Policy Instruments for Environmental and Natural Resource Management

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Natural Resource Management: Challenges and Policy Options

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Abstract

Much of the improvement in living standards in developed and developing countries is attributable to the exploitation of nonrenewable and renewable resources. The problem is to know when the exploitation occurs at rates and with technologies that are sustainable. If the technologies used are not sustainable, resource exploitation presents a serious problem for the future because welfare will decrease. A long-term management perspective is needed to avoid irreversible degradation of renewable resources. This article examines major challenges to natural resource management as well as policy options.

1. ECONOMIC GROWTH AND ENVIRONMENTAL SUSTAINABILITY

A casual reading of the literature on the resource curse and the connections between, for instance, blood diamonds and civil unrest might give the impression that natural resource abundance is primarily a burden condemning countries to poverty and destitution. The negative link between natural resource abundance and economic growth may be explained either by the rent-seeking behavior of powerful groups that try to retain control over the resource (thus affecting economic performance and increasing the probability of social conflicts) or by the appreciation of the exchange rates, which in turn leads to declines in productivity and competitiveness of key productive sectors (Dutch disease). These views miss the rather obvious point that natural resources represent potential wealth and that many developed nations, such as the United States, Norway, and Canada, have prospered and still do prosper tremendously from natural resources. Although individual countries' dependence on natural resources poses some risks for continued economic growth, it also represents enormous opportunities if natural resources are managed effectively.

Economic growth and environmental sustainability are complex aggregates that are determined by the interplay of various factors such as technology and output composition. Moreover, these parameters are determined endogenously in the economy. The composition of output tends to develop in ways that reflect factor endowment, tastes, and comparative advantage. Similarly, technology choices are made by economic agents and can be highly influenced by suitable policies. Simple correlations between resource dependence and slow growth, for instance, are not subtle enough to catch the intricacies involved. Growth may in some cases be a function of resource availability, but the reverse causalities also need to be taken into account: Slow growth will typically mean that no new sectors such as industry develop, and thus the economy will be classified as resource dependent by commonly used measures (e.g., share in GDP of resource-intensive sectors).

The intricacies of the very measurement of economic growth are at the center of this debate. Popular press and business interests can sometimes describe the situation of a country (region or sector) as involving spectacular but not sustainable economic growth because such growth entails so much resource destruction and environmental damage. Economists should, however, balk at such a description because income, correctly measured, would not be as high or growing as fast if all the destruction of resources was taken into account. Hicks (1935) was very clear on this point when he defined income as the amount that a person or a country can consume during a certain period and still be at the end of the period as well off in terms of endowment as at the beginning of the period. The key phrase is the second part of this definition, which implies that we must deduct from gross income the depreciation of wealth or capital caused in the course of earning the gross income. To most people it is fairly obvious that we should deduct the wear and tear of machines, for instance, from income, and thus it may be surprising that wear and tear are not deducted in GDP. However, GDP is the gross value, and the corresponding net value is net domestic product. The latter is thus a much better measure of income yet is much less commonly used. The reason why it is less used is significant: We do not know net income exactly because we do not know the exact depreciation of our physical capital such as machines and buildings. This also gives us the key to understanding why we do not regularly discuss true measures of income that take environmental and natural resource stock depreciation into account. Just as we are uncertain about the exact depreciation of human-made capital, we are even more ignorant of the true magnitude of the depreciation

we cause to natural ecosystems because this would entail answering, e.g., exactly how many fish are left in the ocean, what such fish and all the food webs are worth, and what the cost of a thinning ozone layer really is.

Reconciling economic freedom, growth, and ecological constraints may require a careful blend of policy instruments to influence the composition and the technology of consumption and production. In terms of resource management, the tasks are to ensure that the resources are used in ways that maximize long-term social welfare and capture as large a fraction as possible of the benefits. If the resource is nonrenewable, it is also important to draw it down at a rate and in a manner that provides the greatest economic benefit to the rest of the economy.

Research and policy experience together show that the most immediate causes of overexploitation are imprecise property rights, mispricing of the inputs and products of resource exploitation, poor information availability, monopoly arrangements or other forms of market power, or poor investment decisions by state agencies (see, for instance, Ascher 1999). It is not easy to say whether market failures or policy failures, which are also strikingly common across the different types of natural resources, dominate. In fact, it is sad and ironic that these failures often go hand in hand. The collected experience of ocean fisheries across the world does, for example, leave no doubt that unregulated fishing in the absence of private property rights implies a gigantic market failure and that some form of public policy would be needed (Costello et al. 2010). However, public policies are so often flawed that one commonly sees market failure compounded by policy failure. In another example, insecure property rights on communal or private lands encourage overexploitation: Many reforestation programs have resulted in deforestation because of poor instrument design (Sayer et al. 2004). Poor policy design also occurs when oil-rich nations set low domestic prices on petroleum products, undermining potential economic growth: Excessive consumption of these products encourages pollution and reduces conservation incentives (Reyes-Loya & Blanco 2008). In this article, we discuss several institutional and policy failures responsible for the depletion of natural resources as well as policy reforms and policy challenges.

2. NATURAL RESOURCE MANAGEMENT: POLICY OPTIONS

In this section, we present the main categories of policy instruments used for environmental and natural resource policy. We also briefly describe how each instrument works.

Policy instruments are often classified as market based versus command and control, but this classification is poor. It is very difficult to classify policy instruments neatly, although we have tried our best in Sterner & Coria (2011). Market-based instruments involve both prices and quantities, and regulations are also backed by economic sanctions in case of noncompliance. One possible typology (based on World Bank 1997) for organizing the rich diversity of actual experiences in the field divides the policy instruments into four categories: environmental regulations, market use, market creation, and public engagement. **Table 1** lists the various kinds of policy instruments in and actual applications to natural resource management.

The first category of instruments, environmental regulations, includes bans, (nontradable) quotas or licenses, and regulations that concern the temporal or spatial extent of an activity (zoning). Liability rules can also be included in this category, connecting it to a large area of law making and to the politics of enforcement. Instruments such as liability

Table 1 A taxonomy of policy instruments

Policy instrument	Some applications to natural resource management
Environmental regulations	
Detailed regulation	Zoning
	Regulation of fishing (e.g., dates and equipment)
	Bans on ivory trade to protect biodiversity
	Water quality standards
	Harvesting and replanting rules in forestry
Legal mechanisms and liability	Liability bonds for mining or hazardous waste
Market creation	
Creation of property rights	Private national parks
	Property rights and deforestation
Common property resources	Common property resource management
Tradable quotas or rights	Water trading
	Individually tradable fishing quotas
	Transferable rights for land development, forestry, or agriculture
Market use	
Taxes, fees, or charges	Park fees
	Fishing licenses
	Stumpage fees
Subsidies and subsidy reduction	Reduced agricultural subsidies
Deposit-refund schemes	Reforestation deposits or performance bonds in forestry
Public engagement	
Information provision and labels	Labeling of food and forest products
Voluntary agreements	
Direct provision	Direct provision of parks
International treaties	Reducing emissions from deforestation and forest degradation (REDD) and other forms of international payment
	International treaties for protection of biodiversity, seas, climate, etc.
Macroeconomic policies	Environmental effects of policy reform and economic policy in general
	Policies to manage Dutch disease, such as oil funds

bonds and (more generally) enforcement policies and penalties are all part of the instrument arsenal.

Some of the more sophisticated so-called regulatory instruments offer considerable flexibility to the regulated sector. This point is clear if we compare technology standards or performance standards in, for instance, fisheries. A technology standard prescribes the exact technology that must be used (thus leaving little room for flexibility or innovation), whereas performance standards specify only what is to be achieved (for example, a maximum bycatch rate in a mixed fishery), leaving the search for technological improvements and learning by doing to the entrepreneurs who are regulated.

