

Table 5
Estimates of the propensity of firms to innovate based on micro data from CIS/PICS in catching-up economies

Author(s)	Survey	Country(s)	Sample size	Method	Dependent variable	Key results														
						SIZE	AGE	R&D	BROAD	EDU	BUY	LINK	FOR	EXP	IMP	Y/L	PROFIT	SECTOR	REGION	COUNTRY
Pamukçu (2003)	CIS	Turkey	1108[a]	2probit	INNOV	+				+	0		0	0	+		0	Y		
Lee (2004)	CIS	Malaysia	501[a]	Logit	INNOV	+	−						0	−				Y		
Oerlemans and Pretorius (2006)	CIS	South Africa	189[b]	OLS	INNSALE	−		0	+	+	+	0	0	0				Y		
Crespi and Peirano (2007)	CIS	Chile	1048[a]	Hprobit	INNMKT	+		+				+				+		Y		
Goedhuys (2007a)	PICS	Tanzania	257	Probit	INNPDT	0	0	+	+	+	+	+	0					Y		
Gonçalves et al. (2007)	CIS	Argentina	1256[a]	Probit	INNMKT	+		+	+		+		−	+	+	+		Y		
					INNPCS	+		+	+		+		0	0	+	+		Y		
		Brazil	6626[a]		INNMKT	+		+	+		+		+	0	+	+		Y		
					INNPCS	+		+	+		+		+	+	+	0		Y		
Hegde and Shapira (2007)	CIS	Malaysia	1819	Logit	INNPDT	+	−	+	+	+		+	0	0				Y		
					INNPCS	+	0	+	+	+		+	0	0				Y		
					INNORG	+	0	+	+	+		+	0	0				Y		
Sung and Carlsson (2007)	CIS	Korea	1124[a,b]	Logit	INNPDT	0	0	+				+	0	0			0	Y		
					INNPCS	+	0	0				+	+	0			+	Y		
Srholec (2007)	CIS	Czech Rep.	3801	Mlogit	INNOV	+	−						+					Y	Y	
Almeida and Fernandes (2008)	PICS	43 countries	15,522[a]	Probit	INNPCS	+	−	+		+	+		±	+	+			Y		Y
Falk (2008)	CIS	6 new EU	10,018	Probit	INNMKT	+	0						+	+				Y		Y
					INNPDT	+	0						+	+				Y		Y
					INNPCS	+	0						+	+				Y		Y

(*continued*)

Table 5 (*continued*)

Author(s)	Survey	Country(s)	Sample size	Method	Dependent variable	Key results SIZE	AGE	R&D	BROAD	EDU	BUY	LINK	FOR	EXP	IMP	Y/L	PROFIT	SECTOR	REGION	COUNTRY
				Flogit[b]	INNSALE	−	−	+	+		+	+	+	+				Y		Y
Jaklic et al. (2008)	CIS	Slovenia	1972[b]	Probit	INNOV	+		+		0		+	0	0		0		Y		
Karray and Kriaa (2008)	CIS	Tunisia	300[a]	Probit	INNPDT	0		+		+			−					Y		
Srholec (2008)	PICS	28 countries	15,818	Mlogit	INNPDT	+	−	+	+	+								Y		Y
Srholec (2009)	CIS	7 new EU	28,846	Probit	INNOV	+	−						+	+				Y		Y

[a] Manufacturing (industrial) firms only.
[b] Innovative firms only.
Variables—Y/L: output (Y) per employee (L), small caps denote growth; PROFIT: profitability given by profit to sales; INNOV: dummy for product or process innovation; INNMKT; dummy for product innovation new to the market; INNPDT: dummy for product innovation; INNPCS: dummy for process innovation; INNORG: dummy for organizational innovation; INNSALE: sale of innovated products as % of turnover; SIZE: size of the firm; AGE: age of the firm; R&D: internal R&D represented by a dummy or as % of turnover; BROAD: broader non-R&D capabilities, such as design, engineering, ISO norms, ICT, marketing, knowledge management, etc.; EDU: education, skills, or training of the labor force; BUY: acquisition/purchase of external embodied (machinery) or disembodied (external R&D, licensing, etc.) technology; LINK: linkages (cooperation, sourcing information, etc.) with other organizations; FOR: dummy for foreign ownership; EXP: export given by a dummy (EXPBIN) or as % of turnover (EXPINT); IMP: import given by a dummy or as % of turnover/inputs; SECTOR: sectoral differences; REGION: regional differences; COUNTRY: national differences.*Methods*—2probit: two-stage probit; Hprobit: Heckman probit; Flogit: fractional logit; Mlogit: multilevel logit; OLS: ordinary least square.
Symbols—"+": significantly positive at least at 10% level; "−": significantly negative at least at 10% level; "0": not significantly different from zero at 10% level; "Y": yes.

