Capítulo 22

Oh trilhas de rumo errante
Onde pasta o manso gado
Riscando o verde pujante
Dos campos do meu cerrado

É lá do alto da serra
Daonde o sol pinta o mundo
E doa aos filhos da terra
Este lar rico e fecundo

Geovane Alves de Andrade

Environmental Valuation and its Applications

Joshua Farley

Abstract

One of the most serious economic problems we currently face is macro-allocation: how much ecosystem structure should we conserve in order to protect vital life support functions and other ecosystem services, and how much should we convert to economic goods and services? Monetary valuation of ecosystem goods and services and the internalization of the resulting prices into the market economy have been proposed as a potential solution to this problem. Before we apply this tool however we must understand the role of prices in a market economy, and the limitations of valuation for non-market goods and services. Among other limitations, valuation tends to assign greaters weight to the preferences of the wealthy, it is limited by our ignorance of ecosystem functions and the impacts of human activities on them, and it may not be able to measure all types of value in the same units. In addition, when applied to non-rival resources, the rationing function of price creates artificial scarcity. When natural capital stocks are relatively abundant and far from critical thresholds, monetary valuation may play a useful role in macro-allocation. However, when natural capital nears critical thresholds below which it cannot maintain itself or cannot provide essential ecosystem services, marginal valuation is inappropriate. Instead, we should make conservation decisions based on the best available science weighted by ethical concerns towards risk and obligations to future generations. Prices can then adjust to biophysical limits, as biophysical limits cannot adjust to prices.

Introduction

In today's global economy, the majority of decisions about resource allocation are determined by market forces. While markets assign value to ecosystem structure such as plants, animals, land and water, the values of many ecosystem functions are often not reflected in market decisions, desspite of the fact that many of them are essential to human survival. We know from the laws of physics that we cannot create something from nothing, so all economic production entails the transformation of ecosystem structure. We also know that energy is required to do work, fossil fuels are the dominant source of energy, and combustion of fossil fuels generates waste. Both the extraction of ecosystem structure and emissions of waste degrade ecosystem function and the supply of vital services. As these services become increasingly scarce, it becomes even more important to develop effective institutions for their sustainable, just and efficient allocation. Conventional economics focuses primarily on micro-allocation – how do we apportion resources provided by nature among different economic products to maximize monetary value? We need a new approach to economics that focuses on macro-allocation (also known as sustainable scale) – how much ecosystem structure should we conserve to protect vital life support functions and other ecosystem services, and how much should we convert to economic goods and services?

Estimating monetary values of non-market goods and services could potentially help solve this allocation problem in at least three ways. First, the estimated values could be directly incorporated into market prices (for example, via taxes), thus internalizing these values in market decisions. Second, the values could be used to adjust national accounts, such as GNP, to provide a more accurate measure of economic growth. Third, the values could be used simply to call attention to the importance of the environment, without claiming that measurement in the same unit implies substitutability. These approaches however are quite controversial, and should not be applied at random.

The goal of this chapter is to briefly review the strengths of weaknesses of monetary valuation so that better decisions can be made about when and how to use it. To begin, I critically examine the role of prices in a market economy, and explain why markets fail to generate prices for many ecosystem services. Next, I discuss some key issues concerning the estimation of monetary values for these non-market ecosystem services. I then turn to critical natural capital, defined as ecosystem structure that generates vital life support functions, and describe how we might use valuation for different stocks of such capital. I conclude with a brief summary of key points. As they have been addressed in considerable detail elsewhere, this chapter does not discuss methods for valuing non-market ecosystem goods and services, as well as their many shortcomings (see for example. FREEMAN III 1993; FARBER; COSTANZA et al. 2002; KOPP; SMITH, 2003). Owing to space constraints, I also ignore a number of other important issues, such as how we should weight future values relative to present ones.