The second category of instruments, market creation, consists of mechanisms for delineating rights. Different nations have different and often diverging legal traditions and even legal systems for the creation of rights. In the United States, more rights tend to belong to people in the economy who earn them either as a function of owning adjacent land (which sometimes gives rights to water, oil, minerals, etc.) or through the act of capture or prior appropriation (as with wild animals, oil, and water, particularly in California). In contrast, in Europe as well as in large parts of Africa and Asia, there is a somewhat stronger role for society, represented sometimes by local communities and sometimes by the state.

The third category of instruments is market use. It includes subsidy creation or (in later phases of policy making) subsidy reduction, environmental charges on inputs or products, user charges (taxes or fees), performance bonds, deposit-refund systems, and targeted subsidies.

The last category of instruments, public engagement, includes mechanisms such as information disclosure, labeling, environmental auditing and certification, and community participation in environmental or natural resource management. Dialogue and collaboration among the environmental protection agency, the public, and polluters may lead to voluntary agreements (VAs), which have recently become a popular instrument. Public engagement cannot easily replace other instruments such as regulation or taxation; evidence shows that voluntary action or VAs work best when the threat of other instruments is palpable.

Other mechanisms are potentially important in various contexts. Such mechanisms include direct provision of environmental services (such as national parks) and state resource exploitation, international agreements (which are a policy at only the multinational level), and macro policies in general (all fiscal, monetary, and trade policies have implications for the whole economy and thereby for the environment).

2.1. Direct Provision of Environmental Services and State Resource Exploitation

The most straightforward policy that a resource or environmental ministry can apply is to use its own personnel, know-how, and resources to solve a given problem. In the environmental arena, this mechanism is essentially the provision of public goods; whether the term policy instrument is appropriate in this context is not clear (some economists would reserve "instrument" for policies that influence other agents), but it is important to start here.

Providing and maintaining natural parks are a prime example of public goods provision; the creation of parks and protected areas that exclude livelihood activities is a common approach to protecting biodiversity. Protected areas have strictly defined borders that unauthorized people are not supposed to cross. Marine protected areas are a somewhat more recent addition to the plethora of land-based parks. In some cases they are

designed specifically to protect a stock. This policy works best if the area chosen creates services that are of value for other areas in the neighborhood that are still being fished.[1]

The role of the state can be broken down into several components: financing, administration, provision, and control. During the past couple decades, in most countries the state has started to refrain from acting as direct producer of goods and services, focusing instead on financing. Several activities that were formerly thought of as natural state monopolies have been organized in such a way that the government agency retains merely a control function, and private entrepreneurs are hired to provide the services. One of the factors that have contributed to this change is the negative popular image of state enterprises as incompetent (Ascher 1999). One of the main problems is that state enterprises can be subjected to rent-seeking behavior by government officials, who can use state enterprises' resources to gain political support from key actors outside the government and sometimes even affect the result of elections. Nevertheless, we must realize that state resource enterprises are still very common due to the strategic nature of many natural resources.

For exploitation rates to be sustainable and dynamically efficient, governments must ensure that state enterprises are kept accountable for the quality of their resource management and the damage they cause. Governments must also ensure that directives to state resource enterprises call for appropriate rates and methods of resource exploitation. Unfortunately, such goals are often not attained. Instead, governments fail to keep state resource managers accountable, demand that state enterprises engage in over- or underexploitation of resources, make inappropriate investments within and outside the resource exploitation process, or set the prices of state-produced outputs too high or too low. Undercapitalization of state enterprises is also common due to the government's unwillingness to approve adequate investment budgets, its excessive taxation of state operations, or its failure to prevent funds from being diverted away from needed investments (Ascher 1999, Kolstad & Søreide 2009).

2.2. Environmental Regulations

This category involves two main instruments: regulation of performance and the direct regulation of technology. Although these instruments are grouped together, they do, as mentioned above, differ considerably in the freedom given to individual firms.

2.2.1. Regulation of technology. One way of regulating the behavior of firms, households, agencies, and other agents in the economy is by prescribing the technology to be used or by restricting the use of certain methods or technology to specific locations or timing (zoning). In agriculture and forestry, examples of technology regulation include mandatory replanting of trees after harvest, mandatory construction of soil bunds and terraces to prevent soil erosion, and guidelines for pesticide and fertilizer use as well as other land

[1]Other examples of direct provision of environmental services include taking responsibility for major environmental threats and managing certain kinds of research and control functions typically undertaken by environmental protection agencies. In some countries, ordinary sewage treatment or municipal waste management is provided as a public good, although the state or municipality usually tries to cover costs by charging user fees. Such fees may be part of property taxes or other taxes, or as is becoming increasingly common, they may be user fees tied more specifically to the service provided.

management practices. In fisheries, the restrictions or prescriptions of certain types of vessel and gear can be extremely detailed.

With mandatory technology, firms have little choice and are not encouraged to explore cost-efficient ways of exploiting natural resources. Instead, the best-available-technology concept tends to encourage specific types of solutions. Unhappily, the impact of such programs on total exploitation costs and technological development is obvious. For instance, in fisheries, the use of cyanide and dynamite is banned, which most people agree is reasonable (because these methods are so dramatically destructive to the actual habitat). However, techniques that are not necessarily destructive but are perhaps more effective, such as those that involve enhanced nets and the use of equipment such as lights or sonar search equipment to attract or find fish, are also sometimes restricted (Crutchfield 1982).

Even more negative is the effect of such regulations on the incentive to undertake research on more efficient fishing methods and equipment: It does not make sense to waste money on development if success only generates a new set of restrictions on whatever improved technique or gear results. However, even if the total level of harvest is optimal, the scarcity of the resources is not reflected in the price, and thus output is not reduced.

Restricting fishing seasons also has several disadvantages but is a very common practice. Restrictions tend to encourage derby-style fishing during the short period the fishery is open and therefore induce overcapitalization or so-called capital stuffing (Homans & Wilen 1997). The higher productivity leads to shorter and shorter seasons. In the case of one famous U.S. halibut fishery, the season was a mere 48 h, and fishermen adapted to this two-day season by investing in three identical electronic systems, for which two were backups. The extra capacity may be idle part of the year or may migrate to other areas, contributing to overfishing elsewhere. Short seasons may also lead to lower commercial value of catch because it has to be sold frozen for most of the year. Finally, short seasons lead to fishing even in bad weather, which increases safety risks (NRC 1999).

Under certain conditions, however, achieving desired levels of harvest through technology regulations is possible. For instance, the standardization of technology holds major advantages if technical and ecological information is complex, crucial knowledge is available at the central level of authorities rather than at the firm, firms are unresponsive to price signals (e.g., because of noncompetitive markets), investments have long-run irreversible effects, monitoring costs are high, or only a few competing technologies are available and one is superior.

In real life, all these conditions will not be fully met, but in many situations, some of them are important. Presumably, this is why technology standards are still frequently used. Moreover, these restrictions are sometimes seen as a way of protecting the livelihood and interests of certain groups, usually those that use the older and more labor-intensive technology (Aarseta & Jakobsen 2009).

2.2.2. Performance regulations. In many real-world cases, natural resources are controlled by licensing procedures or quotas. The logic of this instrument is fairly simple. The regulator chooses to maximize or minimize some variable, for instance, the maximum allowable harvest for each firm.[2] Then, output is directly regulated, and each firm

[2]The regulator may also regulate various other aspects, such as percentage bycatch for fisheries.

optimizes within this constraint. Optimally chosen, harvesting limits imply that the product prices will reflect the scarcity of the resource.

