CHAPTER

31

The Economics of Recycling

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31.1 INTRODUCTION

Recycling is generally considered to be an important strategy for alleviating the pressures of society on the environment. Natural resources are saved, emissions are decreased, and the burden of solid waste is reduced. At the same time, recycling creates employment and attracts investments. In recent years, many countries have experienced large increases in recycling. Besides domestic causes, international trade has played an important role in the expansion of the global recycling sector. In recent decades, international trade of recyclable materials has increased significantly. This chapter aims to identify the main economic drivers of recycling, address the private and external costs of recycling-related activities, and demonstrate the effectiveness of the most important economic instruments to promote recycling.

31.2 ECONOMIC TRENDS AND DRIVERS

Waste is a byproduct of consumption and production activities. Considering the increasing scarcity of natural resources, waste is also seen as a potentially valuable input to production, substituting for virgin resources. Recycling is generally considered as an important strategy for alleviating the pressures of the economy on the environment by saving natural resources, decreasing the emissions of pollutants in the environment, and reducing the burden of solid waste. Recycling also contributes to economic activity, attracts investment, and creates employment. Globally, drivers for recycling vary between industrialized countries and developing countries. In the industrialized countries, drivers for recycling of waste result from increasing disposal costs, increased public concern about the health and environmental impacts of waste disposal, and the fear of future scarcity of certain natural resources. In developing countries, recycling is mainly driven by direct economic motives. International trade, including trade between industrialized and developing countries, has played an important role in the expansion of the global recycling sector. As is the case for any commodity, international trade in recyclable waste allows countries to exercise their comparative advantages to increase the efficiency of the allocation of resources

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of the global recycling industry. However, there is also fear that (hazardous) waste is shipped to foreign destinations to avoid costly regulations for disposal and storage.

31.2.1 Generation of Waste

The volume of waste that is generated each year in the world is vast and increasing. Large volumes of waste are generated by mining operations, construction and agriculture, but it is difficult to put a number on these volumes as they are often not recorded. It has been estimated that extraction waste, mostly from mining, in the United States alone amounted to 2,500,000,000 t per year in the 1990s—an order of magnitude larger than either industrial or municipal solid waste (Porter, 2002). In developed countries, most manufacturing firms have financial incentives to minimize waste disposal costs. Nevertheless, the Organization for Economic Cooperation and Development (OECD) reports a volume of manufacturing waste in OECD countries in 2010 of 458 Mt, excluding the United States and Canada (OECD, 2013a). Municipal solid waste supply in OECD countries was 661 Mt in 2010, a modest increase from 641 Mt in 2000 (OECD, 2013b).

Research has established that the supply of household solid waste grows proportionally with population, grows less than proportionally with household income, and decreases less than proportionally with increasing charges of waste collection services. In economic terms, this means that household demand for waste services has unitary elasticity with respect to population and is inelastic with respect to income and price (Johnstone and Labonne, 2004). It has been investigated if the supply of municipal solid waste would eventually start to decline with rising income, according to the so-called environmental Kuznets curve (EKC) hypothesis. On the one hand, higher-income families consume more and would therefore produce more waste; on the other hand, it has been suggested that they tend to have a consumption pattern that does not favor waste-intensive goods (Ferrara, 2008). The evidence on the EKC hypothesis is mixed: some researchers found a turning point where household waste supply starts to decline (Abrate and Ferraris, 2010) and others have not (yet) (Mazzanti and Zoboli, 2009; Nicolli et al., 2012).

31.2.2 Recycling

Given this vast amount of waste, there is much interest in reuse or recycling—if not for the potentially valuable materials and energy that can be extracted from the waste, then at least for the increasing costs of disposal and storage. In many countries, an increasing share of industrial and municipal waste is designated for recovery operations, including incineration with energy recovery, composting, and recycling. For example, in the United States, the share of municipal solid waste that is being recycled has increased from 14% in 1990 to 26% in 2010. Among all countries, Germany has the highest share of recycling of municipal solid waste (46%) (OECD, 2013b).

