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Abstract

Much of the improvement in living standards in developed and developing countries alike 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 they are not sustainable, this state of affairs presents a serious problem for the future. A long-term management perspective is needed in order to avoid irreversible degradation of renewable resources. This paper examines major challenges to natural resource management as well as policy options.

Key Words

Natural resources, policy instruments, property rights, environmental regulations, tradable quotas, taxes, voluntary agreements, liability, subsidies, subsidy reduction, deposit-refunds.

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 get the impression that natural resource abundance is primarily a problem that relegates countries to poverty; either due to rent seeking behavior by powerful groups that try to retain control over the resource (thus affecting economic performance and increasing the probabilities of social conflicts), or due to appreciation of the exchange rates which in turn leads to declines in productivity and competitiveness of the secondary sectors (Dutch disease). These views miss the rather obvious point that natural resources represent potential wealth and many developed nations, as United States, Norway or Canada have and still do prosper tremendously from natural resources. While 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, determined by the interplay of numerous factors, as for example, technology and output composition. Moreover these parameters are determined endogenously in the economy. The composition of output tends to develop in certain ways that reflect factor endowment, tastes, and comparative advantages during certain periods. 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 indeed in some cases be a function of resource availability but it is also clear that the reverse causalities need to be taken into account: slow growth will typically mean that no new sectors such as industry develops and thus the economy will be classified as resource dependent by such measures as commonly used (e g share in GDP of resource intensive sectors).

Furthermore the intricacies of the very measurement of economic growth are at the centre of this debate. Popular press and business interests can sometimes describe the situation of a country (region or sector) by saying that economic growth is spectacular but, unfortunately, it is not sustainable since

it entails so much resource destruction and environmental damage. Economists should however balk at such a description since income, *correctly measured*, would not be so high or growing so fast, if all the destruction of resources were taken into account, already 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 at the end of the period be as well off in terms of endowment as at the beginning of the period. The key phrase is the second part of the sentence 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 come as a surprise that it is not deducted in GDP. This is natural enough since 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 much less commonly used. The reason why it is less commonly 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 are not regularly discussing true measures of income that take environmental and natural resource stock depreciation into account. Just as we are uncertain about the exact depreciation of man-made capital – we are even more ignorant of the exact and true magnitude of the depreciation we cause to natural ecosystems since this entails answering exactly how much fish there is left in the ocean and what this and all the food webs are "worth" or what the cost of a thinning ozone layer really is.

To reconcile 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 non-renewable, 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 over-exploitation are imprecise property rights, mispricing of the inputs and products of resources exploitation, poor information availability, monopoly arrangements or other forms of market power or poor investment decisions by the state agencies (see for instance, Ascher 1999). It is not easy to say whether the market failures dominate or policy failures which are also strikingly common across the different types of natural resources. In fact, it is sad and ironic that they often go hand in hand. The collected experience of ocean fisheries across the World does for instance 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 it is so common for the public policies to be flawed that one commonly sees the market failure compounded by policy failure. Another example is provided by the insecure property rights on communal or private lands that encourage over-exploitation; many reforestation programs have resulted in deforestation because of overpricing of reforestation subsidies (Sayer et al. 2004). On the other hand, low domestic prices of petroleum products have undermined the growth potential of oil-rich nations: excessive consumption of these products also encourages air pollution and reduces the incentives to conserve fuel (Reyes-Loya and Blanco 2008).

In this paper we discuss several institutional and policy failures responsible for the depletion of natural resources as well as policy reforms for improving their management.

2. Natural Resource Management: Policy Options

In this section, we present the main categories of policy instruments used for environmental and natural resources policy as well as short descriptions of how each instrument works.

Policy instruments are often classified as "market based" versus "command and control", but this classification is poor. In fact it is very difficult to classify policy instruments neatly although we have tried our best in Sterner and Coria (2011). Markets-based instruments involve both prices and quantities, and regulations are also backed by economic sanctions in case of non-compliance. 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, using markets, creating markets, and engaging the public. The various kinds of policy instruments and actual applications to natural resource management are listed in Table 1.

The first category of instruments, "environmental regulations" includes bans, (non-tradable) quotas or licenses, and regulations that concern the temporal or spatial extent of an activity (zoning). Liability rules also can also be included in this category, connecting it to a large area of lawmaking and to the politics of enforcement. Such instruments as liability bonds, and (more generally) enforcement policies and penalties are all part of the instrument arsenal.

It may be useful to point out that some of the more sophisticated "regulatory" instruments actually 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 will prescribe the exact technology that must be used (thus leaving little room for flexibility or innovation), while performance standards only say what is to be achieved (for instance a maximum by catch rate in a mixed fishery) leaving the search for technological improvements and learning by doing to the entrepreneurs that are regulated.

The next category of instruments, "creating markets," consists of mechanisms for delineating rights. Different nations have different and often quite diverging legal traditions and even legal systems for the creation of rights. In the US, 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). Instead, in Europe as well as in large parts of Africa and Asia, there is a somewhat stronger role for society sometimes represented by local communities and sometimes by the state.

