THE RISK OF

Ecosystem Service Losses

Ecological Hedging Strategies

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The supply of ecological goods and services is both economically important and at risk because of climate change and other threats. Although we may not be able to eliminate the risk of climate change—hence the need to adapt—we can make investments in ecological production to reduce the negative consequences of climate change on ecological wealth.

An economic rationale referred to as "option value" is well established for protecting natural resources even when the resource's current benefits are less than the benefits of developing, degrading, or not conserving the resource. This reasoning hinges on uncertainty regarding the social costs of environmental damage and the relative irreversibility of ecological losses.

Option values take two general forms. The first is a risk-aversion premium, where in the option value is like an insurance premium designed to ensure adequate future supply of a resource. The second form reflects the value of information gained from delayed ecological degradation, during which time uncertainty regarding the scale of implied environmental damage is reduced.

The idea of option value in environmental economics is analogous to the value of options contracts in financial markets. In financial markets, it is valuable to purchase an option to some future action, such as the purchase of an asset at a given price. Importantly, options are not obligations. Rather, they give decisionmakers the ability to take one action over another in the future upon the resolution of current uncertainties.

The Practical Implications of Option Value

If we are to act on the basis of option value, we need to estimate the ways in which ecological and economic uncertainties can be reduced in the future and how we can act on better future information. In general, the larger and more irreversible potential ecological damages are—and the quicker and more successfully we expect the science of ecological prediction to develop—the higher the option value. In these circumstances, the value of information associated with delayed degradation is highest.

Unfortunately, it is nearly impossible today to calculate the option value associated with conservation. Clearly, it is desirable to make some investments in protection, restoration, and management of ecological systems to hedge against the ecological and economic risks associated with systems likely to be altered and disturbed by climate change. And although it is difficult to make a clear argument for the appropriate magnitude of such investment, several principles can and should be applied to the hedging strategy we put in place.

Assessing Ecological Resilience

First, analysis of ecological resilience is the best way to identify the most desirable hedging strategies. The concept of resilience captures the notion that species and ecological systems are able to adapt to shocks, stressors, and threats, but that resilience is itself a depletable feature of natural systems. Certain species, for example, may be able to adapt to elevated temperatures by moving to locations with lower temperatures (such as higher latitudes or elevations), but only if suitable habitats

and pathways through which species can migrate exist within those ranges.

This example highlights that resilience can be managed by protecting the natural landscape's ability to adapt and provide critical forage, reproduction, and migratory resources. The growing discipline of ecosystem-based management emphasizes the need to evaluate the ability of ecosystems to rebound from disturbances. From this line of thought arise two types of ecological hedging: *refuges* and *investments in restoration and management of natural systems and their services.*

In practice, refuges have several general features associated with contiguity and connectivity—at the top of the list are a minimum size and connections or pathways to other resources needed to support migration, reproduction, and forage. Exam-

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Volunteers have begun a coastal restoration project in the Pass a Loutre Wildlife Management Area at the mouth of the Mississippi River. The area is still contaminated with oil from the Deepwater Horizon *oil spill, and the restoration project includes planting marsh grass in biodegradable burlap bags, which contain soil mixed with natural oil-eating microorganisms and marsh grasses. They are placed strategically in the marsh in hopes that the grasses will take hold.*

ples of the latter are migratory pathways to allow the free movement of terrestrial species over often very large distances.

Accordingly, ecologists have proposed protected area networks, or refuges, designed with climate resilience in mind. Although they are desirable for ecological reasons alone, refuges also preserve the economic value of that ecological production. As a result, protected-area networks are one of the principle hedging strategies available to preserve ecological wealth.

Other prime strategies for ecological hedging are investments in restoration and management of natural systems and their services. Like protected-area designations, restoration of wetlands, riparian forest buffers, and native plant species can enhance resilience and help ecosystems adapt to climate change. Similarly, water management (such as diversion of flows to stock subsurface aquifers) and land management (selective harvests, cropping practices, and removal of invasive species, for example) are measures by which we can hedge against the loss of ecosystem goods and services.