Recycling rates differ per material recycled. According to the industry itself, the global recycling rate of paper is currently 56% (ICFPA, 2013). Europe is the leader, with a paper recycling rate of 70%. Recycling rates for metals vary from very high (gold) to negligible for many specialty metals, such as lithium and tellurium. Recycling rates tend to be higher when the metals are used in large quantities in easily recoverable applications (e.g. lead in batteries, steel in automobiles) or when they have a high value. Increasingly however, small quantities of (rare) metals are used in complex products such mobile phones (Graedel et al., 2011). In this context, Porter (2002) distinguishes between *economies of scale* in recycling (unit costs of recycling go down when the supply of waste material increases) and *diseconomies of scope* (unit costs of recycling go up when the number of different recyclable materials and applications increases). Next to these techno-economic factors, key drivers for recycling are the scarcity, costs, and volatility of prices of substitute primary materials; the cost of waste disposal; public pressure; and government regulations.

31.2.3 International Trade

Recycling has become global business. International trade in recyclable resources is increasing at a fast rate. In 2007, international trade in waste exceeded 191 Mt, almost five times as much (in physical weight) as the international trade in passenger automobiles (Kellenberg, 2012). The most important incentive to international trade is the difference in recycling costs and benefits across countries. Van Beukering (2001) has shown that a number of trade theories predict trade flows of recyclable materials from the north to the south. The basic idea is that the north is abundantly endowed with capital and recyclable or secondary resources and the south with labor and primary resources. All other things equal, this would lead to net export of recyclable resources from the north to the south. This tendency would be enforced by income differences that cause southern consumers to demand lower quality and therefore cheaper materials and products. Finally, laxer environmental standards of waste handling and disposal in the south may also be an additional factor for trade. Empirical observations have supported these predictions. For example, Lyons et al. (2009) showed on the basis of detailed trade statistics that the United States is a large net-exporter of recyclable materials (such as iron and steel, paper, plastics, aluminum, copper, nickel, and zinc) to developing countries, especially Mexico and some Asian countries, including China.

An illuminating way to picture the patterns of international trade in recyclable materials is to make a distinction between the recycle recovery rate and the recycle utilization rate. The recycle recovery rate is the ratio between domestic collection of recyclable material and total consumption of the material (both of recycled and primary origin). The recycle utilization rate is the ratio between the consumption of the recycled material and the total production of the material. For net-exporters of recyclable materials (the north), the recovery rate exceeds the utilization rate. For net-importers (the south), the reverse is true (Grace et al., 1978). Van Beukering (2001) showed that this relationship holds for international trade in recycled paper and that the difference between recovery rate and utilization rate in the industrialized countries and developing countries also increased between 1970 and 1997. Hence, international trade in waste plays an important role in bridging domestic gaps between demand and supply of recyclable materials. However, there is also some evidence that a part of international trade in waste has less welfare-enhancing consequences, when it is in fact a cover-up of dumping waste in places with lax environmental regulations at the expense of human health and the environment. This is called the "waste haven" effect. Using bilateral waste trade data between 92 developed and developing countries, Kellenberg (2012) has indeed found robust statistical evidence of such a waste haven effect, even when controlling for relative productivities in recycling industries, effects of the Basel Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal, and other potentially relevant covariates. Hence, while international trade offers a solution to the oversupply of recyclable material in the north and the lack thereof in the south, the present situation is still far away from the ideal of a "closed loop" industrial ecosystem (Lyons et al., 2009).

31.3 ENVIRONMENTAL AND SOCIAL COSTS AND BENEFITS

Recycling is widely assumed to be environmentally beneficial (Craighill and Powell, 1996). It slows down the exhaustion of scarce resources and limits the use of landfill space. Recycling, however, also generates significant environmental impacts through the collection, sorting, and processing of materials into new products. Therefore, it is unclear when recycling is to be preferred to the use of virgin goods or when waste recovery should replace landfilling or incineration. Due to differences in environmental effects, studies about the desirability of recycling sometimes lead to opposite conclusions (Leach et al., 1997; Ackerman, 1997; Bartelings et al., 2005; Eshet et al., 2006; Erikssonn and Baky, 2010).

31.3.1 Economic Valuation

In economics, environmental and social effects are generally defined as external effects. An external effect, or externality, is said to exist if an economic agent's decision has an influence on another agent's well-being or production possibilities and the former does not (properly) take these effects into account. Because of its unwanted nature, solid waste is often considered an externality. The extent to which solid waste actually is an externality depends on the method by which it is processed. Clearly, if waste is littered or illegally dumped, the externality will be substantially larger than if the waste is recycled or reused in a sustainable manner. For many other waste processing methods, however, this choice between recycling and alternative methods is less straightforward.