The category "using markets," includes creating subsidies – 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, "engaging the public", includes such mechanisms as information disclosure, labeling, environmental auditing and certification, and community participation in environmental or natural resources management. Dialogue and collaboration among the environmental protection agency, the public, and polluters may lead to voluntary agreements, which have become a fairly popular instrument recently. This is not to say that it can easily replace other instruments such as regulation or taxation. On the contrary there is quite some evidence showing that "voluntary" action or voluntary agreements work best when the threat of other instruments is palpable.

There are also other mechanism potentially important in various contexts: direct provision of environmental services (such as national parks) and state resource exploitation; international

agreements (which are only a policy at 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" 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 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 is 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. Certainly, this policy will work best if the area chosen truly does create "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 of 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 merely retains a control function, and private entrepreneurs are hired to provide the services. One of the factors that have contributed to this change is the remarkably negative popular image of state enterprises as incompetent elephants beyond the control of the government. Nevertheless, state resource enterprises are still very common, partially due to the strategic nature of many natural resources and rent-seeking opportunities that permit government officials to gain the political support from key actors outside the government.

For exploitation rates to be sustainable and dynamically efficient, government must ensure that state enterprises are kept accountable for the quality of their resource management and the damages they cause. Governments must also ensure that directives to state resource enterprises call for appropriate rates and methods of resource exploitation. Unfortunately, this is not often the case. Instead, governments fail to keep state resource managers accountable, demand that state enterprises engage in over or under-exploitation 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 the failure to prevent that funds are diverted away from needed investments (Ascher 1999).

[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 some kind of 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.

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.

2.21 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 restricting the use of certain methods or technology to specific locations or timing (zoning). In agriculture and forestry, examples of technology regulation include the 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-management practices. In fisheries, the restrictions or prescriptions of certain types of vessel and gear can get very very 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 are 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 perhaps simply 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.

Even more negative is the effect of such regulations on the incentive to undertake research in 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 result. On the other hand, 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 nonetheless very common practice. They tend to encourage derby-style fishing during the short period the fishery is "open" and so, they induce "overcapitalization" or "capital stuffing" (Homans and Wilen 1997). The higher productivity leads to shorter and shorter seasons. In the case of one famous US halibut fishery the "season" was down to 48 hours and fishermen adapted to this two-day season by investing in three identical electronic systems, where two were backups. The extra capacity may be idle part of the year or migrate to other areas, contributing to overfishing elsewhere. Short seasons might also lead to lower commercial value of catch, because it has to be sold frozen most of the year. Finally, it leads to fishing even in bad weather, which increases safety risks (NRC 1999).

Under certain conditions, however, it is possible to achieve desired levels of harvest through technology regulations. For instance, 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 a noncompetitive, transitional setting) and investments will have long-run irreversible effects, the standardization of technology holds major advantages, of only a few competing technologies available, one is superior and if monitoring costs are high: monitoring performance is difficult and may be open to subtle interpretations, while monitoring technology is relatively straightforward

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. Also, because these restrictions could in some cases be seen as a way of protecting the livelihood and interests of certain groups, usually those who use the older and more labor-intensive technology.

2.22 Performance Regulations

A regulation that imposes a certain individual limit to harvest is called a quota. A quota regulates quantities and as such is sometimes referred to as a command-and-control mechanism. This categorization is somewhat unfortunate since, compared to technology standards, it still give firms considerable flexibility in the choice of method by which to meet the mandated goal. The logic of this instrument is fairly simple. The regulator chooses to maximize or minimize some variable. If it is the maximum allowable harvest for each firm, then output is directly regulated and each firm optimizes within this constraint. Optimally chosen, harvesting limits imply that the product prices will reflect the scarcity of the resource. The regulator may however also regulate various other aspects (such as percentage by catch for fisheries) and many other parameters when it comes to forestry that are related for instance to the risk for fire, the leaving of wastes that serve as habitat for birds and insects and so forth.

In many real-world cases, natural resources are controlled by licensing procedures; these procedures do not allow for flexibility in attaining efficiency through trading. Furthermore, licensing procedures might give many opportunities for rent-seeking since the information and resources available to parties (industries and local or national authorities) who negotiate the individual quotas may be asymmetric, often leading to fairly lax environmental quotas. The fact that many firms appear to prefer licensing to market-based instruments reinforces this impression. However, if well managed by knowledgeable authorities, these negotiations may give reasonable outcomes (e.g., Brännlund et al. 1996 on "command and control with a gentle hand").

One negative feature of individual quotas is that they do not imply full control on total harvest since the total levels also depend on the number of agents. Since 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 often pertain to the regeneration of private lands to ensure rapid reforestation after harvests of the previous stand of mature timber. Regulations initially were imposed in many countries to protect against anticipated timber supply "shortfalls", which usually are not actual shortfalls but an argument used in the price bargaining between forest owners and sawmills or paper industries. However, reforestation regulations also may 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.

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[2]. 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 and Pease 1997, Flores and Thacher 2002, Roach and Wade 2006 and Riera 2008). Different measures have been proposed based on either the physical natural resource needed to compensate for the harm (resource to resource or habitat to habitat compensation), or based on the social value of the harm (value to value).