Table 6
Estimates of the link between innovation and productivity based on micro data from CIS/PICS in catching-up economies

						Key results															
Author(s)	Survey	Country(s)	Sample size	Method	Dependent variable	SIZE	AGE	K/L	INNSALE	INNOV	INNPDT	INNPCS	INNORG	R&D	BROAD	EDU	FOR	EXP	SECTOR	REGION	COUNTRY
Benavente (2006)	CIS	Chile	438[a]	CDM	Y/L[d]	+		+	0							+			Y		
Chudnovsky et al. (2006)	CIS	Argentina	1410[a]	CDM	Y/L[c]	−				+	0	+				+	0	0	Y		
Jefferson et al. (2006)	CIS	China	5451[a]	CDM	Y/L[d]			+	+								+		Y		
					PROFIT			+	+								+		Y		
Goedhuys (2007b)	PICS	Brazil	1061[a]	2LS	Y[c]	−	+				0	0		+	+	+	+	+	Y	Y	
Goedhuys et al. (2008a)	PICS	Tanzania	187[a]	OLS	Y/L[d]	0		+			0	0		0	+	+	+		Y		
Goedhuys et al. (2008b)	PICS	5 countries	389[b]	OLS	Y/L[d]	0		+			0	0		0		+	+		Y		Y
			365[b]		Y/L[d]	0		+			0	0		+		0	0		Y		Y
			956[b]		Y/L[d]	0		+			0	0		+		+	0		Y		Y
Lee and Kang (2007)	CIS	Korea	2539[a]	WLS	Y/L[c]	+	−				0	+		+	0			+	Y		
de Negri et al. (2007)	CIS	Brazil	1860[a]	CDM	K/L	+				+						+	+	+	Y	Y	
					K	−	−				+	+							Y	Y	
Roud (2007)	CIS	Russia	497[a]	CDM	Y/L[c]	−		+	+			0				+		0	Y		
Masso and Vahter (2008)	CIS	Estonia	1142[a]	CDM	Y/L[c,d]	−		+			+	+	+					+	Y		
					y/l[c,d]	−		+			0	0	+					0	Y		
Raffo et al. (2008)	CIS	Argentina	1308[a]	CDM	Y/L[c]	0		+			0	0	0			+	+		Y		
		Brazil	9452[a]		Y/L[c]	+		+			+	+	+			+	+		Y		
		Mexico	1515[a]		Y/L[c]	+					+	+	0			0	+		Y		
Damijan et al. (2008a)	CIS	Slovenia	4947	CDM	Y/L[d]	−		+		+							+	0	Y		
			4171		Y/L[d]			+		+	+	+					+	+	Y		
Goedhuys and Srholec (2009)	PICS	42 countries	19,147	Mlinear	Y/L[d]	+		+						+	+	+	+		Y		Y

[a] Manufacturing (industrial) firms only.
[b] 389 in food, 365 in textiles and 956 in garments and leather industries.
[c] Sales denote the output.
[d] Value added denotes the output.
Variables—Y/L, K/L: output (Y) or capital (K) per employee (L), small caps denote growth; PROFIT: profitability given by profit to sales; INNOV: dummy for product or process innovation; INNPDT: dummy for product innovation; INNPCS: dummy for process innovation; INNORG: dummy for organizational innovation; INNSALE: sale of innovated products as % of turnover; SIZE: size of the firm; AGE: age of the firm; R&D: internal R&D represented by a dummy or as % of turnover; BROAD: broader non-R&D capabilities, such as design, engineering, ISO norms, ICT, marketing, knowledge management, etc.; EDU: education, skills, or training of the labor force; FOR: dummy for foreign ownership; EXP: export given by a dummy (EXPBIN) or as % of turnover (EXPINT); SECTOR: sectoral differences; REGION: regional differences; COUNTRY: national differences.
Methods—2LS: two-stage least square; CDM: Crépon–Duguet–Mairesse model; Mlinear: multilevel linear; OLS: ordinary least square; WLS: weighted least square.
Symbols—"+": significantly positive at least at 10% level; "−": significantly negative at least at 10% level; "0": not significantly different from zero at 10% level; "Y": yes.

has been applied to at least eight developing countries. Statistically significant effects of one of the innovation variables have been confirmed in most cases. Using a different approach, Lee and Kang (2007) found a positive effect of process innovation, but no effect of product innovation, on productivity. In contrast, Goedhuys and associates, in series of papers based on the PICS data, failed to confirm any significant effect of innovation on productivity (Goedhuys, 2007a,b; Goedhuys et al., 2008a,b).