Policy makers generally use the level of externalities to determine the preferred ranking and mix of waste management options. Generally, landfilling is considered an environmentally less-favorable option than recycling. However, whether the level of externalities of landfilling always exceed those of recycling or incineration is unclear and requires the relevant external effects to be valued in economic terms. The main reason to express external effects in monetary values is that it allows for the comparison between private costs of various waste management options and the environmental and social costs and benefits related to these options. Economic valuation can express external effects in monetary units. This approach facilitates the comparison of multiple environmental impacts and allows for a trade-off between the benefits and costs of many kinds of environmental improvement.

Ideally, economic valuation forms an integral part of the overall environmental assessment of waste management. As shown in Figure 31.1, an example of such an integrated assessment commonly applied in the waste management sector is the impact pathway approach (COWI, 2000). This approach proceeds sequentially through the lifecycle or pathway of an economic process, linking impacts to burdens, and subsequently valuing these impacts economically. First, overall emission levels and other external effects are determined in physical terms. Then, the impacts of these effects on economic activities and human well-being are assessed. Next, these impacts are translated into monetary values.

An advantage of the impact pathway approach is that it enables the comparison of the benefits of some environmental improvement in the waste sector with the costs to realize such an improvement. Because many studies have applied valuation methods, standard values can be derived for most pollutants or impacts. These allow translating emissions directly into costs bypassing the elaborate impact pathway approach. The valuation of external effects encounters various problems. First, because external effects, by definition, occur outside the market, market values for these effects are generally absent. Therefore, special techniques are required for the estimation of external values. Second, external effects of recycling-related processes occur at various locations. When it is not possible to value these effects at each individual location, values estimated at one location need to be transferred to other locations. Therefore, a disadvantage of this approach is that the complexity of economic

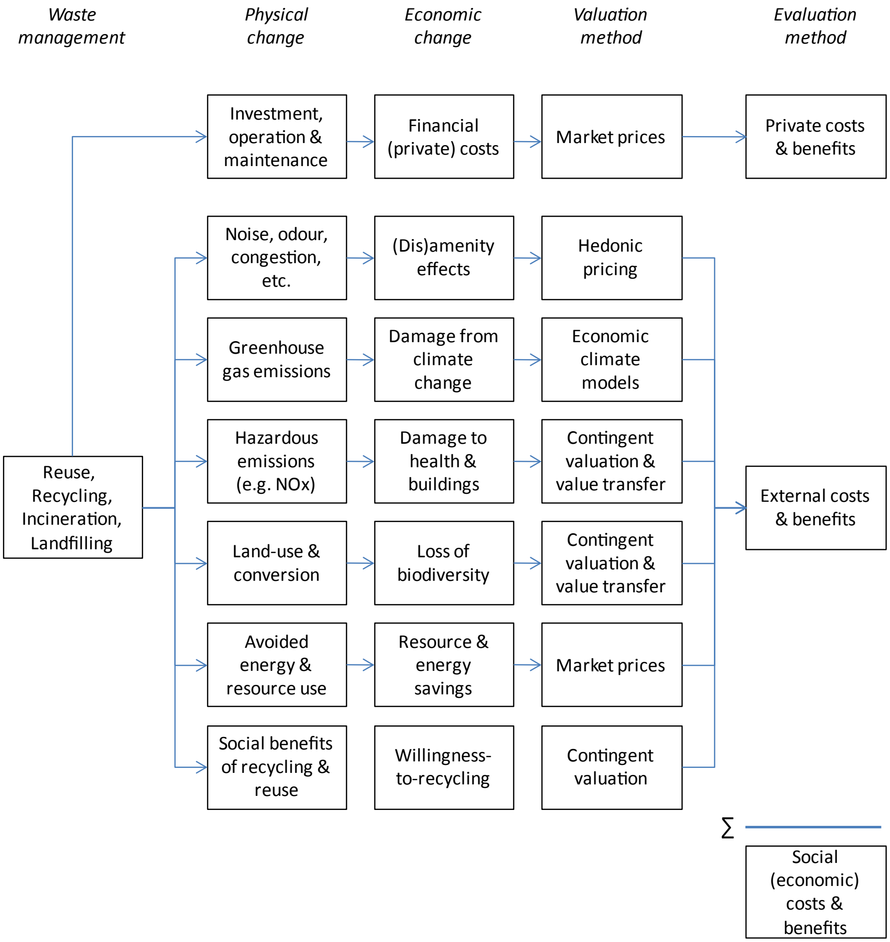

FIGURE 31.1 Economic valuation and the impact pathway approach.

valuation often leads to high degrees of uncertainty on the final results.