Clearly, the choice of metric has a clear impact on the cost of remediation and financial liability, especially when the resource damaged is very scarce (for instance, endangered species or rare landscapes). On the other hand, there is a clear limit to a firm's liability: the worst-case scenario is not the loss of value equal to maximum environmental damage but bankruptcy of the firm (which typically is worth less than the value of the environmental damage). Thus, although most legal schemes gives 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 could have more serious repercussions. The owners of plants that represent particularly large hazards can divide them into separate subsidiaries—legally distinct companies. Such separations allows 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 Creating Markets

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 surround 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; it is this inalienability that gives owners the confidence and incentive to make long-term and costly productive investments in their properties.

In many countries, agricultural and grazing land has suffered from serious problems of overuse and inadequate efforts to reduce soil erosion due to insecure property rights. Economic theory postulates three links between tenure security and agricultural economics incentives (Besley, 1995). The first link is referred as "security argument" and captures the direct and positive link between tenure security and investment incentives. The second link is referred as "collateral-based argument" and is based on the

[2] 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 the OPA and CERCLA schemes, includes compensation for interim lost use resulting from petroleum releases. The International Oil Pollution Compensation Funds (IOPC Funds, 2010) have also well-established protocols to compensate for spills of persistent oil from tankers worldwide. All of these approaches are intended to deliver non-punitive compensation.

premise that when land tenure is secure and thus easier to collateralize, it can reduce the price of capital and subsequently increased the value of investments. The final link is referred as "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, lack of land titles, undeveloped credit markets, 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 or Zambia – the effective functioning of land rental markets is very important for agricultural development. Land rental markets have an important role as 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, they promote short-term agricultural efficiency since they allow land to be used by farmers who are more capable to earn 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.

There is a large literature investigating the short-term efficiency impacts of land lease contracts (See for example, Holden et al. 2009, Benin and Pender 2009 and Zikhali 2010); the results highlight the dependence of impacts of land tenancy on the local context and policies and suggest that 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, promote sectors growth, encourage 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 started to be granted to private forestry companies (see for instance, Banerjee and Avapalati 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; which provided incentives for sustainable and efficient harvest methods while maintaining the long-term condition of the basic resource. Furthermore, increased transparency in the regulatory environment, as well as of concessions' allocation creates demand and maintains investors confidence. Unfortunately, in many countries concessions typically have been allocated noncompetitively, in ways that are nontransparent and possibly corrupt, partly because of the gigantic scale of some of these transactions.

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 and 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 demonstration of acceptable performance. If the bond is truly a guarantor of environmental performance, then it must 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 typically is 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, where governments have underpriced the basic resource by failing to charge royalties for companies' access to the oil and mineral deposits.

2.3.2 Common Property Resources' Management

Some researchers maintain that common property resources (CPRs) may be a superior institution under certain conditions (Ostrom 1990, 1997, 1999, Stevenson 1991, Migot-Adholla et al. 1993, Dasgupta 1993 and Balland and Plateau 1996). For instance, people may find it in their interest to collaborate intensely when the "services" provided by a certain ecosystem are erratic (e.g., rainfall in some areas) or mobile (e.g., the availability of fish or game). Also, when the "services" provided by a certain ecosystem are meager (e.g., pasture in extremely dry areas), and thus the productivity of the land may be too low to cover the basic costs of enforcing private property rights (e.g., by installing fences).[3]

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 and 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 ultimately will break down because of the temptation to free ride. In her early work, Ostrom tried hard to characterize the rules that characterized sustainable CPR but they proved elusive and she therefore developed eight more general "principles" that seemed to characterize sustainable CPR management (Ostrom 1990):

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. Nested enterprises

Condition 1, clear boundaries and exclusion of outsiders, 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 (e.g., 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.

[3] However, this kind of relationship is not defined indefinitely; 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.

Rules and processes must be democratic, legitimate, efficient, and effective. Principle 8 concerns the way in which for instance irrigation systems may be nested with smaller "local systems making up bigger ones. These design principles spurred a very considerable body of subsequent research which has recently been revisited in an extensive and elaborate retrospective meta-analysis by Cox et al. (2010). They find that all the more than one hundred studies reviewed find empirical support for the principles. Some studies suggest some additional principle or discuss how details may be refined – for instance in the interaction between the principles and the differences in how they apply at different scales. Both Ostrom and Cox et al. (2010) do however insist that the principles should not be seen as a "blueprint" to be applied everywhere: one of the essential principles being that of local ownership and adjustment to local conditions. Cox et al. (2010) do however tentatively suggest a slight reformulation of the principles and the interested reader is referred straight to their text.

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

This is an area in which there is considerable current research that 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 and Plott 2003, Ostrom 2006, Van Soest and Vyrastekova 2006 and Cardenas 2009). Experimental evidence highlights also the role institutions for control and punishment and peer enforcement mechanisms in overcoming overexploitation of CPR. In a recent study, Hasson et al. (2010) have also analyzed the role of trust in enhancing. At local levels, trust can be fostered through communication, signaling and commitment.