Licensing procedures may give many opportunities for rent seeking because the information and resources available to parties (industries and local or national authorities) that negotiate the individual quotas may be asymmetric, often leading to fairly lax environmental quotas. That many firms appear to prefer licensing to market-based instruments reinforces this impression. However, if well managed by knowledgeable authorities, these negotiations may yield reasonable outcomes (see Brännlund et al. 1996).

One negative feature of individual quotas is that they do not imply full control of total harvest because the total levels also depend on the number of agents. Because the total harvest level is the decisive factor for sustainability, parameters are sometimes set by formulating the harvest quotas as an individual share of harvest, rather than in terms of absolute levels.

In the case of forests, command-and-control regulations also pertain to the regeneration of private lands to ensure rapid reforestation after harvests of the previous stand of mature timber. Regulations were initially imposed in many countries to protect against anticipated timber supply "shortfalls," which are usually not actual shortfalls but an argument used in price bargaining between forest owners and sawmills or paper industries. However, reforestation regulations may also be motivated by environmental concerns for birds or biodiversity. Indeed, several countries have included specifically environmental objectives, such as leaving dead trees for birds or leaving protective corridors along streams, as a part of overall forestry regulations (Sterner & Coria 2011).

2.2.3. Liability and other legal instruments. During the past three decades, several countries have enacted legal schemes to ensure that the operators whose activities cause destruction or damage to natural resources are held financially liable and responsible for restoring the environmental damage to a baseline condition.[3] These schemes aim at inducing operators to adopt measures and develop practices to minimize the risks of environmental damage such that their exposure to financial liabilities is reduced.

In discussions about restoration-based compensation measures, the use of equivalence analysis to calculate the amount of resources or services needed to replace an equivalent level of ecological services lost due to an incident has become popular (see, for instance, Jones & Pease 1997, Flores & Thacher 2002, Roach & Wade 2006, and Riera 2008). Different measures have been proposed on the basis of either the physical natural resource needed to compensate for the harm (resource-to-resource or habitat-to-habitat compensation) or the social value of the harm (value to value).

The choice of metric influences the cost of remediation and financial liability, especially when the resource damaged is very scarce (for instance, endangered species or rare landscapes). However, a firm's liability has a clear limit: The worst-case scenario is not the loss of value equal to maximum environmental damage but firm bankruptcy (which is typically worth less than the value of the environmental damage). Thus, although most

[3]For instance, in the case of oil spills, current programs in the United States are defined by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Oil Pollution Act of 1990 (OPA). The European Union has also developed the Environmental Liability Directive (2006), which, as do the CERCLA and OPA schemes, includes compensation for interim lost use resulting from petroleum releases. The International Oil Pollution Compensation Funds also have well-established protocols to compensate for spills of persistent oil from tankers worldwide. All these approaches are intended to deliver nonpunitive compensation.

legal schemes give priority to the former metric, they also contemplate the monetary metric. Unfortunately, limited company liability can be abused by entrepreneurs who repeatedly and systematically use bankruptcy to get rid of debts. In the case of large hazards, the situation may have more serious repercussions. The owners of plants that represent particularly large hazards can divide them into separate subsidiaries—legally distinct companies. Such separations allow the parent company to reap the profits but avoid the risks because, in the event of an accident, only one subsidiary goes bankrupt, and damages to the parent company are thus minimized.

2.3. Market Creation

Market creation helps to remove the externalities implied by the absence of property rights or the public good character of the environment. With policy instruments such as rental markets, concessions, or tradable quotas, policy makers create property rights to new resources or shares in the assimilative capacity or the sustainable rent production of ecosystems.

2.3.1. Creation of property rights: rental markets and concessions. One of the most obvious ways to create markets is to create property. The definition of property rights is a powerful policy instrument and the most fundamental one. Once real property is created, trading will often evolve on its own. However, in many countries, a considerable degree of skepticism and uncertainty surrounds the concept of creating new property rights, particularly private or common property rights. The defining feature of property rights is that they are perceived to be permanent and enforceable; this inalienability gives owners the confidence and incentive to make long-term and costly productive investments in their properties.

Economic theory postulates three links between land tenure security and economic incentives (Besley 1995). The first link, the security argument, captures the direct and positive link between tenure security and investment incentives. The second link, the collateral-based argument, is based on the premise that when land tenure is secure and thus easier to collateralize, it can reduce the price of capital and subsequently increase investment value. The final link is referred to as the gains-from-trade argument and is based on the fact that tenure land rights expand trading opportunities and the ability to take advantage of gains from trade by lowering transaction costs if land is to be either rented out or sold.

Unfortunately, land sales markets are usually poorly developed in developing countries due to asymmetric information about land quality, the lack of land titles, undeveloped credit markets, the inability of poorer farmers to pay the collateral value of the land, and/or various policy distortions. Where land sales markets do not function well or are prohibited—as in Ethiopia, Eritrea, and Zambia—the effective functioning of land rental markets is crucial for agricultural development. Land rental markets have an important role as a safety net for poor landlords in many places in Africa; food and income from rented-out land are very important, particularly for poor, female-headed households that lack the capacity to farm the land themselves. In such a sense, such markets promote short-term agricultural efficiency because they allow land to be used by farmers who are more capable of earning the highest return from it; however, if rental contracts are very

short term due to tenure insecurity of landlords, the incentives of tenants to invest in sustainable land management practices may be very limited.

A large literature investigates the short-term-efficiency impacts of land lease contracts (see, for example, Benin & Pender 2009, Holden et al. 2009, and Zikhali 2010). The results highlight the dependence of impacts of land tenancy on the local context and policies and suggest that the rental market functions better in regions where tenants feel sufficiently confident about their long-term ability to renew their lease contracts. In such settings, they have incentives to make investments in land improvements and to adopt more sustainable land management practices, despite the short-term nature of the contracts. In contrast, in regions where landowners fear further redistributions, tenants appear to have a shorter-term perspective, and the ability to assure sustainable land management seems more compromised.

Concessions have become a common management strategy to stabilize the exploitation of natural resources, promoting sector growth, encouraging investments, and collecting public revenues. Through this strategy, the state sells the rights to exploit natural resources for a predetermined period of time. For instance, in countries with large, government-owned forests, forest concessions have begun to be granted to private forestry companies (see, for instance, Banerjee & Alavalapati 2010). Forest concessions can counteract some of the negative incentives for forest management. If concessionaires can limit access and competition from illegal loggers, then they should feel sufficient security to manage their concessions sustainably. Furthermore, increased transparency in the regulatory environment, as well as in concessions' allocations, creates demand and maintains investors' confidence. Unfortunately, in many countries concessions have typically been allocated noncompetitively in ways that are nontransparent and possibly corrupt, partly because of the gigantic scale of some of these transactions (Kolstad & Søreide 2009).

Concern for the condition of the resource at the end of the concession has led some environmentalists to suggest a liability bond on the environmental performance of concessionaires (Ruzicka 1979, Paris & Ruzicka 1989). In the ideal case, the concessionaires would submit a bond at the outset of the exploitation agreement. The bond would be returned on the demonstration of acceptable performance. For the bond to truly be a guarantor of environmental performance, it should be set high enough to compensate for all costs of returning the resource to an acceptable condition in the event of noncompliance.

Governments usually collect a portion of the rent related to the exploitation of the resource. If the concessions are granted to private companies, the government is typically tempted to increase this share. Instead, some developing or formerly planned economies charge almost nothing and thus make no public revenue at all. This has also been the case in the oil and mining sector, in which governments have underpriced the basic resource by failing to charge royalties for companies' access to oil and mineral deposits (Ascher 1999).