31.3.2 External Costs and Benefits

As shown in Figure 31.1, various categories of external effects are associated with waste management. This section illustrates how some of these external effects affect welfare and thus can be economically valued. First, pollution from recycling-related activities can have many impacts on human health, ranging from short periods of coughing to premature death. The valuation of human health impacts remains one of the most controversial aspects of any valuation study. Many reactions to the monetary valuation of these impacts are partly caused by the unfortunate choice of terminology, such as the "value of a statistical life".

Second, climate change is an important impact category in the valuation of externalities related to waste management. Methane (CH_4)

emissions from landfills contribute approximately 16% to the world's total methane emissions (WRI, 1996). Depending on the efficiency of the incinerator and the composition of the burned materials, waste-to-energy practices may avoid carbon dioxide (CO_2) emissions through supplying electricity to networks. Recycling is usually less energy intensive than primary production processes and therefore may reduce the impact on global warming. Comprehensive climate models that are linked to economic models calculate the costs of climate change. They include agricultural damage, increased morbidity and mortality, damage caused by sea level rise and by extreme events, and loss of species.

Third, disamenity effects of waste-related processes are likely to make up a significant share of the externalities caused. Landfill sites or incinerators generate substantial social costs for their neighboring population. Disamenity effects may occur in different forms. The trucks that transport the waste to and from the sites may cause noise externalities as well as congestion. The landfill site may emit noxious odors and create visual pollution. Increased health risk, or at least an increased perception of higher health risk, is caused for the people living in the vicinity of an incinerator or landfill.

Fourth, all industrial processes involve the (direct or indirect) use of material resources. These resources may be renewable (e.g. planted forests) or nonrenewable (e.g. fossil fuels, ores). When valuing the use of resources, one may ask whether the actual market price (i.e. the internal costs of one unit of the resource) adequately reflects the real cost to society of using that resource unit. There are two ways in which the social cost of resource use may deviate from its market price. There may be external effects in mining and processing the resource. The environmental impact of (nonrenewable) resource extraction tends to increase as the rate of depletion grows. Ideally, these effects should be incorporated in the analysis and valued accordingly. Moreover, the market price may lead to a higher rate of resource depletion than would be optimal, not taking into account the needs of future generations.

Fifth, recycling may also generate positive externalities as it caters people's willingness-to-recycle. Environmental consciousness plays a crucial role in recycling activities (Ackerman, 1997; Jones et al., 2010). Without the voluntary participation of consumers in waste recovery programs, the level of recycling would be significantly less. From the purely private perspective of the consumer, landfilling or incineration of household waste in a distant site or plant might be the most optimal way to eliminate waste residues. The increased awareness of pollution, however, can motivate consumers to play their part to alleviating the waste problem. Consumers may be interested in waste management for other reasons than purely money savings on their bills (Sterner and Bartelings, 1999). This willingness to recycle can be considered a positive externality.

31.3.3 Private and External Costs

The ultimate purpose of the impact pathway approach is to determine the real costs and benefits of recycling and other waste management options. The external costs of waste management have been the subject of a relatively large number of studies in recent years. Most of these studies focus only on one specific externality. Only a few studies attempt to aggregate a number of the most relevant environmental effects, thereby allowing for a fair comparison internationally (Ascari et al., 1995; COWI, 2000; Dijkgraaf and Vollebergh, 2004; Bartelings et al., 2005). By combined published sources, Kinnaman (2006) estimated the marginal cost of landfilling solid waste in Europe between \$5.39 and \$8.76 per ton (Kinnaman, 2006). Isely and Lowen (2007) estimated these costs at \$5.26 per ton in the United States. Illustrating the composition of the social costs of waste

TABLE 31.1 Private and External Costs of Incineration and Landfilling (€/Ton of Waste)

Private and External Effects	Incineration	Landfill
• Gross private costs	125	40
• Displaced costs—energy	−21	−4
• Displaced costs—materials	−3	0
Net private costs	**101**	**36**
• Health	7.09	0.70
• Disamenity	9.09	3.50
• Transport-related	1.67	1.25
• Solid waste	0.11	0.00
• Climate change	0.11	4.21
• Other environmental pollution	0.13	0.52
• Displaced effects—energy	−7.63	−1.14
Total external effects	**10.57**	**9.04**
Total social costs	**111.57**	**45.04**

Sources: Bartelings et al. (2005) and Dijkgraaf and Vollebergh (2004).

management alternatives, Table 31.1 summarizes the various categories of the private and external costs of landfilling and incineration (Bartelings et al., 2005). On the one hand, private costs are estimated taking into account displacement benefits. On the other hand, externalities are estimated accounting for climate change, other environmental pollution, land use effects, health effects, and disamenity effects.