The Function of Prices in a Market Economy

Before we can decide when the monetary valuation of non-market goods and services is appropriate, we must understand the function of prices in a market economy. Most people assume that market prices reflect value, but fail to think about what specific values they reflect. Economists long ago recognized that prices do not necessarily reflect the actual contributions of commodities to our welfare. As Adam Smith (1776) pointed out, diamonds contribute little to human welfare, but are very expensive, while water is essential to life but is generally quite cheap. Economists realized that the value of diamonds is determined more by their scarcity than by the benefits they provide, which led them to distinguish between use value and exchange value. The use value of something is basically the contribution of all units consumed to our welfare. The first units of water consumed have essentially infinite value, but as more and more water is consumed, each additional unit is used for less and less important uses and has lower and lower marginal value. Use value is the sum of the marginal value of each unit across all units consumed. In the case of water, use value is essentially infinite. Exchange value in contrast is the price someone is willing to pay for the last unit consumed; its marginal value. Market values are therefore determined by both supply and demand. Neoclassical economics is almost solely concerned with marginal values. In a market economy, marginal value is theoretically equivalent to price.

Prices play a critical role in a market economy by balancing supply with demand, costs with benefits. Very briefly, there are two basic functions of price that lead to this result: the rationing function and the allocative function. The rationing function of price apportions commodities to whoever is willing to pay the most for them, thus maximizing monetary value across all consumers. The allocative function of price apportions factors of production to whatever industry is able to pay the most for them, generally the industry capable of adding the most monetary value to the factor, which maximizes monetary value across all producers. The price mechanism therefore maximizes the monetary value of both inputs and outputs. Prices also reflect scarcity, and provide incentives for alleviating it. When demand for a resource exceeds supply, prices go up to reflect this scarcity, leading consumers to demand less or consume a substitute and producers to supply more or to create substitutes. When supply exceeds demand, suppliers will lower their prices or reduce production until the market again clears. As prices do all this using only the free choice and decentralized knowledge of consumers and producers, it is no wonder that economists are enamored of such an elegant system.

Unfortunately, to be a market good with a market price, a resource must be excludable, which is to say that people who do not pay to use a resource can be prevented from using it. If someone cannot be prevented from using a resource whether or not they pay, they are unlikely to pay. Markets will therefore not generate prices reflecting the marginal values of non-excludable resources, and the markets will fail to produce or preserve appropriate amounts. Excludability is solely the result of human institutions protecting property rights, and is therefore a policy variable. However, while it is generally quite simple to make ecosystem structure excludable, many ecosystem services are inherently non-excludable – for example, there is no practical institution that could make climate regulation or flood regulation excludable. In this case, the market system will pay the resources owners for the benefits of conversion (e.g. timber and farm land from cleared forests), but fails to pay them for the benefits of conservation (e.g. flood and climate regulation from intact forests). Markets therefore systematically favor the conversion of ecosystem structure to market production over its conservation to provide ecosystem services, even when the non-monetary benefits of conservation outweigh the monetary benefits of conversion[1].

Many economists argue that if we can estimate the monetary value of ecosystem services and either charge those who destroy them or those who use them, we can solve this market failure.

[1] This problem is compounded when ecosystem structure is unowned (e.g. oceanic fisheries) or property rights are poorly enforced (e.g. Amazonian forests), in which case markets fail even to maximize monetary values of ecosystem structure, but we will not address this problem here.

Problems with Prices in a Market Economy

Before we can decide if marginal valuation is the appropriate tool for solving the macro-allocation problem, however, we need a solid understanding of the role of prices in a market economy. Specifically, we must consider precisely what values are maximized by allocation and rationing via market prices, whether prices adequately measure scarcity and provide incentives for innovation and substitution, and finally, whether prices efficiently ration all types of resources.

Is monetary value what we want to maximize?

Via the price mechanism, markets are meant to maximize monetary value. However, whether or not monetary value is indeed what we want to maximize is a normative question. Market demand, which determines prices, is a function of preferences weighted by wealth and income and hence systematically ignores the preferences of the poor. It follows from this that different initial distributions of resources in a market economy would lead to a different set of market prices and a different allocation of resources. The same holds true for estimated market values of non-market goods. A final market allocation of goods and services will therefore be no more desirable than the initial distribution of resources that gives rise to it.

A concrete example can help us understand the implications of this for allocation. Aventis developed a compound, eflornithine, which kills trypanosomes, the parasite responsible for African sleeping sickness, a debilitating and often lethal disease. Though the only other treatment for second stage sleeping sickness is extremely painful to administer, often ineffective and sometimes lethal, the African's strong preference for eflornithine, weighted by their very low incomes, generates negligible market demand. As a result, Aventis discontinued production for that purpose. Eflornithine however also removes unwanted facial hair in women, a use for which market demand is very high, and Aventis was happy to license production for this purpose. Only after the NGO Médecins Sans Frontières threatened to publicize the issue did Aventis agree to again produce eflornithine as treatment for African sleeping sickness (GOMBE, 2003; WORLD HEALTH ORGANIZATIONS, 2006). Had the market been left to its own devices, the rationing function of price would have continued apportioning eflornithine to wealthy, hirsute women rather than destitute Africans suffering from debilitating disease. The allocative function of price in general apportions far more resources towards industries that supply luxuries for the rich rather than basic needs for the poor. Many people would question whether markets maximize the appropriate values in this case.