2.3.2. Common property resource management. Some researchers maintain that common property resources (CPRs) may be a superior institution under certain conditions (Ostrom 1990, 1998, 1999; Stevenson 1991; Dasgupta 1993; Balland & Plateau 1996). For instance, people may find it in their interest to collaborate intensely when the services provided by a certain ecosystem are erratic or mobile or when the value of the services

provided by a certain ecosystem is too low to cover the basic costs of enforcing private property rights (e.g., by installing fences).[4]

One basic criterion for determining the need for CPR management is whether the profitability of a private property rights regime would be lower than that of a common property rights regime as a result of either the excessive cost of private property rights on marginal lands or technological factors that make CPRs more productive (see Hanna & Jentoft 1996 and McWhinnie 2009 for some fishery examples). However, many social scientists have questioned the sustainability and optimality of CPR institutions, arguing that they will ultimately break down because of the temptation to free ride. In her early work, Ostrom (1990) developed eight general conditions that seemed to characterize sustainable CPR management:

1) Boundaries are clear, and outsiders can be excluded.
2) Rules of provision and appropriation are adapted to site-specific conditions.
3) Decision making is participatory (democratic).
4) Locally designated agents monitor resources.
5) Graduated sanctions are used to punish infringements.
6) A local court or other arena is available to resolve conflicts.
7) Outside government respects the CPR institutions.
8) If there are large and complicated CPRs, they may need governance structures at several levels (i.e., nested enterprises), all of which should fulfill the same rules.

Condition 1 is a general prerequisite for any kind of property. Condition 2 concerns adaptation of the rules of provision and appropriation to local ecological conditions; rules concerning rights to harvest that are appropriate for one setting may be inappropriate in another. Conditions 3–7 concern the internal sociology of decision making. Rules and processes must be democratic, legitimate, efficient, and effective. Condition 8 concerns the way in which, for example, irrigation systems may be nested, with smaller local systems making up bigger ones. These design conditions spurred a very considerable body of subsequent research that was recently revisited in an extensive and elaborate retrospective meta-analysis by Cox et al. (2010). They find that all the more than 100 studies reviewed find empirical support for these conditions. Some studies suggest some additional conditions or discuss how details may be refined, for instance, in the interaction between the conditions and the differences in how they apply at different scales. Both Ostrom (1990) and Cox et al. (2010) do, however, insist that the conditions should not be seen as a blueprint to be applied everywhere: One of the essential conditions is that of local ownership and adjustment to local conditions. Cox et al. (2010) tentatively suggest a slight reformulation of the principles, and the interested reader is referred to their text for more details.

Local CPR management is a policy instrument that operates primarily at a decentralized level, but central (or local) government also plays an important role. If government is prepared to accept the autonomy of CPRs, it can benefit from their good management. Central authorities can aid CPR management by providing the necessary legitimacy and by not interfering too much, as suggested by Condition 7 above (which discusses respect

[4]However, this kind of relationship can change with new technology: Productivity and the costs of enforcement can change dramatically, which may alter the balance between costs and benefits of different types of property significantly.

for CPR institutions). In situations without CPRs or in which the underlying culture has broken down, the central government may try to revive or recreate communal institutions, but rebuilding is generally much more difficult than sustaining institutions that have already evolved.

This is an area in which considerable current research combines methods from behavioral economics, anthropology, and political science as well as other related disciplines. A good deal of experimental work has been done on this topic, and results indicate that norms to support sustainable CPR management may evolve easily, particularly if the proportion of permanent free riders is not too large (see, for instance, Casari & Plott 2003, Ostrom 2006, Van Soest & Vyrastekova 2006, and Cárdenas 2009). Experimental evidence also highlights the role of institutions for control and punishment and peer enforcement mechanisms in overcoming overexploitation of CPR.

2.3.3. Tradable quotas or rights. In general, the process of modifying rights is fairly slow, but some environmental policy instruments can evolve relatively quickly. In this sense, the development or assignment of new kinds of property rights—as tradable permits and quotas—is a definitive policy instrument of natural resource or environmental management.

For instance, water trading is an allocative mechanism in which entitlements of water quotas can be transferred between users, intravalley (within the same water basin) or intervalley (between water basins). Water is thus reallocated to users with higher values, which incentivizes the holder of the right to conserve water. Potential purchasers are also incentivized to use efficient technologies to reduce water consumption and water losses in order to reduce costs of purchase.

In particular, water trading is used to ensure sufficient irrigation resources, but urban water trading schemes can also be implemented. In such schemes, urban households and industrial water users are able to buy and sell water entitlements and water allocations. Nevertheless, transaction costs may be an important impediment to fully reaping the benefits of trade. The costs of identifying potential trades and recording and enforcing changes in water intakes and conveyance infrastructure may be very large in comparison to the value of water; hence a trading system would be justified only in areas confronted with severe enough water shortages. The institutional costs associated with establishing and enforcing the rights may also be very high with both public and private institutions; for example, water user associations may be required to operate at the levels of ditch, canal, and river basin. There is often a perception that everyone has an inherent right to some water, which may create social disapproval of full privatization and may prevent trading by not respecting water property rights.

In contrast, large hydrologic effects can occur as a consequence of interbasin trading if trading is permitted without a complete understanding of the water system. If the trading scheme does not assure minimum water flows in the lower sections of the rivers, aquifers can be depleted, increasing water pollution and changing ecosystems. Water trading is also contested on the grounds that it reallocates water resources from productive agriculture to urban uses, although the empirical evidence is mixed in this direction. However, operational rules are enforced in some regions to explicitly prevent large agriculture-to-urban transfers. In spite of these pitfalls, evaluations of trading programs in place indicate that the welfare gains of water trading are sizeable (see, for instance, Peterson et al. 2005, Qureshi et al. 2009).

Another major set of tradable permit programs that has seen some measure of success is the individual transferable quota (ITQ) program for fisheries (see Costello & Deacon 2008). Since the late 1970s, when countries began to enclose the ocean commons by establishing exclusive economic zones, several countries followed New Zealand's and Iceland's lead in establishing ITQs to manage fisheries. Fisheries appear to have several special characteristics that make ITQs particularly effective: the high value of the resource, the mobility of the resource (and thus the difficulty of creating ordinary private property rights on the basis of territory), and the strong negative externalities exercised by one fisherman vis-à-vis other fishermen (Christy 1973). Many of these programs have dramatically reduced excessive fishing effort and thus restored profits and saved fish stocks. Despite this success, the process has not been without problems. Fisheries are a valuable resource, and the concentration of shares in the hands of a relative minority has created considerable social tension in some fishing communities. Also, some problems remain, such as the discarding of juvenile fish. Still, the overall picture is positive, and one of the contributing innovations is that the quotas are not for fixed harvests of fish but for fixed percentages of a total allowable catch. The total allowable catch, in turn, can be changed at short notice in response to variations in the stock. Thus, this instrument strikes a delicate balance between the need of certainty (ease of collateralization) required by the resource users and the need for flexibility in response to ecological variation imposed partly by nature.

Other examples of tradable permit programs in natural resource management include grazing rights and transferable development rights (TDRs) for land planning. TDRs allow land planners to overcome many of the shortcomings associated with traditional zoning practices, such as the costs of expropriating properties from landowners. A TDR program restricts development in one zone, for instance, to allow for the creation of a park. In exchange, the landowner is given the right to transfer a development right to another zone where development is permitted, with the help of TDRs purchased from the first zone. Creation of a green zone around a city usually entails the problem and cost of expropriating properties from landowners. Hence through the use of TDRs, these landowners are partially compensated, and a large group of landowners shares the burden. However, numerous legal issues still surround this instrument (Miller 1999). Among the latest innovations in trading are schemes for river or wetland restoration; see, for instance, Palmer & Filoso (2009).