Both external and private costs are surrounded by large uncertainties. Kinnaman (2009), for example, reported the marginal cost of operating a municipal recycling program at roughly $120 per ton for the first ton recycled, yet these costs decrease with economies of scale by an estimated $2.13 per 1000 t recycled (Kinnaman, 2009). For external costs, the uncertainties are even higher, depending on contextual (e.g. location) and methodological assumptions (e.g. discount rate). The best way to deal with such uncertainties is to conduct an extensive sensitivity analysis to evaluate whether the ranking of preferred waste management options changes with different methodological assumptions (Erikssonn and Baky, 2010).

31.4 ECONOMIC INSTRUMENTS

For most products and materials, 100% recycling is neither feasible nor desirable from a social cost-benefit point of view. Although there may be disagreement on the optimum level of recycling, many citizens and policy makers feel that current levels are still below that optimum. For certain categories of products and waste, targets are set to increase the recycling rates. Some of these even have a binding character. For example, in the EU minimum recycling rates have been determined for packaging waste, batteries, cars, and electronic equipment. Member States are obliged to achieve these targets by specified dates.

One way of stimulating people and companies to recycle more is by making it financially attractive for them to do so. Policy instruments that aim to provide such a financial incentive are called economic (or market-based) instruments.[1]

[1] There is no clear distinction between the two terms and they are often used interchangeably (e.g. in EEA, 2005). Possibly the term *economic instrument* refers more to the financial incentive that the instrument conveys, whereas *market-based* emphasizes the role of the market mechanism in achieving the environmental objective. In that sense, instruments such as ecolabeling could also be called "market-based," although they do not provide financial incentives and therefore are not economic instruments.

They can be applied in many different ways and at many different points along the value chain from resource extraction to disposal. Basically, we can distinguish two types of economic instruments for recycling:

- Those that create a financial disincentive for nonrecycling behavior (e.g. dumping waste or sending it to landfills and incinerators);
- Those that create a financial incentive for recycling.

Taxes and charges[2] (but also penalties on littering) are examples of the first category; subsidies and public facilities belong to the second. In practice, mixtures of incentives and disincentives are also common. Examples include, for instance, tradable landfill permits, differentiated tax rates, and deposit-refund systems. The latter will be discussed separately below.

31.4.1 Taxes and Charges

"The polluter pays" is a key principle in environmental policy. In the area of waste prevention and recycling, it can be applied in various ways. Taxes at the end of the chain, on landfilling and incineration, improve the competitive position of recycling *vis-à-vis* these disposal options. Taxes (or charges) on (potentially) waste-generating products make it more attractive to use less of them, to use them for a longer time, and/or to switch to alternatives that generate less waste. A classic example is the tax on plastic bags in Ireland. After its introduction in 2002, the use of plastic bags dropped by 90% (Convery et al., 2007). Taxes can also be applied at the beginning of the chain (i.e. on natural resources), but such taxes appear to be less effective in terms of promoting recycling (see e.g. Söderholm, 2006).

Charges for waste collection and processing can also play a role in stimulating recycling. Many households still pay fixed charge rates for municipal waste collection. Making these rates variable (i.e. related to the amount of waste offered: "pay-as-you-throw") can incite them to display a less wasteful and more pro-recycling behavior. Differentiating the rates (e.g. by applying a reduced or zero rate to separated types of waste such as glass, biowaste, and paper) may further enhance this impact. Such differential and variable rate (DVR)-based schemes have been shown to be very effective (see e.g. OECD, 2006; Oosterhuis et al., 2009; Hogg et al., 2011), especially in the presence of a comprehensive system for the collection of segregated materials for recycling. In some countries, such as South Korea, DVR schemes are already applied on a nationwide scale.