Finally, we examine how differences in contexts to which firms belong have been taken into account by the available literature. Information on this is included in Tables 5 and 6 in the last three subcolumns under "Key results." As is evident from the tables all of the studies controlled in one way or another for sectoral differences but only some considered territorial differences. Gonçalves et al. (2007) and Raffo et al. (2008) estimated the same model on data for a number of different countries, which allowed them to throw light on the underlying structural and institutional differences. Almeida and Fernandes (2008), Falk (2008), Goedhuys et al (2008b), and Srholec (2009) pooled micro data from different countries, using dummies for possible country effects, many of which were significant. In a related exercise Goedhuys (2007b) and de Negri et al. (2007) found regional dummies to be significant predictors.

Hence, there appear to be important differences across countries, regions, and sectors, but the approach commonly used (based on dummy variables) is unable to explore the reasons for those differences. To do that, a more useful approach might be to specify separate variables for the underlying "framework conditions" that contribute to these contextual effects. Another reason for concern may be that standard regression techniques usually assume that observations are independent from each other. However, if observations belonging to the same group, such as a sector, region, or country, are influenced by context-specific factors, this assumption is likely to be violated. In such cases so-called multilevel modeling (Goldstein, 2003)—also known as hierarchical, random coefficient or variance component models—which relaxes the independence assumption may be a more efficient tool for the analysis.

Srholec (2007), using multilevel modeling on CIS data from the Czech Republic, found that various regional factors, including the quality of the regional innovation system, influenced the propensity of firms to innovate, but that the strength of these effects depended on various firm-level characteristics. Using a multilevel model on PICS data from 28 countries, mostly developing, Srholec (2008) demonstrated that in addition to firm-level characteristics, including a rich set of capability indicators, a number of variables representing the national framework conditions contributed to the explanation the likelihood of firms to innovate. Similarly, Goedhuys and Srholec (2009), in a follow-up study based on evidence from PICS in 42 countries, showed that various national factors influenced firms' abilities to benefit from their own technological capabilities. For example, firms located in countries with a higher R&D intensity benefitted considerably more from their own R&D spending than otherwise similar firms in low R&D environments. Hence, national and firm-level capabilities interact in the process of development.

A shortcoming of the literature surveyed in this section is that panel data in most cases do not exist. This makes it difficult to consider the issue of the direction of causality in a satisfactory manner. In principle, instrumental methods may help dealing with this problem but good instruments are hard to find. Griffith et al. (2006), in the context of CDM modeling, point out that despite the best efforts, one by and large still deals with correlation rather than causation, and this probably goes for many of the studies considered here.

5. International sources of innovation in developing countries

While the building of national capabilities may be the aspect of catching-up that is most directly influenced by domestic policy, the process also depends on foreign sources of knowledge and technology. Knowledge from abroad may flow through a variety of channels, such as migration, licensing, trade, and FDI.[15] Some of these flows are not mitigated through markets, such as in the case of scientific and technical cooperation with foreign governments (as part of development aid). However, knowledge may also flow in as a direct result of market transactions, such as the licensing of a patent. Other market-related forms include knowledge flows associated with trade and investment, or labor migration (although the latter is usually from developing nations to the developed world). Arora et al. (2004) argue that there is now also an explicit market for knowledge itself, for example in the form of engineering services, but this is mostly relevant for developed countries.

The "capabilities" literature that was summarized above has mostly focused on the catch-up experience of individual countries (e.g., Lall and Urata, 2003). From these individual country histories, it appears that there is no single answer to the question of which channels are most important for sourcing knowledge from abroad. In Asia, Japan is the earliest example of a successful catching-up country. Industrialization in Japan started in the latter half of the nineteenth century, but a significant break in the process occurred with World War II. Goto and Odagiri (2003) describe how, in the postwar phase, the Japanese sourced technology mainly by importing capital goods, licensing of technology (and other forms of alliances) from Western firms, reverse engineering, and the use of trade missions and other forms of intelligence targeted at learning about foreign technology. In summary, Japan acquired advanced foreign technology through all channels except for inward FDI (Goto and Odagiri, 2003, p. 89).