2.3.3 Tradable quotas or rights

In general, the process of modifying rights is fairly slow, but some environmental policy instruments (e.g., tradable water permits, transferable grazing or fishing rights) can evolve relatively quickly. A permit or quota should for instance be seen as a real title to property. In this sense, the development or assignment of new kinds of property rights is a definitive policy instrument of natural resources or environmental management.

Water trading is as an allocative mechanism in which entitlements of water quotas can be transferred between users, intra-valley (within the same water basin) or inter-valley (between water basins). Water is thus reallocated to users with higher values and this 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.

Water trading is particularly used to insure sufficient irrigation resources, but urban water trading schemes can also be implemented, in which urban households and industrial water users were able to buy and sell water entitlements and water allocations. Nevertheless, transaction costs might be an important impediment to fully reaping the benefits of trade. The costs of identifying potential trades,

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 might also be very high with both public and private institutions such as water user associations being required to operate at the level 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 prevent trading by not respecting private property rights over water.

On the other hand, large hydrologic effects can occur as a consequence of inter-basin 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, though 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 seem to 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 ITQ program for fisheries (see Costello and 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 individual transferable quotas (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" based on territory), and the strong negative externalities exercised by one fisherman vis-à-vis the others (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 needs 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 resources 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. 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. To create a green zone around a city usually entails the problem and cost of expropriating properties from landowners. Using 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 and Filoso (2009).

2.4 Using Markets

2.4.1 Taxes, fees, or charges

In natural resources management, taxation is mainly used 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 might 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, for instance, this is presumably the reason that explains why individual transferable fishing quotas (ITQs) have become the main instrument: ITQs provide a scarcity signal but still leave the rent with the fishermen. On the opposite side, in some cases governments resort to extract rents in a way that clearly distorts the exploitation incentives.

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 instead key tax instruments for the non-renewable 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 and these are negotiated in advance, which tends to give governments an unnecessarily small share of successful projects. On the other hand, arbitrary changes in 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 is one of China's most ambitious initiatives and one of the largest land-conservation program in the developing world (Bennett 2008 and 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. For 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 forests' types to account for differences in average yields.[4]

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, some of the problems in program design and implementation of the SLCP is that the fast expansion has created some shortfalls in required funds leading to problems in implementation and subsidy delivery.

[4] In the case of ecological forests, the subsidies are provided during a period of 8 years while the payments are limited to 5 years for economic forests.

On the other hand, 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 the villages (Xu et al. 2010).

An additional argument against subsidies are 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 than when unregulated.

2.4.3 Subsidy Removal

In reality, the most relevant issue for the natural resource management is not subsidies for conservation but the prevalence of perverse subsidies for over-exploitation. Inappropriate subsidies promote rather than prevent wasteful and environmentally destructive behavior. 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 and 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 in itself. 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 after the house is bought by taxing fossil fuels, 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.

2.4.3 Deposit refund schemes

In addition to the basic policy instrument types already mentioned, 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. Assuming disposal is inappropriate for ecological reasons, the deposit– refund combination may be categorized as a tax expenditure or a presumptive tax on inappropriate disposal. The polluters (i.e., those who do not return the item) pay a charge, whereas those who do return the item collect a refund and thus pay nothing. 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.

Usually, deposit–refund systems are 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 main) motivation. However, the concept is spreading. 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. Since reforestation costs have been estimated at $500 per hectare, the Philippines' deposit may be too low to encourage sufficient reforestation (Steele and Ozdemiroglu 1993)

2.5 Engaging the public

2.5.1 Labeling and Certification

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.

In natural resource management, green labeling and certification might be useful instruments to counteract information asymmetries and give consumers information about the environmental sustainability of various management practices. In forestry, several certification programs have been implemented: 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 gain shares in markets dominated by environmentally oriented consumers. In Europe, for instance, most industrial and retail companies are joined 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 in Poland, and more than 13 million hectares in the United States. Among the developing countries, Brazil, Mexico, and Bolivia together had about 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 developing quickly. Those already certified are receiving some benefits, but the potential payoff for small woodland owners is less clear since the costs of forest certification has some fixed components making it relatively less attractive to them (Rametsteiner and Simula 2003). It is also the case that the current incentives seem to be insufficient to attract producers in tropical developing countries to seek certification since the costs of improved management seem significantly greater than the market benefits they perceive.