31.4.2 Subsidies and Public Facilities

Although subsidies in general conflict with the "polluter pays" principle, they may still be useful policy instruments in situations where market imperfections (e.g. transaction and monitoring costs) preclude the use of "first best" tools, such as waste disposal fees. For example, Dinan (1993) and Eichner (2005) concluded that the optimum instrument package should include subsidies on reuse or recycling. Likewise, Fullerton and Wu (1998) showed that, if market signals cannot be corrected by means of disposal charges, welfare can be improved by subsidies to recycling or recyclability (in combination with product taxes).

In particular, positive incentives for recycling may play a role in cases where there is a high risk of illegal waste disposal practices, for instance, because the cost of enforcement would

[2] The distinction between a tax and a charge is related to the destination of the revenue. Tax revenues tend to accrue to the general public budget (although they may sometimes be earmarked for specific purposes), whereas the revenues from charges are spent on purposes that are directly related to the product or activity on which the charge is levied.

be prohibitively high. An example is ship waste: there are no policemen at sea who might fine for waste dumping. Port reception facilities can make it more attractive for captains to refrain from dumping. Likewise, households can be encouraged to separate their waste by providing a well-organized system of collection facilities (e.g. glass containers). Clearly, the incentive does not need to be a financial one: recycling behavior can also be made attractive by reducing the time and effort involved.

31.4.3 Deposit-Refund Systems

Deposit-refund schemes (DRS) are basically a combination of two instruments: a tax on the purchase of a certain product and a subsidy on the separate collection of the same product in its after-use stage. International experiences show that DRS can achieve very high return rates (Ten Brink et al., 2009; Ecorys, 2011; Van Beukering et al., 2009) and that they do lead to a reduction in litter (Hogg et al., 2011; Ecorys, 2011). On the other hand, the handling and administration costs can be substantial. DRS are widely applied in the area of drinks packaging, mainly on a voluntary basis. Some countries, however, apply mandatory DRS (e.g. Denmark, Germany, and a number of states in the USA).

In principle, there is no reason why DRS should be restricted to drinks packaging. At the theoretical level, several authors have studied the conditions under which DRS can be considered a useful policy instrument to attain maximum welfare and how they should be designed. For example, Aalbers and Vollebergh (2008), using a general equilibrium model, found that DRS can provide the optimal incentives to recycling, landfilling, and dumping, taking into account the possibility of waste mixing and the efforts needed to keep waste streams separated. Calcott and Walls (2005) argued that a deposit-refund should be applied to *all* products, combined with a disposal fee (waste tax).

31.4.4 The Importance of Instrument Mix Design

Economic instruments can play an important role in making recycling a more attractive waste management option and in reducing the attractiveness of other, environmentally less desirable options. Shaping a recycling policy, however, is not a matter of picking one or more instruments from a pre-existing toolbox. In reality, a tailor-made instrument mix will have to be designed that takes into account specific situation characteristics and conditions. These include, among others, the price-responsiveness of the producers and consumers involved (in economic terms: the price elasticity of supply and demand), as well as numerous social, cultural, political and institutional factors. Designing economic instruments for recycling is therefore an art that requires skills and creativity, but which can also benefit from theoretical insights and practical experiences gained by researchers and practitioners.

31.5 CONCLUSIONS AND DISCUSSION

In the first part of this chapter on the economics of recycling, we explained the main economic drivers and developments of recycling. It shows how recycling takes place in a volatile, dynamic, and globalizing world, which complicates the projections in future developments in the recycling sector.

Next, the chapter demonstrated which private and external costs of recycling-related activities need to be taken into account and how these effects can be valued in economic terms. Internalization of externalities leads to better decisions on which waste management policies to pursue. However, a proper valuation study incorporates all externalities across the (international) life cycle. Therefore, valuation remains difficult because of spatial and temporal variations and boundary issues.

Finally, the most important economic instruments to promote recycling are identified and explained. Economic instruments may have a larger role to play in waste policies of most countries in the world. Economic instruments are most effective in changing behavior by targeting the subject as directly as possible. Major immediate effects from economic instruments are limited because "low-hanging fruit" has already been harvested. Real-world conditions (e.g. trade effects, long-term contracts, high costs of recycling) may limit the effectiveness of economic instruments. DVR schemes (differential and variable rates in waste collection charges) are an essential precondition for the effectiveness of many other economic instruments.

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