The absence of FDI as a channel for knowledge transfer is also typical for some other Asian catching-up countries that followed suit after Japan, such as Korea (Kim, 1997, 2003) and Taiwan (Aw, 2003). Like Japan, these countries tended to rely on "arms-length" relations with foreign firms, combined with the building up of capabilities of domestic firms, facilitated by domestic policies for learning (e.g., education, industrial policy and trade policy). A direct role of foreign firms in the domestic economy was explicitly discouraged by policy, at least in the initial phase of catching-up (this changed in the late 1970s and 1980s, especially in Korea). However, in some other Asian countries, most notably Singapore, FDI was an important channel of knowledge transfer from the beginning of the catching-up process (Wong, 2003).

The relatively low importance attached to FDI as means of catching-up in the above cases may partly be related to the existence of strong domestic firms. Amsden (1989) has argued that in Korea, the existence of large domestic conglomerate firms was a decisive factor in generating growth. As in Japan and Taiwan, these firms, helped by an active government policy, were able to build up their own technological capabilities by means of assimilating foreign knowledge. This process took the form of gradual learning, resulting eventually in the ability to undertake product innovation by means of R&D. However, an important intermediate step in this process of building up capabilities was so-called Original Equipment Manufacturing (OEM), in which Asian firms would manufacture products for foreign (Japanese as well as Western) firms, according to exact specifications supplied by the foreign firms (Hobday, 2000).

[15] For overviews see Cincera and van Pottelsberghe (2001) and Keller (2004).

Thus, multinational enterprises (MNE) play an important role in the transfer of knowledge across borders and not only through FDI. They are responsible for a large part of R&D performed in the private sector in the developed part of the world[16] and for them knowledge is a key asset and source of competitive advantage. Such knowledge-assets can be exploited in foreign markets through three main mechanisms (Blomström and Kokko, 1998): the licensing of technology to foreign actors, investment in the foreign country, or exports.

Data on licensing and other forms of "arms-length" knowledge trade, arguably a decisive channel of knowledge transfer, have until recently not been very widely available. Hence, there is little (econometric) work on the impact of technology payments in developing countries, despite the fact that this seems to be an important channel for knowledge transfer, especially in the early phases of catching-up. Technology inflows measured in this way were typically in the order of magnitude of about 0–0.5% of GDP in the early twenty-first century, with the highest values recorded in the developed part of the world (including South-East Asia). As such, they are an order of magnitude lower than FDI flows, which may range up to 5% of GDP.

FDI is what clearly has received most scholarly attention, although as mentioned above this does not seem to be warranted by the literature.[17] Knowledge transfer associated with FDI can take the form of joint ventures between domestic and multinational firms, other forms of cooperation such as strategic alliances, linkage effects (i.e., contacts with local suppliers or customers), labor mobility, informal contacts between the MNE and local firms, and demonstration effects (i.e., an MNE showing that a technology works reduces uncertainty for local firms). The literature also identifies increased competition as a source of spillovers of FDI to the host economy, that is, the effect on domestic firms that are forced to increase efficiency in order to compete with the foreign firms.

The impact of FDI is partly related to the strategy of foreign firms with regard to their presence in developing nations. For instance, although most foreign affiliates may be mere passive adopters of foreign technology, some may be actively involved in knowledge creating activities in developing countries and this may increase the possibility for spillovers. Using data from innovation survey in Argentina, Bell and Marin (2004) and Marin and Bell (2006) examined the role of knowledge-generating activities of foreign affiliates for knowledge spillovers. They found that while spillovers are likely to be generated by foreign affiliates that are technologically active in the host country, there was no significant effect in that regard for those that were not.

Because most of the channels through which FDI generates spillovers are hard to observe directly, unless a case study approach is used,[18] most of the empirical literature relies on estimating productivity

[16] According to the "Innovation R&D Scoreboard" prepared by the Department of Trade and Industry in the United Kingdom, in 2007, Microsoft was the largest corporate R&D spender in the world, with a total R&D budget of about 8.2 billion US$. According to the IMF database, this is comparable to the total GDP of Mozambique (8.1 billion US$). The median value of GDP in the IMF database is 20.7 billion US$, that is, about 2½ times the Microsoft R&D budget. According to the R&D Scoreboard, there are 29 (69) companies that spent more than 2 (1) billion US$ on R&D in 2007.