2.4. Market Use

Economists often view environmental charges as the most natural instrument for environmental and natural resource policy and tend to use them as a point of reference for other instruments. The other kind of price instrument is often said to be a subsidy. Although economists tend to think of subsidies as being similar to taxes, at a deeper level there are important differences between taxes and subsidies with regard to their implications for the questions of ownership and rights to nature. Also, there are combinations between taxes and subsidies that can be very interesting from a policy perspective because they allow decision makers to keep some of the positive aspects of an instrument while avoiding some of the negative ones.

2.4.1. Taxes, fees, or charges. In natural resource management, taxation is used mainly to catch a share of scarcity or land rent (such as mining royalties, stumpage fees, user fees,

and land taxes) or to avoid or correct for externalities created (see, for instance, Lund 2009). The levy of taxes and fees may lead—under several classical assumptions, including fully informed, honest, welfare-maximizing regulators and appropriate concepts of property rights—to an optimal rate of exploitation while capturing for the public some of the benefits generated. However, the effect and efficiency of taxation depend on exactly how the tax base is defined, the type of owner, and the type of resource.

Tax solutions are not easy to implement if they capture the rents of groups perceived as vulnerable (or simply powerful). In fisheries, this is presumably the reason why ITQs have become the main instrument: ITQs provide a scarcity signal but leave the rent with the fishermen. In contrast, in some cases governments resort to extracting rents in a way that clearly distorts the exploitation incentives (Ascher 1999).

In forestry, three common tax bases are land, standing timber, and harvested timber (or severance taxes). In addition, some communities have introduced preferential tax treatment for ecologically sensitive forestry (see Klemperer 1996 for a summary); royalties and corporate income taxes are key tax instruments for the nonrenewable sector.

Returns on investment in natural resources are highly uncertain, investors are risk averse, and governments often depend on potential investors for information about the value of the resource. Thus, investors in resource projects insist on fairly mild tax regimes. Such regimes are negotiated in advance, which tends to give governments an unnecessarily small share of successful projects. However, arbitrary changes to regulations in place lead to income losses through reduced investment. Pressures to renege on promised tax agreements are especially strong in times of high resource prices.

2.4.2. Subsidies. Subsidies may apply to payment in support of certain environmental services, prices for certain inputs or technology, loans, or access to credit markets. For example, the Sloping Land Conversion Program (SLCP) is one of China's most ambitious initiatives and one of the largest land conservation programs in the developing world (Bennett 2008, Xu et al. 2010). Initiated in 1999, it has the purpose of reducing water and soil erosion and increasing China's forest cover by retiring steeply sloping and marginal lands from agricultural production. Toward that aim, it provides subsidies to those farmers who convert degraded and highly sloping cropland back into either ecological forests (which in the Chinese context means timber-producing forests) or economic forests (i.e., plantations of trees with direct medical or other value). Farmers are compensated with an annual in-kind subsidy of grain, a cash subsidy, and free seedlings provided at the beginning of the planting period (Xu et al. 2010). The payments differ across regions and across forest types to account for differences in average yields.[5]

The most practical argument against subsidies is that they are too expensive as a policy instrument—especially in developing countries, where the opportunity cost of public funds is high. Indeed, one of the problems in program design and implementation of the SLCP is that its fast expansion has created some shortfalls in required funds, leading to problems in implementation and subsidy delivery. However, there is some evidence of mistargeting of plots for retirement in terms of the SLCP's stated target of highly sloping land, which indicates that considerations other than plot slope have been important in the enrollment choice of villages (Xu et al. 2010).

[5]In the case of ecological forests, the subsidies are provided for 8 years, whereas the payments are limited to 5 years for economic forests.

An additional argument against subsidies is their perverse output effect. They tend to encourage the entry (or delay the exit) of new firms, resulting in too many firms and too much exploitation compared with the unregulated scenario.

2.4.3. Subsidy removal. In reality, the most relevant issue for natural resource management is not subsidies for conservation but the prevalence of perverse subsidies for overexploitation. Inappropriate subsidies promote rather than prevent wasteful and environmentally destructive behavior (see, for example, van Beers & van den Bergh 2001 and Bull et al. 2006). Well-known examples include large subsidies for energy use in many countries, particularly oil-exporting countries and the formerly planned economies (Kosmo 1987). The formerly planned economies subsidized the domestic consumption of not only energy but all natural resources (Bluffstone & Larson 1997). In the fishing industry, a prime example is subsidies to help fishermen purchase more equipment (e.g., boats, nets, and technology) when catches decline. The trouble is that more efficient equipment speeds up stock depletion and thus adds policy failure to market failure.

Perverse subsidies are so common that subsidy removal is often classified as an environmental policy instrument. However, the removal of subsidies is politically complicated because subsidies become intertwined with vested interests. In fact, the value of subsidies is typically capitalized in property values. If an individual buys a house with electric heating in a cold climate, then the dependability of the heating system is one of the most important attributes of the house. If the government changes the value of this attribute by taxing fossil fuels after the house is bought, then the value of the house may plummet in expectation of future energy bills. Properties acquired just before a policy change can suffer particularly serious losses in value, and this mechanism fuels political rent seeking.

2.4.4. Deposit-refund schemes. In addition to the basic policy instrument types mentioned above, several more complex instruments exist, many of which are combinations of the other instruments. A deposit-refund system encompasses a charge on some particular item and a subsidy for its return. This instrument can be used to encourage environmentally appropriate recycling. If we assume that disposal is inappropriate for ecological reasons, the deposit-refund combination may be categorized as a tax expenditure or as a presumptive tax on inappropriate disposal. The polluters (i.e., those who do not return the item) pay a charge, whereas those who return the item collect a refund and thus avoid paying the charge. The distinguishing feature of the deposit-refund system is that it has a clever disclosure mechanism: The refund is paid when the potential polluter demonstrates compliance by returning the item that carries the refund, thus making the monitoring of illegal disposal unnecessary.

Deposit-refund systems are usually used for certain final outputs (beverage cans and bottles are the classic examples), and abating environmental pollution has been far from the only (or even the main) motivation. However, the concept is spreading. For instance, environmental performance bonds are a type of deposit-refund scheme in the area of natural resource management. Individuals or companies pay such bonds to responsible authorities but are refunded to the extent that they avoid causing environmental damage or remedy any damage they do cause. Indonesia has used performance bonds for forestry. Under a scheme initiated in the late 1980s, loggers paid deposits of \$4 m^{-3} of extracted timber and could obtain refunds through reforestation. One problem with this system was that the fee was far lower than replanting costs, giving logging companies insufficient

incentive to reforest. Another problem was that the bonds created incentives to clear cut forests to start plantations to qualify for refunds (O'Connor 1994). Similar forestry bonds of approximately $400 per hectare have been introduced in the Philippines. Because reforestation costs have been estimated at $500 per hectare, the Philippines' deposit may be too low to encourage sufficient reforestation (Steele & Ozdemiroglu 1994).

2.5. Public Engagement

All policy instruments require information to function, and disclosure of information has come to be seen as an instrument in its own right. Information disclosure can take any of several forms, depending on the degree of interpretation and aggregation of information as well as on the character of the organization that is responsible for certification: labeling, public disclosure, or rating and certification. Another instrument that builds heavily on information disclosure is VAs.

2.5.1. Labeling and certification. In natural resource management, green labeling and certification may be useful instruments to counteract information asymmetries and to give consumers information about the environmental sustainability of various management practices. In forestry, several certification programs have been implemented whereby products from certified forestlands can, through chain-of-custody certification, move into production streams and in the end receive labeling that allows customers to know that the product came from a certified, well-managed forest.

