Chapter 10
Securitizing the Biosphere

Graciela Chichilnisky
Geoffrey Heal

A handful of firms in traditionally dirty industries have decided that they can make more money by embracing environmental goals than by fighting them. At the leading edge of the environmental movement, British Petroleum, Monsanto, Dupont, Compaq, 3M, S.C. Johnson, Dow Chemical, Weyerhauser, and Interface are major corporations improving their financial performance by cleaning and greening their operations [1]. They are making money by reducing their environmental impact. This is not entirely surprising: Costanza et al. [2] have suggested that environmental services have great value, although they did not indicate how this value can be realized. Here we take this line of argument further and propose various economic instruments that would allow investors to obtain economic returns from environmental assets such as forests and landscapes while ensuring their conservation. One of us [3] has proposed the creation of an international financial institution to promote this process, a suggestion officially adopted by the Group of 77 developing countries and China in the Kyoto meetings on December 1, 1997.

The environment's services are clearly valuable. The air we breathe, the water we drink, and the food we eat are all available only because of services provided by the environment. How can we transform these values into income while conserving the underlying natural capital? We have to "securitize" natural capital and environmental goods and services and enroll market forces in their conservation. This means assigning to corporations—possibly innovative public-private corporate partnerships—the obligation to manage and conserve natural capital in exchange for the right to the benefits from selling the services provided. E. O. Wilson [5] talks of "the need to draw more income from the wildlands without killing them, and so to give the invisible hand of free market economics a green thumb." Privatizing natural capital and ecosystem services is a key step. It enlists self-interest and the profit motive in the cause of the environment. Although these motives will never conserve everything that we value in the environment, they will conserve a lot, leaving regulation and appeals to higher motives to focus on really hard cases.

10.1 Investing in the Biosphere

In 1996 New York City decided to invest between $1 billion and $1.5 billion in natural capital in the expectation of producing cost savings of $6 billion to $8 billion over 10 years, giving an internal rate of return of between 90% and 170% and a payback period of between four and seven years. This return is an order of magnitude higher than is normally available, especially on relatively riskless investments. New York's water comes from a watershed in the Catskill Mountains. Until recently, purification processes carried out by root systems and microorganisms in the soil as the water percolates through, together with filtration and sedimentation occurring during this flow, were sufficient to cleanse the water to the standards required by the U.S. Environmental Protection Agency (EPA). Recently, sewage, fertilizer, and pesticides in the soil reduced the efficacy of this process to the point that New York's water no longer met EPA standards. The city was faced with a choice: restore the integrity of the Catskill ecosystems, or build a filtration plant at a capital cost of $6 billion to $8 billion, plus running costs of the order of $300 million annually. In other words, New York had to invest in natural capital or in physical capital.

Which was more attractive? Investment in natural capital in this case meant buying land in and around the watershed so that its use could be restricted and subsidizing the construction of better sewage treatment plants. The total cost of measures of this type needed to restore the watershed is expected to be in the range of $1 billion to $1.5 billion. Thus, investing $1 billion to $1.5 billion in natural capital could save an investment of $6 billion to $8 billion in physical capital. These calculations are conservative, as they consider only one watershed service, although watersheds, typically forests, often provide other important services.

The support of biodiversity is one, and carbon sequestration is another. The commercial value of biodiversity can be partly captured by bioprospecting deals such as that between Merck and Costa Rica's InBio (see the following discussion). Joint implementation offers the possibility of commercializing the carbon sequestration role. This allows carbon emitters in industrial countries to be credited with emission reductions that they support financially in developing countries: It allows them to buy abatement credits through bilateral trades. Several such deals have been brokered by the Global Environment Facility. The implementation of a global multilateral carbon emission market, as proposed by the United States in the context of the Kyoto negotiations, will provide a more robust way of selling sequestration services: It will allow credits for carbon sequestration, which can be cashed in the emissions market. In principle, then, a forest ecosystem can sell many different services. Recent provisions in Costa Rica recognize this, as they credit forested conservation areas with income for the services that they provide as watersheds and as carbon sinks to the extent of $50 per hectare for the former and $10 per hectare for the latter. This is sufficient to tip the balance in favor of conserving land of marginal agricultural value.