2.5.2 Voluntary Agreements

Another instrument that builds heavily on information disclosure is referred to as Voluntary agreements (VA). The term VA appears to be used mainly for a form of negotiated (and verifiable) contract between environmental regulators and firms. One of the first such agreements followed on the Toxic Release Inventory which was a large-scale release of information (on chemical emissions). This in turn lead to much publicity and the firms involved soon agreed (voluntarily) to reduce emissions by

large percentages by given dates, see Sterner and Coria (2011) for details. The 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, and 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 "voluntary" agreements may work best when there is a real threat of other regulation. The main difference may however 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, Lyon and Hackett 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 voluntary agreements in natural resource management include conservation of endangered species (Langpap and Wu 2007) and privately owned forest (Juutinen et al. 2007). Through the first, landowners are provided with assurances regarding future regulations if they agree on a conservation program. Through the second, landowners agree on producing biodiversity services on their lands and receive a compensation that is lower than the market price based compensation. When offering voluntary agreements, 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 might have to settle for inefficient levels of conservation (Langpap and Wu 2007). Nevertheless, voluntary conservation programs may still induce lower costs than traditional mandatory programs since 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 policymaking plays a necessary role in the provision of public goods and in dealing with transboundary environmental threats such as climate change or the loss of biodiversity. For instance, the Convention on Biological Diversity is dedicated to promoting sustainable development; it was signed by 150 government leaders at the 1992 Rio Earth Summit who committed to develop national strategies for the conservation and sustainable use of biological diversity On the other hand, when stakes are high and costs real, it is still difficult to reach agreements as we can see in the area of climate change.

Deforestation is a significant source of climate gases (mainly carbon dioxide)[5]. The perceived need for some form of early action has led to the development of various funds for carbon payments by the Carbon Fund, the Global Environment Facility (GEF), and even individual countries and firms. Developing countries can apply to receive funds by finding and designating a suitable area that "fits

[5] For instance, total emissions from tropical deforestation amount to some 4.4+-2.0 GtCO2/yr, rivaling the contribution of the global transport sector to climate change, though uncertainties still abound (van der Werf et al. 2009)

into" the windows of opportunity created by the sponsoring organizations. Although far from ideal, this instrument open up interesting possibilities in some cases.

Although the basic idea—compensating developing countries for reduction in the emissions from deforestation and forest degradation—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, baseline 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-plus which was partly driven by the concern that if rewards were only given for reducing deforestation rates, and not maintaining existing forest carbon stocks, the incentive to participate would be limited for countries with large tracts of forest but currently 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 non-participating countries, drastically reducing the environmental effectiveness of the regime. However, the shift was also driven by countries such as India and China that historically have cut most of their forests and presently are increasing their forest cover again, and that saw a potential for getting remunerated for this development.

The protection of tropical forests through international payments might entail some positive effects for biodiversity conservation. In such sense, connecting global and national action on climate change to biodiversity conservation might help to restore biodiversity and ecosystems. However, understandably, all forest or ecosystems cannot be preserved since it would be prohibitively expensive; some areas will be developed 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 to be able to determine the size of reserves and 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 obligations to spread the obligation (and thus cost) of protection more broadly among forest owners. If it is only the owner of a particular parcel of forest that is affected by conservation decisions, there will be strong incentives for forest owners to lobby against being classified into some category of reserve or protection status.

2.7 Macroeconomic Policies

As mentioned previously, economic growth and environmental sustainability are complex aggregates, determined by the interplay of numerous factors. Among of them, a good environment for business.

Of foremost importance for a good business environment appears to be a transparent, predictable, and reasonable legal and political structure. It should preferably be reasonably free from corruption and exaggerated bureaucracy but also structured enough to avoid the costly uncertainty of contract enforcement. A good business environment also requires a reasonable natural environment; employees can hardly thrive or be healthy in a deteriorated environment. The distribution of environmental quality is crucial. If the living environment of the poor is so degraded (e.g., through disease or malnutrition) as to inhibit their productive development, then the economy experiences not only a direct decrease in human welfare but also a loss of productive potential.

Central recommendations for successful and sustainable development include formulating the correct macroeconomic policies, creating a market-friendly orientation, being open to trade, and investing in people through health and education and strengthening institutions (World Bank 1991, Acemoglu et al. 2001, and Adhikari 2005). During the 1990s, many countries were quick to implement a market-

friendly orientation and macroeconomic policies (López, Thomas, and Wang 1999). Barriers to trade and finance were broken down; price controls and deficits were reduced. Some countries significantly increased education and health expenditures, and many countries experienced economic growth as well as declining poverty. The 1990s also showed how easily advances in some areas could evaporate into economic crisis and the enormous price (as environmental damage) of so called economic progress in some countries. (It is not really progress if the costs outweigh benefits; when correctly measured income and wealth measure will show little "progress"). It also became strikingly clear that corruption not only is an issue of morals but also entails enormous economic costs (Lopez 2000).

3. Choosing among Policy Instruments: Further Complexities in Natural Resource Management

Management of natural resources is crucial for the world and economically vital in most developing countries. The dynamics of several resources are technologically and ecologically complex. In real policymaking, several other aspects such as uncertainty and information asymmetry, market power, technological progress and distributional concerns must be addressed in the face of a partly stochastic outcome from nature.

Policy formulation and implementation have also many political, cultural, and psychological dimensions. It is therefore important to respect and follow the traditional rules for decision-making—sometimes referred to as due process—without naively opening up opportunities for corruptive lobbying. Given the sometimes rapid changes in technology, ecology, and of current understanding of technology and ecology, any instrument used must be flexible enough to allow for adaptation to new circumstances yet not so flexible as to completely blast open the Pandora box of rent seeking and attempts to litigate against regulations instead of complying.