Do prices measure scarcity?

Though prices may fail to maximize value as many people understand it, do they at least measure scarcity and stimulate greater production and innovation in response? Oil is a finite commodity, and every barrel used depletes the stock, increasing scarcity. Over the past 100 years, we have depleted in ground stocks while developing thousands of new uses for oil and surprisingly few substitutes. Demand has soared. Nonetheless, the mean price of oil, though showing considerable fluctuation, remained relatively unchanged in real terms between 1879 and 2000 with the notable exception of the OPEC oil embargoes and Middle East crises of the 1970s (WTRG ECONOMICS, 2007). Prices apparently failed to reflect its growing scarcity. If we think about it, this is hardly surprising –if the best informed petroleum geologists disagree about how much oil is left in the ground (HEINBERG, 2003), how would the decisions of billions of ignorant consumers reveal this information?

In regard to renewable natural resources, price increases are likely to promote more rapid extraction. While this increases supply in the short run, it also diminishes the capacity of the resource to reproduce, decreasing long run supply, and decreasing the provision of ecosystem services that structure would otherwise provide. If prices increase more rapidly than extraction costs, or if technologies are dedicated to more cost effective harvesting and extraction rather than to the development of substitutes, we run the serious risk of exhausting critical resources before we develop substitutes for the resources themselves or for the services they provide, many of which are likely to prove non-substitutable. As future generations cannot bid in today's markets, market prices will not reflect potentially dire future scarcity. Markets at best reflect scarcity for the current generation, and only offer appropriate measures of marginal value if we believe that future generations have no rights to natural resources (BROMLEY, 1989).

The problem with non-rival resources

Finally, there is an entire category of resources that prices fail to efficiently ration. A non-rival resource is one for which one person's use does not leave less for another person to use – for example, when you read this chapter, you do not leave less information for the next person who reads it. Rivalness is a physical characteristic of a particular use of a resource – water used for irrigation is rival, water used for swimming or navigation is non-rival but congestible (which is to say it becomes rival at high levels of use, but is non-rival at low levels of use), while the role of large bodies of water in regulating climate is purely non-rival. Many of the most important ecosystem services, such as climate regulation, storm protection, flood regulation, and protection from UV regulation are non-rival.

If use of a non-rival resource does not diminish the quantity available, then using price to ration use simply creates artificial scarcity. If use creates value, and our goal is to maximize value, then using prices to ration consumption is counter-productive. In other words, while markets lead to the sub-optimal supply of non-excludable resources, they lead to the sub-optimal demand for non-rival resources. When a resource is both non-rival and non-excludable, it is by definition a pure public good, and price rationing is basically impossible. However, many non-rival resources are excludable. To take a real life example relevant to conservation, corporations have patented non-ozone depleting refrigerants, thus allowing them to charge monopoly prices which ration their use to those who can afford them. China and India are therefore more likely to use ozone depleting HCFCs as refrigerants, which has presumably contributed to the worst depletion of the ozone layer in history during 2006 (UNEP, 2006).

Issues with monetary valuation of non-market goods and services

Unfortunately, as compared to market commodities, monetary valuation may be even less appropriate for allocating or rationing non-marketed commodities. The accuracy of estimated monetary values will be constrained by our limited knowledge of ecosystem function. Compounding this problem, many ecological changes may be irreversible. Furthermore, it may not be possible to measure all environmental resources in monetary units. Anyone considering the valuation of environmental resources must first consider these issues.

Uncertainty, ignorance and irreversibility in complex systems

Whether estimated or derived from markets, values reflect our knowledge of a resource's attributes. Unfortunately, we frequently lack detailed knowledge about environmental goods and services. Too often, we do not know what values an ecosystem provides or what impacts human activities have on those values. In many cases, the only way we can discover the value of an ecosystem or species is to destroy it and see what happens (VATN; BROMLEY, 1994). Even then, if our sample size is a single ecosystem, the information is anecdotal, with a sample size of one (FARLEY et al., 2005).