Agriculture provides another example of the returns from investing in biodiversity to preserve genetic variation. In the early 1970s a virus called the "grassy stunt" virus posed a major threat to Asia's rice crop. This threat was defeated by the transfer of an immunity-conveying gene from wild rice to commercial varieties. A similar event occurred in 1976: Another threatening disease was defeated by transferring to commercial varieties the immunity carried by certain strains of wild rice, preserved for just this reason by the International Rice Research Institute in the Philippines. The returns to this investment in conservation have been almost incalculable.

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New York City recently floated an "environmental bond issue" and will use the proceeds to restore the functioning of the watershed ecosystems responsible for water purification. The cost of the bond issue will be met by the savings produced: the avoidance of a capital investment of $6 billion to $8 billion, plus the $300 million annual running costs of the plant. The cash that would otherwise have gone to these will pay the interest on the bonds.

These cost savings could have been "securitized." This means pledging a fraction of them to the providers of the capital as a return on their investment. New York City could have opened a "watershed savings account" into which it paid a fraction of the costs avoided by not having to build and run a filtration plant. This account would then pay investors for the use of their capital.

This same financial structure is already used in securitizing the savings from increased energy efficiency in buildings. Securitization of the savings involves issuing contracts—securities—entitling their owners to a specified fraction of the savings. Typically, these contracts are tradable, issued to the providers of capital, and can be sold by them, even before the savings are realized. This is a way of making investment in saving energy attractive: It does not imply any transfer of ownership of the underlying asset. The U.S. Department of Energy has a standard protocol for estimating the savings from enhanced building energy efficiency. Several financial agencies are willing to accept these estimates of energy savings as collateral for loans.

Securitization of ecosystem services is not new. It has a pedigree going back at least to 1624, when in a deal structured by the Grand Duke Ferdenando II of Tuscany, a member of the Medici family, the Monte di Paschi di Siena[1] was recapitalized by the issue of bonds secured on the income received by the grand duke from the use of his pasture lands in the Maremma.

10.3 Privatizing the Biosphere

One could take the introduction of market forces a step further. Imagine a corporation managing the restoration of New York's watershed, the "Catskill Watershed Corporation." This has the right to sell the services of the ecosystem, which is different from ownership of the asset itself. In the case of New York's watershed, the services are the provision of water meeting EPA standards. Ownership of this right would enable the corporation to raise capital from capital markets, to be used for meeting the costs of conserving New York's watershed. If we were conserving biodiversity rather than a watershed, the corporation would own and sell (or licence) the rights to intellectual property derived from the biodiversity. Such a framework would harness private capital and market forces in the service of environmental conservation.

In privatizing the provision of ecosystem services, we are creating private property rights where none existed previously. Common property is being assigned to individuals and corporations. If the common property is in a privately produced public good, then the issues considered in the other chapters of this book are relevant: The property rights have to be assigned in particular ways to ensure that an efficient outcome is attained. In the case of a watershed, the purity of the water is indeed a local privately produced public good, as it is determined by pollution and land use decisions of a large number of people in the area of the watershed. Water quality is a public good, as it is a function of pollution, which is in turn clearly a public good (bad). The implications of this for the management of a watershed are set out in the Appendix of this chapter.

10.4 Financing the Biosphere

What is the practical potential of securitization and privatization? How significant a contribution could it make to meeting the challenge of conserving the biosphere?

[1]Monte di Paschi di Siena, founded in 1472, is currently one of the largest banks in Italy.

Many important watersheds are threatened by development. These include not only that of New York but also the watersheds of Rio de Janeiro, the basin of the river Paraibo do Sul in the Mata Atlantica coastal forest in Brazil, and the watershed for parts of Buenos Aires. The Mata Atlantica is a region of great biotic uniqueness, and its conservation would convey benefits far in excess of the value of the water provided. Thus, arrangements of the type discussed could be applied to the watersheds of some of the largest cities in the Western Hemisphere and undoubtedly many more. Within the United States alone, over 140 cities are now considering watershed conservation as an alternative to water purification. Not only could this be cost effective, but it could also represent a major impetus to environmental conservation and a happy alignment of market forces with the environment.

The EPA recently estimated that over the next 20 years, ensuring safe and adequate drinking water in the United States will require infrastructure investment of $138.4 billion. The equivalent figure worldwide will be in the trillions of dollars. Taken in the context of the other pressing infrastructure needs of developing countries, such a number is almost certainly not attainable by the public sector. Watershed conservation could cut the investment needed substantially, and securitization or privatization could ensure that much of the balance remaining is provided by the private sector.