Large producers are scrambling to obtain certification and thereby to gain shares in markets dominated by environmentally oriented consumers. In Europe, for instance, most industrial and retail companies join together to buy only certified forest products. One of the main certifying organizations is the Forest Stewardship Council (FSC), an international nongovernmental organization that accredits third-party certifiers and facilitates development of forest management standards around the world. As of May 2010, the FSC had certified more than 125 million hectares of forest in 80 countries; of this total, more than 10 million hectares were in Sweden, 7 million hectares were in Poland, and more than 13 million hectares were in the United States. Among the developing countries, Brazil, Mexico, and Bolivia together had approximately 7.8 million hectares certified by the FSC, whereas Malaysia and Indonesia together had only 1.3 million hectares (FSC 2010).

On the whole, the impact of forest certification to date is still modest. However, it is increasing quickly. Those owners already certified are receiving some benefits, but the potential payoff for small woodland owners is less clear because the costs of forest certification have some fixed components, making it relatively less attractive to such owners (Rametsteiner & Simula 2003). Additionally, the current incentives seem to be insufficient to attract producers in tropical developing countries to seek certification because the costs of improved management seem significantly greater than the perceived market benefits.

2.5.2. Voluntary agreements. The term VA appears to be used mainly for a form of negotiated (and verifiable) contract between environmental regulators and firms.[6] The

[6]One of the first such agreements was the Toxic Release Inventory, which was a large-scale release of information (on chemical emissions). This in turn led to much negative publicity, and the firms involved soon agreed (voluntarily) to reduce emissions by large percentages by given dates; see Sterner & Coria (2011) for details.

general format is that a firm agrees to invest, clean up, or manage natural resources according to some standard to reduce negative environmental effects. In exchange, the firm may receive some subsidies or perhaps some other favor, such as positive publicity, a good relationship with the environmental protection agency, or perhaps speedier and less formal treatment of other environmental controls.

What distinguishes this kind of policy from an ordinary command-and-control kind of licensing or regulation may not be immediately apparent, and there is some evidence that VAs may work best when there is a real threat of other regulation. However, the main difference may also be a cultural and psychological one. For example, the covenanting process—that is, the dialogue itself, rather than the formal agreement—has been touted as the feature that makes VAs successful (Glasbergen 1999, Anton et al. 2004). Today, most companies have environmental expertise of their own and are conscious of image and public relations issues. They may prefer a new label on what is essentially the same old negotiation with an environmental protection agency. The proactive, voluntary approach may be a good way not only of building public image but also of preempting effort by the agency. By taking the initiative in some areas, a firm may be able to divert attention from other areas and be able to set a level of environmental regulation closer to its preference (Maxwell et al. 2000). By winning the public relations war, a firm may be able to focus on issues and solutions of its own choosing. In this sense, VAs are closely related to labeling schemes.

Some examples of VAs in natural resource management include conservation of endangered species (Langpap & Wu 2007) and of privately owned forests (Juutinen et al. 2007). Regarding the first, landowners are provided with assurances regarding future regulations if they agree on a conservation program. Regarding the second, landowners agree to produce biodiversity services on their lands and to receive compensation that is lower than the market price–based compensation. When offering VAs, the regulator faces a clear trade-off: He may be able to encourage participation and increase conservation efforts by offering assurances or payments, but by doing so he may have to settle for inefficient levels of conservation (Langpap & Wu 2007). Nevertheless, voluntary conservation programs may still induce lower costs than traditional mandatory programs because they involve environmentally minded landowners at a low cost.

2.6. International Treaties and International Payments for Ecosystem Services

Governments are bound by numerous international conventions concerning the environment and the use of natural resources. International policy making plays a necessary role in the provision of public goods and in dealing with transboundary environmental threats such as climate change, straddling fisheries, marine pollution, or the loss of biodiversity. For instance, the Convention on Biological Diversity is dedicated to promoting sustainable development; it was signed at the 1992 Rio Earth Summit by 150 government leaders who committed to develop national strategies for the conservation and sustainable use of biological diversity. Another example is provided by the United Nations Convention on the Law of the Sea, which established a governance framework for sustainable management of fish across national boundaries. On a more regional scale, nations affected by each other's watersheds and marine pollution have entered into a number of treaties to address that pollution.

The challenge in creating and enforcing a transnational pollution control regime lies in harmonizing international and domestic law, which creates three fundamental constraints. First, international environmental agreements (IEAs) have to be acceptable for all potential participants. Second, the parties must agree on the particular design of an IEA by consensus. Third, the treaty must be enforced by the parties themselves. In such a setting, two types of free-riding behavior may arise. The first implies that a country decides not to join an IEA or—within the agreement—to contribute less to the improvement of environmental quality or reduced natural resource degradation. This type of free riding is usually known as a cooperation problem; in most IEAs the number of signatories falls short of the total number of countries involved in the externality problem (for example, in spring 2001 President Bush announced that the United States would withdraw from the Kyoto Protocol because abatement costs from the emissions reduction obligation were expected to exceed the benefits).

In the second type of free riding, the compliance problem, a country joins an IEA but does not comply with the terms of the agreement. IEAs will endure only if the incentive to free ride on compliance can be controlled by threats to punish deviations. Therefore, the design of a scheme of sanctions to deter noncompliance is a key issue. In this regard, financial penalties are frequently used to punish noncompliance with domestic regulations. However, in the international context, there is no international authority with the ability to impose credible penalties of sufficient magnitude. In practice, international agreements incorporate rules for the peaceful settlement of disputes. For instance, under the Indus Water Treaty, which divides the Indus River and its tributaries between India and Pakistan, a permanent Indus Commission is required to meet regularly to discuss potential disputes and to plan cooperative arrangements for the development of the basin. In the case of disagreement, the disputes are taken up by international negotiations or by arbitration (Ambec & Ehlers 2008).

A general conclusion arising from the literature on transboundary resource management is that it becomes far easier to resolve management conflicts and to enhance participation in the treaty if it is feasible to make side payments to those countries or states that lose from signing the agreement. Such transfers may take many forms, such as, for instance, direct monetary compensation or through markets established for the allocation and management of the natural resource at an international level.

For instance, in the context of climate change, the perceived need for reducing emissions from deforestation and forest degradation (REDD) has led to the development of various funds for carbon payments to compensate developing countries for reductions in emissions from deforestation and forest degradation. Although the idea is straightforward and simple, creating a REDD regime that is environmentally effective, cost-efficient, and equitable is a big challenge because of a series of reasons related to coverage, baselines, and sources of funding (see, for instance, Angelsen 2008 and Angelsen et al. 2009).

The difficulties related to baselines and incentives are illustrated by the expansion of REDD to REDD+, which was driven partly by the concern that if rewards were given only for reducing deforestation rates, and not for maintaining existing forest carbon stocks, the incentive to participate would be limited for countries with large tracts of forest but low levels of deforestation. The result of this could be international leakage, whereby emissions reductions resulting from the REDD system would be offset by increases in deforestation rates in nonparticipating countries, drastically reducing the environmental effectiveness of the regime. However, the shift was also driven by countries such as India

and China that have historically cut most of their forests, that are increasing their forest cover again, and that saw the potential for getting remunerated for this development.