When it comes to ecological complexity, policy instruments should allow for some flexibility in this level 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 regards to this point, stocks of natural resources are complex: there are multiple populations and/or subpopulations and they play an important role ensuring stock viability and genetic variability. Persistence of diversity of stocks should become a principle of management, particularly under a "precautionary approach" since different subpopulations do not breed with each other which needs to be taken into account in models estimating allowable quotas. Svedäng et al. (2010) shows 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 steady 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 as well as social factors.

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 assignment of ownership rights. Indeed, the structure of markets have profound effects on the choice and design of policy instruments. If there is only producer (i.e., a monopoly), then a tax will be passed on to consumers and in fact will have perverse incentives because monopolies are characterized by too low an output level—an effect that may be worsened by a tax. Furthermore, if there is only one producer, decision-makers would tend to use individual negotiation, licensing, or voluntary agreements 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 also may provide an incentive for strategic behavior by the firms.

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.

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 some-times preferred. The sophistication of the instrument may be designed to address an environmental protection agency's lack of resources..

Policies are not only formed by abstract considerations of optimality but through lobbying and the interplay of various interest groups. Policymakers should anticipate this behavior and be particularly cautious about instruments that tend to promote it. The most obvious example is subsidies, which not only are expensive but also can promote lobbying and even corruption. Even the allocation of quotas may attract considerable lobbying, and these consequences must be taken into account. Furthermore, governments are not the only policy makers: policies may be made at international levels as well as by local authorities such as municipalities and even consumer groups, industrial associations or NGOs and so forth may initiate policy instruments such as labeling or voluntary agreements. It is typical that important environmental and resource problems tend to attract the use of multiple instruments created, partly independently by different agents,

Poverty and environmental degradation are two problems that tend to occur together: environmental degradation leads to decreased access to water, fodder, firewood, and other important materials. The desperation and short-sightedness caused by poverty may force poor people into unsustainable practices that worsen resource degradation. All the distinct categories of policy that have been discussed are applicable, depending on the details of the individual case. In rural settings, CPR management may be the most appropriate approach.

Privatization may be beneficial in introducing market principles but is no panacea. If there are distributional, environmental, or other welfare goals in addition to efficiency, then specific public action will be required because an unregulated market will not reach these goals.

The problems related to inefficient resource management ahead are significant but hopefully not insurmountable. It is an important challenge 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 the natural science, technology and also socioeconomic aspects and involves stakeholders. This ongoing process must be informed by theory as well as experience. The careful evaluation of new policies and the sharing and comparison of experiences must be integral to this process.

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, liability	Liability bonds for mining or hazardous waste
Creating Markets	
Creation of property rights	Private national parks Property rights and deforestation
Common Property Resources	CPR management
Tradable quotas or rights	Water trading Individually tradable fishing quotas Transferable rights for land development, forestry, or agriculture
Using Markets	
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
Engaging the public	
Information Provision, Labels	Labeling of food, forest products
Voluntary Agreements	
Direct provision	Direct provision of parks
International Treaties	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 the "Dutch disease" such as oil funds.

References

Acemoglu, D., A. Johnson and J. A. Robinson. 2001. The colonial origins of comparative development: and empirical investigation. American Economic Review 91: 1369-1401.

Adhikari, B. 2005. Poverty, property rights and collective action: understanding the distributive aspects of common property resource management. Environment and Development Economics 10:1:7-31.

Angelsen, A. 2008. How do we set the reference levels for REDD payments?. In A. Angelsen (ed), Moving ahead with REDD: Issues, options and implications, CIFOR, Bogor, Indonesia.

Angelsen, A., M. Brockhaus, M. Kanninen, E. Sills, W.D. Sunderlin and S. Wertz-Kanounnikoff (eds). 2009. Realising REDD+: National Stragety and policy options. CIFOR, Bogor, Indonesia. Available online at www.cifor.cgiar.org/Knowledge/Publications/Detail?pid=2871.

Anton, W., G. Deltas and M. Khanna. 2004: "Incentives for environmental self-regulation and environmental performance", Journal of Environmental Economics and Management 48: 632-654.

Ascher, W. 1999. Why Governments Waste Natural Resources. Policy Failures in Developing Countries. The Johns Hopkins University Press. Baltimore, London.

Balland, J.-M. and J. P. Plateau. 1996. Halting Degradation of Natural Resources: Is There a Role for Rural Communities? Oxford, U.K.: Clarendon Press.

Banerjee, O. and J. Alavalapati. 2010: "Illicit exploitation of natural resources: The forest concessions in Brazil", Journal of Policy Modeling 32(4): 488-504.

Benin, S. and J. Pender. 2009. Land Rental Markets and Land Management in the Highlands of Ethiopia. In The Emergence of Land Markets in Africa: Impacts on Poverty, Equity and Efficiency, Environment For Development, T. Sterner Series Editor, RFF Press: 213-237.

Bennett, M. T. 2008. China's Sloping Land Conversion Program: Institutional Innovation or Business as Usual?. Ecological Economics 65 (4): 699–711.