One reason for our ignorance is the fact that ecological-economic systems exhibit highly complex, dynamic and non-linear behavior, in which a clear understanding of the part rarely translates into a clear understanding of the whole. In such systems, marginal activities, such as the conversion of a forest landscape or even a hectare of forest to pasture, may lead to reasonably linear changes in the value of ecosystem services over some range, yet highly non-linear changes over another range. Non-linear changes may include the presence of abrupt, irreversible thresholds (FARBER et al., 2002; LIMBURG et al., 2002; FOLKE 2006).

For example, research shows that the Amazon rainforest recycles much of the rain that falls on it: torrential rains strike the forest canopy, dissipating its energy. Much of the rain evaporates directly from the canopy, while the remainder falls to the ground as a fine mist, where it readily percolates into soils aerated by the extensive roots systems. Some of this rain is absorbed by the trees, returning to the atmosphere through evapotranspiration. Enough rainfall returns to the air as water vapor that it forms clouds and falls again. When forest cover is removed, the rains fall on bare soils, compacting them, then swiftly runs off into the river systems where it flows downstream and is lost from the system forever. Studies suggest that if as little as 30 % of the total forest cover is lost, enough water will be lost from the system that it will no longer be capable of spontaneously regenerating itself (SALATI; VOSE, 1984; SALATI, 1987). Furthermore, clearing leads to a hotter and drier microclimate, more conducive to fires, and fires in turn cause more forest loss in a vicious circle. If nothing is done, much of the forest could convert to a drought resistance savannah ecosystem (NEPSTAD, 2007) As the Amazon plays a critical role in regulating global and regional climates (FLANNERY, 2005; NEPSTAD, 2007), its loss will have profound but uncertain impacts around the globe.

Not only are we frequently unaware what services an ecosystem generates until the ecosystem is irreversibly degraded, but time lags between loss of the ecosystem and noticeable loss of the service may also be greater than a human lifespan. Take Brazil's Atlantic Forest as an example. The heterogeneous forest is a biodiversity hotspot, with over 8,000 recorded species. Though biodiversity is not an ecosystem service itself, it plays a critical role in sustaining all ecosystem services (MEA, 2005). Originally spanning 1.5 million km^2, cover has dwindled to only 100,000 km^2, some 7 % of the original area (TABARELLI et al. 2005). Forest remnants still exhibit some of the highest levels of terrestrial biodiversity and endemism ever recorded (CONSERVATION INTERNATIONAL, 2001). As a result of habitat loss, the forest currently harbors more threatened and endangered species than any other Brazilian ecosystem (COSTA et al., 2005). A rough rule of thumb from island biogeography suggests that when an ecosystem declines in size by 90%, the number of species is likely to decline by 50% (MACARTHUR; WILSON, 2001). If this holds roughly true for the Atlantic Forest, it is due for a catastrophic collapse in biodiversity, but there may be a time lag of centuries. For example, we might see top predators slowly extirpated from remnants too small to support viable populations, followed by a boom in herbivore populations, over consumption of seeds, seedlings and plants, and a decline in plant species. The loss of large vertebrates to transport large seeded tree species will also contribute to dramatic declines in plant diversity (TABARELLI ; PERES, 2002). Long-lived keystone tree species might linger for centuries, but when they go, so must the species that depend on them in a chain reaction.

Another dynamic could lead to more rapid loss of the Atlantic Forest. Condensation from moisture laden ocean breezes can contribute considerable moisture to tropical forests (BRUIJNZEEL, 2000). Forests also helps maintain a moist and cool microclimate in which it is difficult for fires to start or burn. Once forests are cleared and planted to pasture however, the microclimate becomes hotter, drier and much more conducive to fires. Fires ignited in pastures slowly encroach on remnant forest stands. If this dynamic continues, the remaining forests may be destroyed, and we may see a flip to an alternate state (NEPSTAD, 2007).

Unless something is done, the loss of biodiversity and the ecosystem services it provides is almost certainly inevitable, but what those services are we cannot say. We cannot possibly value what we do not understand.