An Ecological Investment Portfolio

A second key hedging principle is the idea of a portfolio of investments. Because of the numerous uncertainties associated with ecological change, it is desirable for society to invest in a diversified portfolio of natural resources and systems. Ecological diversification should take place to hedge against the following:

» losses in ecosystem goods we use directly, such as agricultural soils, water, and species we consume for food;

» loss of ecological processes, functions, and inputs necessary to produce those consumed goods; and

» changes in demand for ecosystem goods by demographic changes (population, industrial activity) associated with climate change.

Consider a concrete example. If we wish to hedge against the loss of marine fish populations on which we are dependent for food, we should consider the following forms of diversification: protecting numerous different species whose adaptive responses to climate change are uncertain and protecting the food webs on which these species depend—which themselves will adapt unevenly to climate change.

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Policies to Achieve a Diversified Portfolio of Ecosystem Functions and Services

Given our current lack of information, how should policies be designed to foster investments in ecosystem services adaptation? First, we should realize that current environmental policies—even those designed in the most sophisticated manner—have not been based on climate adaptation objectives. Going forward, environmental policies should be designed and targeted in close collaboration with natural scientists engaged in adaptive ecological management and strategy. Also, policy design should take into account the economic value of ecosystem goods and services for which patterns of production are likely to change in the future. Consider the following policy instruments and ways in which they could facilitate ecological hedging strategies.

Public Lands Management

The current U.S. portfolio of protected lands is large and provides opportunities for the management of water flows, land use, and land cover to facilitate ecological adaptation. The Department of the Interior and other public trustees should experiment with management practices designed to increase the resilience of ecological systems.

Public Lands Designation

U.S. public land holdings are designed to serve many public purposes. However, land acquisitions as well as wilderness and other protected designations have not been made with climate adaptation in mind. A portfolio approach to adaptation may include new investments in land acquisition and protection and new land use restrictions.

Marine Resource Management and Protection

As in the previous two examples, the designation of new marine reserves and fishery management practices could facilitate the resilience and continued productivity of ocean resources.

Payments for Ecosystem Services

Payments for ecosystem services, from targeted farm conservation payments to schemes that transfer revenues from water users to up-watershed landholders, typically focus on delivery of a single service. Such schemes can facilitate a range of other ecological benefits, including resilience and adaptation benefits. Calculation of—and payment for—these additional benefits will create opportunities for greater investment in ecological resilience.

Greenhouse Gas Markets

Many carbon sequestration practices generate a range of associated biophysical effects that influence the broader delivery of ecosystem services and resilience. For example, reforestation can provide numerous potential ancillary benefits beyond carbon sequestration, including support for species abundance, recreation and subsistence benefits, and enhanced water supply. Greenhouse gas markets and other payments could and should take these differential benefits into account.

Natural Resource Damages

In the United States, responsible parties are liable for natural resource damages under Superfund regulation and the Oil Pollution Act. These laws require injurers to compensate the public for the lost economic value associated with damaged natural resources. Federal agencies, including the National Oceanic and Atmospheric Administration and Department of the Interior, are the designated trustees responsible for the assessment and adjudication of these damages. Natural resource damage practices should be adapted to capture the possibility that resource injuries are degrading resilience and option value.

Many other policies could be adapted to foster ecological resilience, including rules governing wetland loss mitigation, tax laws that affect the incentive to donate conservation easements on private property, local zoning regulations, designated water use determination under the Clean Water Act, and the definition of critical habitat under the Endangered Species and Magnuson-Stevens Acts.

Conclusion

From an economic perspective, the idea that delay has an economic value holds true for *any* decision characterized by irreversible consequences and uncertainties that can be at least partially resolved through delay. This does not necessarily imply that we should always delay an environmentally damaging housing development, fishery, dam, or power plant. It does mean, though, that we should invest in science and economics designed to better understand the option value of ecological protection.

In the meantime, it is economically rational to devise hedging strategies as best we can. For ecosystem goods and services, climate adaptation policies should foster investments in geographically diverse portfolios of species, lands, resources, and ecological systems designed to hedge against future losses in supply or increases in demand brought about by climate change. Creating these portfolios will require coordinated analysis by natural and social scientists.