What is the potential for application of privatization or securitization to ecosystems other than watersheds? Daily [4] identifies the following social and economic functions of ecosystem services: purification of air and water, mitigation of floods and droughts, detoxification and decomposition of wastes, generation and preservation of soils, control of the vast majority of potential agricultural pests, pollination of crops and natural vegetation, dispersal of seeds, cycling of nutrients, maintenance of biodiversity, protection of coastal shores from erosion, protection from harmful ultraviolet rays, partial stabilization of the climate, and provision of aesthetic beauty and intellectual stimulation that lift the human spirit.

Which of these are amenable to the approach that we have indicated? One clear prerequisite is that the ecosystem to be conserved must provide goods or services to which a commercial value can be attached. Watersheds satisfy this criterion: Drinkable water is becoming increasingly scarce, and indeed the availability of such water is one of the main constraints on health improvements in many poorer countries.

Commercial value of an ecosystem service is necessary but not sufficient for privatization. Some of that value has to be appropriable by the producer. A critical issue in deciding whether ecosystem services can be privatized is the extent to which they are public goods. Pure public goods are challenging to privatize; they are goods that if provided for one are provided for all. It is hard, although often not impossible, to exclude from benefiting from their provision those who do not contribute to their costs, so that their providers cannot appropriate all their returns. Water quality is a public good in the sense that if it is improved for one user of a watershed, then it is improved for all. However, the consumption of water itself is excludable, so the watershed case involves bundling a public with a private good. Knowledge, an intermediate category and one of the services of biodiversity, has to be commercialized with care, as shown by the need to protect it with patents, copyrights, and other supports of intellectual property rights.

An ecosystem service that could be treated by securitization or privatization is the support of ecotourism, which requires a significant degree of ecological integrity. It is natural to expect that private investment will be forthcoming to finance the conservation of a region with significant ecotourism potential in return for the right to some of the revenues. The growth of private game reserves is an obvious manifestation of this. There is a close economic resemblance to watersheds, in that the preservation of the ecosystems supporting ecotourism is a public good and benefits all. However, the hotel rooms and guide services are private goods whose value is enhanced by the public good.

The International Rice Research Institute played a key role in preserving access to genetic material that might provide immunity to disastrous new diseases. They played this role by conserving a wide range of rice strains, a clear indication of the commercial value of biodiversity. Costa Rica and the pharmaceutical company Merck have made an innovative financial deal aimed at appropriating to Costa Rica some of the economic value of its biodiversity. The deal has three parts: an agreement by Costa Rica to conserve an area of forest, supported by a payment from Merck; an agreement giving Merck access to the results of bioprospecting in this forest; and an agreement that Merck will pay Costa Rica a royalty on products developed from this bioprospecting. The deal represents a first step in providing a conservation agency in a developing country with a financial stake in the intellectual property of its biodiversity.

Is there a possibility of securitizing biodiversity as a way of encouraging private capital to conserve genetic variation and capture some of its commercial value? Genetic information has been securitized. Incyte, a biotechnology company, has as its only product a database of information about genetic structures. This information has been heavily processed; biodiversity in its natural state represents unprocessed genetic information, which is less commercially usable. There might be a role for private capital in establishing a "preprocessing" center for genetic information from developing countries. Such a center could conduct some preliminary analysis and then sell the right to use these, with a royalty to the originating country.

10.5 Conclusion

For certain types of ecosystem service, privatization or securitization represents a very real possibility. It could play a central role in realizing the economic value of the underlying asset and thus provide powerful economic incentives to conserve it for future generations. Examples of ecosystems services that might be privatized include watershed and carbon sequestration services, preservation of wild animals as a basis for ecotourism, and pollination. Biodiversity as a source of genetic knowledge is also a possible candidate for this treatment, although it is a case that presents more problems.