[17] The literature on FDI, MNEs, and spillovers of their knowledge-related activities addresses both developed and developing countries. An early survey is Blomström and Kokko (1998), a more recent one is Görg and Greenaway (2004).

[18] The electronics industry in Asia is such a case. A series of case studies (e.g., Ernst and Kim, 2002; Hobday and Rush, 2007; Kim, 1997) has shown how Asian electronics firms used knowledge from foreign firms to go through a series of stages: from mere assembly to process engineering and, eventually, product development through R&D and FDI played an important role in this process of technological upgrading.

equations, usually based on a production function approach, for domestic firms or sectors, in which MNE presence is one of the independent variables. The early literature of this type (e.g., Blomström and Persson, 1983, in a study on Mexico) relied on including the share of foreign ownership in regressions explaining sectoral productivity differences, or as an industry-level variable in a microeconomic dataset. This approach cannot distinguish between the different spillover channels, but it does allow, by the inclusion of firm-level variables related to absorptive capacity, for a heterogeneous impact of spillovers among (local) receiving firms. Blomström and Kokko (1998) conclude that the evidence from these early studies is mixed, and suggests that whether or not spillovers from MNEs to local firms take place depends on many aspects of the local and sectoral context. Due to a lack of detailed data, many studies are not able to measure these factors, and, moreover, analyses covering more than a single country were (and still are) rare.

The more recent econometric literature on FDI spillovers has used more refined indicators and methods. With regard to indicators one trend has been to distinguish between horizontal (intraindustry) and vertical (interindustry) spillovers. Wooster and Diebel (2006) provide an overview of 32 econometric studies of the impact of FDI in developing countries (among which they include transition countries in Eastern Europe), covering a publication time span of 1983–2004.[19] They find positive effects of spillovers in about half of the included observations (an observation is a regression result, of which there are generally more than one per paper analyzed), and slightly less than half of the reported coefficients are statistically significant. Among the most salient findings of this exercise are that using an employment-based measure of foreign presence as the independent variable increases the likelihood of finding positive spillovers; that analyses on firm-level data find significant spillovers less often; that in more recent periods it is more likely to find positive spillovers; that spillovers are more likely to be positive in Asia; and that it is important to include R&D and time period fixed effects as control variables.

On the methodological front the use of panel data is an important aspect of recent econometric studies on the subject. But according to Wooster and Diebel, the use of panel data does not change the results significantly. In contrast, Görg and Strobl (2001), in a similar meta-study for a sample of both developed and developing nations, report that using panel data usually yields negative or insignificant spillovers. One needs to keep in mind, however, that the panels used in this literature are usually short, while FDI spillovers are essentially long-run in nature, and that the impact of FDI spillovers may be conditional on unobserved factors, such as for example absorptive capacity, that feed into the (usually undocumented and time-invariant) fixed effects in panel regressions.

Trade is a different way in which developing countries can benefit from knowledge flows (see the chapter by Keller in this volume for a more extensive overview). Spillovers from trade may come in the form of what Griliches (1979) called rent spillovers. This refers to the idea that because of competition, quality improvements of traded goods are not fully reflected in price increases. Trade can also expose firms to new product specifications, and this can lead to imitation. The work on knowledge flows related to trade has mostly focused on sectoral or macro data, mainly because trade data are usually not available at the firm level. The study by Coe et al. (1997) arrived at an optimistic conclusion with regard to the impact of trade-embodied knowledge flows in developing countries. Their methodology involves the estimation of a production function in which "imported R&D" is one of the independent

[19] They do not include studies dealing with vertical spillovers, such as Damijan and Knell (2005) and Smarzynska Javorcik (2004).

variables. "Imported R&D" is R&D performed in the exporting country, but embodied in the exports, through which it may have an impact on growth in the importing country.[20] They estimated that, in 1990, R&D spillovers from developed to developing nations were worth about 22 billion US$, which would be comparable to about half of the total global development aid during that period. Jacob and Meister (2005) applied a similar model to the case of Indonesia, also incorporating linkages at the sectoral level, as well as market structure. They also concluded that trade-embodied knowledge flows are important for productivity growth in that country.