The protection of tropical forests through international payments may entail some positive effects for biodiversity conservation. In that sense, connecting global and national action on climate change to biodiversity conservation may help to restore biodiversity and ecosystems. However, all forest or ecosystems cannot be preserved because such preservation would be prohibitively expensive; some areas will be allocated for commercial resource development. This tendency points to the importance of zoning as an overriding policy instrument. The ecosystems and the services they provide must be sufficiently well understood for determination of the size of reserves and of which other conditions (e.g., buffer zones or connecting corridors) are required to protect ecosystem functions and biodiversity in a satisfactory manner. It may also be advantageous to use some kind of transferable preservation obligation to spread the obligation (and thus the cost) of protection more broadly among forest owners. If only the owner of a particular parcel of forest is affected by conservation decisions, forest owners will have strong incentives to lobby against being classified into some category of reserve or protection status.

3. CHOOSING AMONG POLICY INSTRUMENTS: FURTHER COMPLEXITIES IN NATURAL RESOURCE MANAGEMENT AND POLICY CHALLENGES

Management of natural resources is crucial for the world and is economically vital in most developing countries. In real policy making, several other aspects—such as distributional concerns; uncertainty; information asymmetries; market power; technological progress; and many political, cultural, and psychological dimensions—must also be addressed in the face of a partly stochastic outcome from nature. In this section, we discuss some of these policy challenges.

3.1. Distributional Concerns

Distributional concerns are always very important in discussions of policy challenges. Even in fisheries that have been saved from collapse by instruments such as the ITQ, people often have very strong feelings about the fact that the same instrument often leads to some fishermen becoming wealthier than others. In circumstances of poverty, the conflicts may be very severe. Poverty and environmental degradation are two problems that tend to occur together: Desperation and shortsightedness caused by poverty may lead poor people to unsustainable practices that worsen resource degradation, whereas environmental degradation leads to increased poverty through decreased access to water, fodder, firewood, and other important materials. Together these mechanisms can form vicious cycles.

There are many examples of people suffering as a consequence of conservation interventions. For instance, national parks force population displacement and resettlement outside park borders, which impoverish people and negatively affect the rules that govern the use of resources by members of rural communities, leading to conflicts over natural resources outside the park (Cernea & Schmidt-Soltau 2006). Yet even when local people's needs are integrated into policy design and implementation, there are challenges to ensuring a fair distribution of benefits (Sommerville et al. 2010). In this sense, benefit capture by the elite, variable opportunity, and transaction costs among individuals and

communities may result in the perception of unfair distribution. For instance, Fisher & Treg (2007) show that participants in the Costa Rican system of payments for ecosystem services (PES) are richer and more educated than the average member of local communities. In contrast, the fact that the sociocultural environment of many local communities is strongly tied to consumptive use of resources implies that such communities do not fulfill PES eligibility requirements. For example, the Costa Rican PES scheme excluded most small-scale farmers and indigenous communities because agroforestry was not made eligible.

One natural conclusion from this information is that poor populations should be better targeted, particularly in times of budget cuts and leaner government. However, this is not easy to do because the slightly less poor have appreciable power to protect themselves from cuts in the benefits they receive, and it is possible (and in some cases even likely) that poor populations will be more than proportionately hurt by budget cuts. A certain leakage to nontargeted (or less targeted) groups may be part of the political economy cost of environmental policies; perfect targeting is simply not realistic, considering the characteristics of poor groups.

3.2. Ecological Complexities and Spatial and Temporal Patterns of Extraction

Stocks of natural resources are complex: There are multiple populations and/or subpopulations, and they play an important role in ensuring stock viability and genetic variability. Persistence of diversity of stocks should become a principle of management, particularly under a precautionary approach, because different subpopulations do not breed with each other, which needs to be taken into account in models estimating allowable quotas.

Given the sometimes partial understanding of the ecological complexities, policy instruments should allow for some flexibility as stock assessments vary. Lack of flexibility may entail considerable risk: For instance, if a government incorrectly assesses the carrying capacity of an aquifer, a fishery, or a forest area, then it may find that it has given away key national assets (such as water supplies) inappropriately. With regard to this point, Svedäng et al. (2010) show how cod subpopulations in Scandinavia may have been eradicated as a consequence of the use of imperfect models for assessing available fish resources, putting a former productive sea in a steadily depleted state. The study indicates that policy instruments are needed, but these instruments need to be very carefully fine-tuned to take into account real biological factors.

Spatial configuration and quality of the natural resources also matter because people decide where, when, and how much to extract on the basis of resource quality, costs of extraction, and rules of access. Robinson et al. (2008) show that when the location of the resource implies a distance cost to extraction, the spatial pattern of extraction varies period by period and includes periods in which no extraction occurs in any cluster of the resource while that resource regenerates. This temporal variation in the spatial pattern of extraction suggests that analyses based on a single year of observation of extraction behavior may misjudge the situation and lead to inappropriate policy statements. For example, a government seeking to establish a buffer zone may underestimate the enforcement needs and the impact on welfare if it bases its siting and sizing decisions on the observation of extraction patterns during a year in which distant clusters are left to regenerate. In addition, the cost associated with distance to the extraction site or cluster affords more

distant clusters some measure of protection from excess extraction and degradation, regardless of the property scheme. This result suggests that policy makers can use spatial cost information in siting parks and extraction zones and in allocating typically scarce budget resources to the enforcement of access restrictions, targeting open-access resources closest to villages and communities to a larger extent.

3.3. Market Structure and Dynamic Efficiency

Besides ecological features, policy instruments should also take account of market conditions, such as the degree of competition, the occurrence of missing markets, and the assignation of ownership rights. Indeed, the structure of markets has profound effects on the choice and design of policy instruments. If there is only one producer (i.e., a monopoly), then a tax will be passed on to consumers and will create perverse incentives because monopolies are already characterized by too low an output level at too high a price—an effect that may be worsened by a tax.

Furthermore, if there is only one producer, decision makers tend to use individual negotiations, licensing, or VAs instead of going through the whole process of writing a tax law. When the number of producers is intermediate, the analysis of different instruments can become complex. Tradable quotas are one instrument for which the number of participants is crucial. With few players, the quotas will be traded in thin markets, which may create significant distortions and in some cases very limited trading. Thin markets may also provide an incentive for strategic behavior by the firms, who, for example, may try to prevent the entrance of newcomers to the markets.

Dynamic incentives are also an important aspect to be considered. The development of resource-saving techniques is crucial for sustaining economic growth. Indeed, the vast majority of capital-resource growth models assume that technological progress increases—explicitly or implicitly—the productivity of natural resources. This assumption is critical in obtaining sustained consumption in the long run (see, for instance, Barbier 1999, Groth & Schou 2002, Grimaud & Rougé 2003, and Di Maria & Valente 2008).

A firm that invests in research and development or adopts a new technology typically creates benefits to others while incurring all the costs. The positive externality of innovation comes from the public nature of new knowledge and the existence of knowledge spillovers. In addition, because information about the prospects for success is asymmetric (the innovator is in a better position to assess the innovation's potential), investors may be skeptical about the promised returns and may demand a premium for investment that discourages innovators.

The interplay of technology and market failures implies underinvestment in new technology. It is unlikely that environmental policy alone creates sufficient incentives for technological change, and thus there is a case for second-best policies or additional policies. Raising taxes above the Pigouvian level could boost emissions-saving technologies, but at the expense of decreased output (Hart 2008). Moreover, there is a long history of public support for research in the United States and in other industrialized countries (see Jaffe et al. 2005 for further discussion). Innovation policies include public supply by performing research in public institutions, subsidies, or matching funds provided to firms for specific research proposals or joint industry-government research. In the case of technology adoption, this can be encouraged with tax credits. Tax credits reduce the effective purchase price of new equipment that meets specific criteria and information programs

that increase awareness about the availability of environmentally friendly technologies (Anderson & Newell 2004, Jaffe et al. 2005). Finally, technological standards can also be used to encourage the diffusion of particular technologies. Although such standards can be beneficial, they can also go beyond economic efficiency if the population of adopters is very heterogeneous.