Essential and non-substitutable resources

Humans, like all species, depend on ecological life support functions for their survival, which is to say that ecosystem services in total are essential and non-substitutable. Many market goods such as food, water and energy are also essential and non-substitutable. Such resources exhibit what is known as price inelastic demand (elasticity of demand is a measure of the percentage change in price in response to one percent change in quantity). When a resource has inelastic demand, large changes in price lead to small changes in quantity demanded. Conversely, small changes in supply will lead to large changes in price. This explains why food prices skyrocketed in 2007-2008 as the world began transforming relatively small amounts of food crops into biofuels. When the stocks of such resources reach critical levels below which survival would be impossible without them, they cease to be market goods: farmers do not sell food required to feed their families. Inelasticity of demand poses serious challenges for environmental valuation. It takes time to conduct environmental valuation studies, communicate results to decision makers, develop policies based on those values, and implement the policies. If a system is undergoing rapid changes, by the time the process is completed, the estimated values may have changed enough that they no longer serve as appropriate guides to policy. If an essential system falls below a critical ecological threshold required to sustain its own reproduction or other life supporting services, marginal valuation becomes meaningless.

Incommensurability

Monetary valuation assumes that all relevant attributes of environmental resources can be measured in the same unit – money. However, many people find that the different attributes of environmental assets are fundamentally different from each other, and a single measure such as hypothetical price does not reflect all important information. Many people believe that ecosystem services are a human right, and they are essentially enshrined as such in some national constitutions (e.g. Costa Rica and Brazil). While economists frequently put dollar values on human lives, I have yet to see any try to place monetary values on human or political rights. When different values are incommensurable there is no common scale by which we can measure the different values of ecosystems (VATN; BROMLEY 1994; GOWDY, 1997; MARTINEZ-ALIER et al., 1998). For example, when the supply of an essential and non-substitutable resource, such as water, falls below a critical threshold, people will prefer enough of the essential resource to bring them past the critical threshold over any quantity of money. This is known as lexicographic preferences, and may apply to spiritual or other types of value as well. Such values cannot be measured in monetary units.

When and How Should We Apply Valuation?

So far, this chapter has dealt with the problems pertaining to environmental valuation, but these must be understood before we can consider when and how valuation should be applied. Whether or not valuation is appropriate depends on our goals, on the extent to which valuation studies can be translated into effective policies for achieving our goals, and on the availability of other suitable policies. I take the normative position that the goal of avoiding the irreversible loss of critical natural capital is more important than maximizing monetary value. I also take the position that the allocation that results from maximizing monetary value is no more desirable than the underlying distribution of resources that gives rise to it. Nanetheless a number of the points I make however are relevant even if the goals of sustainability, distribution and efficiency are given different priorities.

The Demand Curve for Natural Capital

Marginal values for a resource depend on its demand curve, which measures how much society is willing to pay for another unit of a resource at any given level of supply. For a rival resource, the marginal value is determined by the maximum amount any individual is willing to pay for another unit of the resource. Most rival resources however are market goods, and there is no need to estimate market values. In this section we are primarily concerned with the demand for non-rival resources, such as most non-marketed ecosystem services. Since use of a non-rival resource by one person does not leave any less for others to use, marginal value is the sum of what all individuals together would be willing to pay for another unit. For example, society should be willing to expand a protected watershed area as long as everyone's marginal willingness to pay for its expansion was at least equal to the full cost of expansion (including opportunity cost). Unfortunately, the full value of a non-rival resource is only realized when there is no price, as any positive price is likely to reduce use and hence value. Markets will therefore fail to measure the full value of non-rival resources, and non-market valuation techniques could in theory provide a better estimate, subject to all the caveats previously discussed.

Economists conventionally draw demand curves as a straight line sloping downwards from the Y axis to the X axis. The curve intersects the Y-axis at a point where price drives demand to zero, and the X axis at a point where no one cares to consume more even at a zero price. But what does a demand curve for natural capital look like?