In summary, the available work on foreign knowledge inflows into developing nations point out that the sources of these knowledge flows are many and heterogeneous in nature. MNEs play an important part in these flows, by their nature as "fluent" entities in the global economy. However, whether or not FDI and other international knowledge sources contribute to the performance of local firms in developing countries, depends on local circumstances and capabilities of the firms on the "receiving end" (Criscuolo and Narula, 2008). It has also been suggested that the contribution of the various channels of international knowledge transfer may change over time. Arguably, changes in governance of the global economy may have closed off catching-up paths that were followed by countries such as Japan and Korea, for example because trade policies that formed an essential part of the catching-up process in these countries are no longer allowed under current WTO rules (Chang, 2002), or because tighter rules about IPRs make the use of some knowledge transfer channels that previously were important for catching-up more difficult or costly (Kim, 2003).

6. Conclusions

This chapter has focused on the literature on innovation and development. Until recently most people would have considered it odd to consider innovation as an important issue for developing countries, and many probably still see it that way. This skepticism is based on the widely shared view that innovation primarily is of interest for high-tech firms in advanced environments. According to this perspective new technologies emerge in advanced economies. However, since technology in this perspective has strong public good properties, it will gradually diffuse to the developing part of the world.[21] Hence, diffusion of new technology, created through innovation in the advanced part of the world, may according to this perspective be expected to work as a powerful equalizer in the global economy, making it possible for poor countries to quickly raise their standards of living.

Although the logic of this "public good" approach to the role of technology and innovation seemed convincing at first, it gradually became evident that it could not be the whole story. Two pieces of evidence in particular came to undermine the approach. First it became evident that the convergence in technology and productivity that the approach predicted did not materialize. In a long-run perspective

[20] The Coe, Helpman, and Hoffmaister methodology has come under critique, on the account that the trade-related weighting scheme may be spurious. This is discussed at length in the chapter by Keller in this volume.

[21] The only worry, according to this perspective, is that the spread of such benefits becomes too quick (and extensive), so that the incentives to development of new technology in the in the developed part of the world are substantially reduced. To avoid this outcome, it is argued, legal instruments that prevent such easy, costless diffusion are needed. Followers of this perspective therefore place great emphasis on intellectual property rights as in incentive to secure steady technological progress in the advanced corners of the globe and hence in the global economy as a whole.

differences were at the increase, not the other way around. How could this happen? Second, the most famous examples of countries that managed to escape the low development trap and raise their standards of living towards developed country levels relatively quickly were far from being passive adopters of new, developed countries technologies. On the contrary countries such as Korea, Taiwan, and Singapore, which were among the prime success stories, placed great emphasis on generating what later became known as "technological capabilities" through a concerted effort by public and private sector actors and apparently it paid off handsomely. Why were such activist development strategies that contradicted much common wisdom, seemingly much more successful than the "hands off" approach advocated by leading authorities and institutions such as the IMF and the World Bank, what is often called the "Washington consensus"?

These were some of the questions that gradually became more central to the agendas of politicians, development experts and economists through the closing decades of the millennium and the beginning of the next and it led as we have shown to the emergence of new theories, approaches, and evidence. Arguably, the process started already back in the 1950s when economic historians started to analyze actual catching-up processes and came up with generalizations that were far from the liberal "hands off" approach in favor among economists. As a consequence, a stream of research emerged, mainly among economic historians and economists with a more heterodox leaning, that focused on "capability building" of various sorts as essential for development processes. This way of looking at things gained momentum during the 1980s and 1990s as the success of the Asian tigers (and Japan before that) became more widely recognized and studied. The term "technological capability," originally developed as a tool for analyzing the Korean case, gradually became more widely used among students of development processes, and a large amount of research emerged using this approach to understand the performance of firms, industries, and countries in the developing part of the world.

It is fair to say, however, that in spite of these developments, many economists continue to be unconvinced by the "capability" approach, maybe because it is seen as a meso or macro approach lacking proper micro foundations, theoretically as well empirically. However, it is particularly at this point that the research is most strongly increasing today, in the form of a massive data gathering effort on innovation activities in developing countries, and analyses based on these new sources of information. These new developments, which follow similar efforts in the developed part of the world (particularly Europe) from the 1990s onwards, has vividly demonstrated that the "high-tech" approach to innovation which has framed much thinking and policy advice on the subject is strongly misleading when it comes to understanding the relationship between innovation and development. In fact, the evidence shows that innovation is quite widespread among developing country firms, is associated with higher productivity (e.g., development) and, as in the developed part of the world, is dependent on a web of interactions with other private and public actors. This is not to say that innovation in developed and developing countries is identical in every respect, but in qualitative terms innovation is found to be a powerful force of growth in both and therefore an issue that is imperative to get a better understanding of, theoretically as well as empirically.

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