3.4. Lack of Expertise and Resources for Policy Making

Many countries may be constrained by a lack of knowledge and organizational, technical, financial, and human resources. Sophisticated instruments might appear to be completely out of their reach, and they might be tempted to conclude that poor agencies should start with command-and-control instruments, leaving supposedly more advanced (market) instruments for later. This approach is unreasonable because all environmental instruments have much common ground; all require systems for monitoring, reporting, verification, and control. For instance, physical command-and-control instruments are not necessarily easy to administer. They require a system of penalties and enforcement that must be severe enough to act as a deterrent, but not so draconian as to be unenforceable in practice. For this reason, informational, legal, or market-based instruments are sometimes preferred. An additional argument in favor of tradable quotas is that as soon as regulations are transformed into rights, they acquire some of the attributes of property and become valuable. Many individuals and/or firms realize that their quotas are more valuable when monitoring occurs and when the whole regulatory system in general is more stringent, thus demanding more transparency and credible enforcement (Coria et al. 2010).

The sophistication of the instrument may be designed to address an environmental protection agency's lack of resources. In that case, it is impossible to generalize about distinct areas of the environment and natural resources or about the groups of countries that are labeled as developing. Some countries have an almost unbroken historic development that gives them special characteristics in areas such as rights and institutions that hinge on trust, culture, and norms. There are no clear reasons to believe that such countries cannot benefit from the additional flexibility that market-based regulations confer over more inflexible regulations.

If we assume that developing countries will over time put more resources and political will behind improving the environment, a critical issue is the type of institutions that they should build over the coming years. The existing international frameworks can be good building blocks for credible programs (Kruger et al. 2003). For instance, the development of the REDD+ scheme would require, at a minimum, a forest emissions inventory and national or international greenhouse gas registries. National institutions will interact with the international REDD+ architecture in several ways: managing the relationship with entities operating REDD+ projects, implementing internationally agreed upon minimum standards, monitoring performance against a reference level of deforestation, and overseeing relations with the international carbon market.

3.5. Political Feasibility

Policies are formed not only by abstract considerations of optimality but by lobbying and the interplay of various interest groups. Different instruments can have dramatically

different consequences for the distribution of the total cost burden. Policy makers should anticipate this behavior and be particularly cautious about instruments that tend to promote it. Usually, incumbents have more influence and can shape technical regulations so that they have a heavy new source bias, which helps explain why physical regulations and licensing are so frequently used. Similarly, grandfathered quotas are popular with incumbents. Least popular are taxes and auctioned quotas because they imply a greater burden (Sterner & Coria 2011).

Striking a balance between what is perceived as fair and what is realistic with respect to those who have power can be difficult. Usually, the success of a policy depends not only on a fair distribution of costs but also on respecting due process, which means following the traditional procedures for gathering information, engaging in debate, ensuring representation, and participating in decision making. For example, Aidt (1998) shows that if the government seeks to maximize a mixture of political contributions and social welfare, competition among interest groups leads to an efficient internalization of detrimental externalities. If the interest groups faithfully represent the interests of their constituencies, their contributions induce public decision makers both to select efficient levels of externality-generating activities and to employ efficient regulatory instruments.

The political regime also affects the selection of policy instruments (Linder 1988; Linder & Peters 1990, 1991; Lundqvist 2001). Democratic regimes tend to apply stronger policy instruments than do authoritarian regimes as strategies for environmental management. Some countries have rules that restrict or prohibit lobbying, whereas others encourage or tolerate it; the prevailing approach affects, for example, the balance between lobbyists and technocrat experts arguing for efficiency.

The characteristics of the policy makers also influence instrument choice. Rationality and time for policy making are limited; policy makers cannot be expected to know everything about all relevant topics, and the time they are given to amass all relevant information on any given topic is usually short. As a result, they commonly rely on various methods to help them make their decisions: consulting experts, applying rules of thumb, learning by doing, and deferring to ideology. Ideologies are not trademarks invented to win elections; they are belief systems that cover not only the goals of regulation but also the means of regulation, which is why some politicians prefer legal restrictions whereas others prefer financial incentives or the persuasive power of good examples (Sterner & Coria 2011). Sometimes ideological perceptions of instruments are excessive, and in those cases we would argue in favor of cool, objective analysis as well as actual experimentation and research to develop the institutions and instruments that work best in different circumstances.

3.6. Multiple Jurisdictions and Multiple Instruments

Major resource problems are often addressed by several jurisdictions and multiple levels of governance. In addition, to achieve their targets, jurisdictions and governments apply various policy instruments at the same time. For instance, agricultural policies are composed of a complex set of instruments that interact with one another in determining land use and input use simultaneously; price support and land diversion are often combined with various forms of environmental policies, such as pesticide or fertilizer restrictions (Just & Antle 1990).

Multiple policy instruments are also used extensively in fisheries. For example, the primary tool for managing fisheries in New Zealand has been the ITQ program. However, more traditional fisheries methods such as gear restrictions, season closures, and size limits are used in conjunction with the ITQ system (Bennear & Stavins 2007). Another example is provided by water management, in which tradable water rights schemes to efficiently allocate water resources are combined with conventional water-rationing schemes that restrict each household or enterprise to water use below a given level during droughts (Kraemer & Banholzer 1999).

What are the joint effects of using several instruments? Sometimes several instruments may be needed to address several goals. This is particularly the case in a second-best world. In such a setting, there are several constraints that prevent the attainment of Pareto optimality. If the constraints are market failures, the elimination of only one of them does not necessarily improve welfare (Bennear & Stavins 2007). Indeed, market failures can be jointly ameliorating (correction of one market failure reduces welfare losses from another), jointly reinforcing (correction of one market failure exacerbates welfare losses from another), or neutral (correction of one market failure does not affect welfare losses from another). For example, a substantial body of literature examines the interactions of environmental externalities and market power. These two market failures are jointly reinforced, and there is a trade-off between social welfare losses that result from decreased production in markets with market power and social welfare gains that result from decreased production in markets with negative externalities.

On other occasions, the use of multiple instruments may reflect historical development or the unintended interaction of legislation at various levels of government (local, regional, national, and international). Indeed, it is rare for a policy innovation to wholly displace existing instruments. Instead, new policy operates in parallel and interacts with existing instruments in a variety of ways.

If additional policy instruments are needed to deal with environmental degradation, regulators should look for a complementary policy that preserves the benefits of the existing policy to the greatest possible extent and that is administratively feasible at a reasonable cost. Coria (2011) shows that the dynamic properties of tradable permits may be affected to a large extent by the use of policy mixes because changes in the firms' constraints induce firms to modify their behavior and by that means affect the permit price and the incentives provided for technology adoption. Nevertheless, although the interaction of policy instruments can cause effects that are undesirable, the gradual evolution of policies in a changing environment necessarily requires changes in the policy instruments used, and several instruments inevitably (and probably desirably) will be used during transition periods. Practical policy making is an art of timing, combining, and sequencing instruments to meet multiple goals amid changing circumstances (Sterner & Coria 2011).

In sum, the problems related to inefficient resource management ahead are significant but are hopefully not insurmountable. An important challenge is to adapt and develop the general principles discussed here to strive for a more sustainable economy. In this endeavor, it is important to take an interdisciplinary approach that includes natural science, technology, and socioeconomic aspects and that involves stakeholders. This ongoing process must be informed by theory as well as by experience. The careful evaluation of new policies and the sharing and comparison of experiences must be integral to this process.

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Contents

The Economics of Human and Environmental Health Risks

Environmental Economics and Policy

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