Appendix

Here we give a formal analysis of the issues discussed previously. This is presented in the context of the securitization and privatization of a watershed. The quality of the water in the watershed is assumed to be a public good, in that it is determined by the levels of polluting activities in the watershed region, and these are traditional public bads. We can also note that the quality of the water in a watershed is the same for all users of the watershed and is thus a nonexcludable property of the watershed. The framework we consider is as follows:

1. The right to sell water is owned by a private company, the Water Company, which sells water to individuals at a market-clearing price.
2. Individuals own shares in the Water Company and receive its profits as dividends.
3. The Water Company is responsible for ensuring that the level of pollution in the water is below a standard that is set by the government. The government is not explicitly modeled. Its only role is to set this standard.
4. Any individual wanting to emit effluent must own effluent permits for the appropriate amount. These permits are tradable and are initially distributed to individuals. The only mechanism by which the Water Company can ensure compliance with the government's standards is by buying effluent permits from individuals until the number left in individual ownership just matches the effluent targets. The Water Company thus has to invest in attaining the specified level of water quality, and it then sells water to individuals and buys permits from them. The difference is the profits, which are distributed as dividends to the owners (individuals).

We work with a simple formal model. Let $u_i(c_i, w_i, q)$ be the utility of a person consuming an amount c_i of a private consumption good and an amount

w_i of water of quality q. The quality, which is a function of the level of pollution in the watershed, is the same for all and thus is a public good for the community at issue. The function u is assumed to be smooth and quasi-concave. There are I such individuals. The only goods in the economy are water and the consumption good. Production of the consumption good leads to effluent, which reduces water quality, so that we can write $q_i = f_i(y_i)$, where y_i is the amount of the private good produced by person i and q_i is the resulting pollution. For simplicity, we do not distinguish people from firms. The production function f_i is assumed to be smooth, increasing, and strictly concave. The total amount of pollution in the water is $q = \Sigma_i q_i$, and this level is the same for all people who use the watershed. The level of pollution is thus a public good that is privately produced. The water itself is of course a private good, as what one person drinks another cannot. There is a fixed amount of water per time period; only the quality of the water can vary. Thus, in each period individuals' consumption levels of water sum to $w : \Sigma_{i=1}^{I} w_i = w$. We model a stationary equilibrium that is the same each period.

Efficient Allocations

The central issues in determining an efficient allocation of resources are now as follows. What should each person produce, what should each consume, and how should the water be allocated between people? Once we know what will be produced and by whom, we know the quality of the water through the functions f_i. Standard arguments show that any Pareto-efficient allocation can be characterized as one that maximizes the utility of one person subject to the constraints that

1. total effluent equals the sum of individual effluents, $q = \Sigma_{i=1}^{I} q_i$ and $q_i = f_i(y_i)$;
2. total consumption equals total production, $\Sigma_{i=1}^{I} c_i = \Sigma_{i=1}^{i} y_i$;
3. supply of and demand for water balance, $w = \Sigma_{i=1}^{I} w_i$; and
4. each other individual attains a specified utility level, $u_j(c_j, w_j, q) = \overline{u_j}\ \forall j \neq i$.

The specified utility levels are parameters in this problem. All Pareto-efficient allocations can be characterized as solutions to such a problem as these levels vary. Formally, this problem is

$$\max\ u_i(c_i, w_i, q) \quad \text{subject to} \quad q_i = f_i(y_i),$$
$$q = \sum_{i=1}^{I} q_i,\ w = \sum_{i=1}^{I} w_i \qquad \text{(A10.1)}$$

$$\sum_{i=1}^{I} c_i = \sum_{i=1}^{I} y_i \quad \text{and} \quad u_j(c_j, w_j, q) = \overline{u_j} \qquad \forall j \neq i.$$

The first-order conditions for optimality are easily shown to be

$$\frac{\partial u_i}{\partial c_i} + p_c = 0, \ \lambda_j \frac{\partial u_j}{\partial c_j} + p_c = 0, \tag{A10.2}$$

$$\frac{\partial u_i}{\partial w_i} + p_w = 0, \ \lambda_j \frac{\partial u_j}{\partial w_j} + p_w = 0, \tag{A10.3}$$

and

$$\frac{\partial f_i}{\partial y_i} \sum_{j=1}^{I} \lambda_j \frac{\partial u_j}{\partial q} - p_c = 0. \tag{A10.4}$$

These imply that

$$\frac{\partial f_i}{\partial y_i} = \frac{\partial u_i/\partial c_i}{\Sigma_{j=1}^{I} \lambda_j \partial u_j/\partial c_j}, \tag{A10.5}$$

which is a version of the Lindahl-Bowen-Samuelson result that the marginal rate of transformation between a public and a private good should equal the sum of the marginal rates of substitution between them across individuals.