Besley, T. 1995. Property Rights and Investments Incentives: Theory and Evidence from Ghana", Journal of Political Economy 103(5): 903-937.

Binswanger, H. P. 1991. Brazilian Policies that Encourage Deforestation in the Amazon. World Development 19(7): 821–829.

Bluffstone, R. and B. A. Larson 1997. Controlling Pollution in Transition Economies. Cheltenham, U.K.: Edward Elgar.

Cardenas, J.C. 2009: "Experiments in Environment and Development", Annual Review of Resource Economics 1: 157-182.

Cassari, M. and C. R. Plott. 2003. Decentralized management of common property resources: experiment with centuries-old institution. Journal of Economic Behavior & Organization 51: 217-247.

Christy, F. T., Jr. 1973. Fisherman Quotas: A Tentative Suggestion for Domestic Management. Occasional Paper no. 19. Honolulu, Hawaii: Law of Sea Institute.

Costello, C., J. Lynham, S.E. Lester and S.D. Gaines. Economic Incentives and Global Fisheries Sustainability. Annual Review of Resource Economics 2: 299-318.

Costello, C. and R. Deacon. 2008. The Efficiency Gains from Fully Delineating Rights in an ITQ Fishery. Marine Resource Economics 22: 347-361.

Cox, M., G. Arnold, and S. Villamayor Tomas. 2010. Design Principles are not Blue Prints, but are They Robust? A Meta-analysis of 112 Studies, http://www.lincolninst.edu/pubs/1707_Design-Principles-are-not-Blue-Prints--but-are-They-Robust-

Dasgupta, P. 1993. An Inquiry into Well-Being and Destitution. Oxford, U.K.: Oxford University Press.

Flores, N.E. and J. Thacher. 2002. Money, who needs it? Natural resource damage assessment. Contemporary Economic Policy 20(2): 171-178.

FSC (Forest Stewardship Council). 2010. Global FSC Certificates: Type and Distribution. Facts and Figures

www.fsc.org/fileadmin/web-data/public/document_center/powerpoints_graphs/facts_figures/Global-FSC-Certificates-2010-04-15-EN.pdf (accessed May 2010).

Glasbergen, P. 1999. Tailor-Made Environmental Governance: On the Relevance of the Covenanting Process. European Environment 9(2): 49–58.

Hanna, S. S. and S. Jentoft. 1996. Human Use of the Natural Environment: An Overview of Social and Economic Dimensions. In Rights to Nature: Ecological, Economic, Cultural and Political Principles of Institutions for the Environment, edited by S. Hanna, C. Folke and K.-G. Mäler. Washington, DC: Island Press, 35–55.

Hasson, R., Å. Löfgren and M. Visser. 2010. Climate Change in a Public Goods Game: Investment Decision in Mitigation versus Adaptation. Forthcoming in Ecological Economics.

Hicks.J R 1935, Theory of Wages, Macmillan, London.

Holden, S. T., K Otsuka and F. M. Place. 2009. The Emergence of Land Markets in Africa: Impacts on Poverty, Equity and Efficiency. Environment For Development, T. Sterner Series Editor, RFF Press.

Homans, F. and J. E. Wilen. 1997. A Model of Regulated Open Access Resource Use. Journal of Environmental Economics and Management 32(1): 1–21.

Jones, C.A. and K.A. Pease. 1997. Restoration Based Compensation Measures in Natural Resource Liability Statutes. Contemporary Economic Policy 15(4): 111-122.

Juutinen, A., E. Mántymaa, M. Mönkkönen and R. Svento. 2007: "Voluntary agreements in protecting privately owned forests in Finland- To buy or to lease? Forest Policy and Economics.

Klemperer, D. 1996. Forest Resource Economics and Finance. New York, NY: McGraw-Hill, chapter 9.

Kosmo, M. 1987. Money To Burn? The High Costs of Energy Subsidies. Washington, DC: World Resources Institute.

Langpap, C. and J. Wu. 2007: "Voluntary conservation of endangered species: when does no regulatory assurance mean no conservation", Journal of Environmental Economics and Management 47: 435-457.

López, R. 2000. The Quality of Growth and the Natural Resources: The Role of the State. Paper presented at the 2nd International Conference on Environment and Development. Sept. 6–8, Beijer Institute, Stockholm, Sweden.

López, R., V. Thomas and Y. Wang. 1999. Addressing the Education Puzzle: The Distribution of Education and Economic Reforms. Paper presented at the World Bank Economists' Forum. May 3–4, Washington, DC.

Lund, D. 2009. Rent taxation for nonrenewable resources. Annual Review of Resource Economics 1: 287-307.

Maxwell, J. W., T. P. Lyon and S. C. Hackett. 2000. Self-Regulation and Social Welfare: The Political Economy of Corporate Environmentalism. Journal of Law and Economics 43(2): 583–617.

McWinnie, S. F. 2009. The tragedy of the commons in international fisheries. Journal of Environmental Economics and Management 57: 321-333.