Privatization and Securitization

The analysis so far is institution free. Equations (A10.2) and (A10.5) characterize Pareto-efficient allocations of water and consumption. Next we check whether or when the framework set out in this chapter will attain these conditions. A typical individual faces the problem

$$\max\ u_i(c_i, w_i, \overline{q}) \quad \text{subject to } p_w w + p_c c = p_c y_i + s_i \Pi + p_e\{T_i - q_i\}. \tag{A10.6}$$

Here $\overline{q}$ is the total level of pollution or of effluents permitted by the tradable permit system. In the budget constraint the market value of the individual's production $p_c y_i$ is supplemented by

1. his or her share of the profits of the Water Company (the profits are Π, and the agent's share in these is s_i), and
2. the market value of the person's net trade $p_e\{T_i - q_i\}$ in effluent permits. The term T_i is i's target level of effluent and q_i the actual level, and the difference is available for sale (if positive) or has to be bought (if negative) at the market price of a permit, p_e.

Applying standard techniques to (A10.6), we see that the conditions characterizing the individual's choice are

$$\frac{\partial u_i}{\partial w_i} + \mu_i p_w = 0, \tag{A10.7}$$

$$\frac{\partial u_i}{\partial c_i} + \mu_i p_c = 0, \tag{A10.8}$$

and

$$\frac{\partial u_i}{\partial c_i} = \mu_i p_e \frac{\partial f_i}{\partial y_i}, \tag{A10.9}$$

so that

$$\frac{\partial f_i}{\partial y_i} = \frac{p_c}{p_e}. \tag{A10.10}$$

We naturally want to know whether the market will lead to Pareto efficiency, so the next step is to check whether the individual choices as modeled previously above satisfy conditions (A10.2) to (A10.5) for Pareto efficiency, that is, whether conditions (A10.7) to (A10.10) describing people's choices imply the conditions (A10.2) to (A10.5) for efficiency. One difference is immediate from comparing (A10.5) with (A10.10):

$$\frac{\partial f_i}{\partial y_i} = \frac{\lambda_j \partial u_j / \partial c_j}{\Sigma_{k=1}^{I} \lambda_k \partial u_k / \partial c_k} \quad \text{vs.} \quad \frac{\partial f_i}{\partial y_i} = \frac{p_c}{p_e}.$$

The right-hand side of (A10.10) is independent of the index i, and the right-hand side of (A10.5) is not and, in principle, could be different for every different person. A necessary condition for the market solution via individual choices to be efficient is thus that $\partial u_i/\partial c_i$ and $\lambda_i \partial u_j/\partial c_j$ be the same for all i and j. This is a familiar condition from the analysis of chapter 3: we are seeking a condition on the equality of the marginal valuations of private consumption across individuals, which is a condition on the distribution of income. The market will attain efficiency only at those distributions at which this condition is satisfied. By following the arguments in Chichilnisky, Heal, and Starrett in chapter 3 of this volume, we can establish the following result:

PROPOSITION 1 Given a regularity condition stated in chapter 3 of this volume, the system of privatization and securitization based on effluent permits described above will lead to Pareto-efficient outcomes only if the distribution of effluent permit lies in a submanifold of codimension one of the sets of possible permit allocations.

Securitization and privatization can work to attain a Pareto-efficient outcome, but there are specific prerequisites that are necessary for this. In particular, the distribution of the property rights created by the privatization must satisfy certain conditions; that is, they cannot be distributed arbitrarily if the outcome is to be efficient.

References

1. *Business Week,* November 10, 1997, pp. 98–99.
2. Costanza, R. et al. "The Value of the World's Ecosystem Services and Natural Capital." *Nature* 387, no. 6230 (May 15, 1997).
3. Chichilnisky, G. "Development and Global Finance: The Case for an International Bank for Environmental Settlements." UNDP-UNESCO Office of Development Studies, New York, September 1996.
4. Daily, G. ed. *Nature's Services: Societal Dependence on Natural Ecosystems.* Washington D.C.: Island Press, 1997.
5. Wilson, E. O. *The Diversity of Life.* New York: W. W. Norton, 1993.