Migot-Adholla, S., B. Peter, B. Hazell, B. Blarel and F. Place. 1993. Indigenous Land Systems in Sub-Saharan Africa: A Constraint on Productivity? In The Economics of Rural Organisation: Theory, Practice and Policy, edited by K. Hoff, A. Braveman and J. E. Stiglitz. New York, NY: Oxford University Press.

Miller, A. J. 1999. Transferable Development Rights in the Constitutional Landscape: Has Penn Central Failed to Weather the Storm? Natural Resources Journal 39(3): 459–516.

NRC (National Research Council). 1999. Sharing the Fish: Toward a National Policy on Individual Fishing Quotas. Washington, DC: National Academy Press.

O'Connor, David. 1994. Managing the Environment with Rapid Industrialization: Lessons from the East Asian Experience. OECD Development Center.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge, U.K.: Cambridge University Press.

———. 1997. The Comparative Study of Public Economies. Acceptance Paper, The Frank E. Seidman Distinguished Award in Political Economy. Workshop in Political Theory and Policy Analysis. Sept. 26, Rhodes College, Memphis, TN.

———. 1999. Coping with Tragedies of the Commons. *Annual Review of Political Science* 2: 493–535.

———. 2006. The value-added of laboratory experiments for the study of institutions and common-pool resources. Journal of Economic Behavior & Organization 61(2):149-163.

Palmer M. and S. Filoso 2009. Restoration of Ecosystem Services for Environmental Markets. Science 325(31): 575-576.

Paris, R. and I. Ruzicka. 1989. Barking Up the Wrong Tree: The Role of Rent Appropriation in Sustainable Tropical Forest Management. Occasional Paper no. 1. Manila, Philip-pines: Asian Development Bank, Environment Office

Peterson, D., G. Dwyer, J. Appels and J. Fry. 2005. Water trade in the southern Murray- Darling Basin. Economic Record 81: 115–127.

Qureshi, M. E., T. Shi, S. Qureshi, W. Proctor and M. Kirby. 2009. Removing barriers to facilitate efficient water markets in the Murray-Darling Basin of Australia. Agricultural Water Management 96(11), 1641-1651.

Rametsteiner, E. and M. Simula. 2003. Forest certification – an instrument to promote sustainable forest management?. Journal of Environmental Economics and Management 67: 87-98.

Reyes-Loya, M.L. and L. Blanco. 2008. Measuring the importance of oil-related revenues in total fiscal income for Mexico. Energy Economics 30(5): 2552-2568.

Riera, P. 2008. Does the equivalency analysis of the European Environmental Liability Directive pass a social cost–benefit analysis test?. Journal of Forest Economics 14(4): 225-226.

Roach, B. and W.W. Wade. Policy evaluation of natural resource injuries using habitat equivalency analysis .Ecological Economics 58 (2): 421-433.

Ruzicka, I. 1979. Rent Appropriation in Indonesian Logging: East Kalimantan. Bulletin of Indonesian Economic Studies 15(2): 45–74.

Sayer, J., U. Chokkalingam and J. Poulsen. 2004. The restoration of forest biodiversity and ecological values. Forest Ecology and Management 201(1): 3-11.

Steele, Paul and Ece Ozdemiroglu. 1993. Examples of Existing Market-Based Instruments and the Potential for Their Expansion in the Asian and Pacific Region. Financing of Environmentally Sound Development. Asian Development Bank.

Sterner, T. J. Coria. 2011. Policy Instruments for Environmental and Natural Resource Management. Second Edition. RFF Press.

Stevenson, G. G. 1991. Common Property Economics: A General Theory and Land Use Applications. Cambridge, U.K: Cambridge University Press.

Svedäng H., J. Stål , T. Sterner and M. Cardinale. 2010. Consequences of subpopulation structure on fisheries management: cod (Gadus morhua) in the Kattegat and Öresund (North Sea). Forthcoming in Reviews in Fisheries Science.

Van der Werf, G. R., D. C. Morton, R. S. DeFries, G. J. Olivier, P. S. Kasibhatla, R. B. Jackson, G. J. Collatz and J. T. Randerson. 2009. CO2 emissions from forest loss. Nature Geoscience 2:737-738.

Van Soest, D. P. and J. Vyrastekova. 2006. Peer enforcement in CPR experiments: the relative effectiveness of sanctions and transfers rewards and the role of behavioral types. In Using Experimental Methods in Environmental and Resource Economics: 113-136, Edited by John A. List, Edward Elgar Publishing.

World Bank. 1991. World Development Report 1990: Poverty. New York, NY: Oxford University Press for the World Bank.

———.1997. Five Years after Rio: Innovations in Environmental Policy. Environmentally Sustainable Development Studies and Monograph Series, no. 18. Washington, DC: World Bank.

Xu, J., R. Tao, Z. Xu and M. T. Bennett. 2010. China's Sloping Land Conversion Program: Does Expansion Equal Success?. Land Economics 86(2): 219-244.

Zikhali, P. 2010. Fast Track Land Reform, Tenure Security and Investments in Zimbabwe. Natural Resources Forum 34(2):124–139.