To answer this question, it is useful to focus on our most important natural capital stocks, those that are essential for sustaining human welfare and for which substitution is difficult or impossible. While the use value of such natural capital stocks is immeasurable, marginal values may not be. Starting out with pristine conditions of vast quantities of natural capital stocks and few people, there is enough natural capital available for all desired uses, and its marginal value will be zero. Such conditions however are scarcely relevant in the inhabited continents. As stocks dwindle and demand rises, some is likely to be used for relatively unimportant activities; as the least important use of a resource is what determines its marginal value, marginal values will be quite low. This was probably the situation in the Amazon 50 years ago. Most healthy ecosystems exhibit a fair degree of redundancy and resilience, so that marginal values initially change quite slowly as more land is cleared or more resources extracted. However, as the quality and quantity of the ecosystem declines, we must give up ever more important uses, such as maintaining an adequate buffer insuring against catastrophic loss. As we use up even more of the resource, reducing natural capital stocks even further, redundancy decreases, more ecosystem services are threatened, and we expect a more rapid rise in marginal values, including insurance value. As natural capital stocks approach the threshold of criticality, they provide increasingly essential benefits for which substitution is increasingly difficult. When a resource is extremely important or essential and substitution is difficult or impossible, it exhibits highly inelastic demand. This means that small changes in quantity will lead to large changes in marginal value.

Eventually, continued loss of natural capital will lead us to thresholds beyond which the ecosystem can no longer meet essential human needs or even sustain itself. When we reach the threshold of criticality, the demand curve becomes vertical, as the marginal value approaches infinity. Beyond this point, marginal valuation becomes irrelevant. Unfortunately, we can never know precisely where that threshold lies.

Fig. 1 below illustrates a hypothetical demand curve for critical natural capital, indicating its marginal value for different stocks. Region 1 indicates relatively abundant natural capital stocks, region two indicates natural capital stocks exhibiting inelastic demand, and region three exhibits critical natural capital, essential to our survival. Unfortunately, it may be very difficult to judge how close natural capital stocks are to criticality thresholds. Given any uncertainty, it is wise to add an insurance premium to any estimated values, and the greater the uncertainty, the greater the premium.

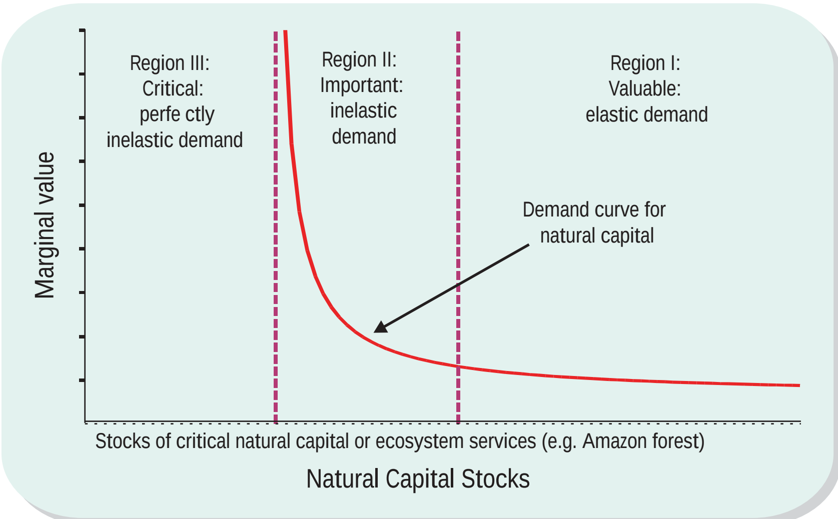

Fig. 1: The marginal value of natural capital stocks that become critical when depleted beyond a certain threshold.

Internalizing Externalities

With this background, we now turn to one of the main theoretical applications of environmental valuation: informing policies that internalize externalities. Such policies can either penalize those who cause damage to ecosystems and the services they provide, or reward those who conserve and enhance them. Valuation, of course, is only the first step. Once values have been estimated, they must be fed to decision makers who transform them into policies which are subsequently implemented.

At the extreme, some economists appear to believe that if we internalized the values of all externalities, the market would lead to the optimal allocation of all resources.

From the viewpoint of an ecological economist, such a goal would be neither possible nor a market solution. Because all economic production requires ecosystem structure and generates waste, and both resource extraction and waste emissions degrade ecosystem services, all economic activities generate externalities. Estimating the marginal values of all ecosystem services and the impacts of all economic activities on these services would take an army of technocrats. The estimated values would then be fed to a central authority which would in turn create policies to feed these values back into the market system. What we love about markets is the decentralized system by which they calculate prices, which unfortunately is the antithesis of price setting by a central authority.

Even if we abandon the notion of internalizing all externalities, we could conceivably internalize some of the most important ones. For example, if we could calculate the marginal value of a hectare of Cerrado, then the tax conversion of the Cerrado accordingly, landowners would cease to convert Cerrado when the tax came to exceed the net returns to conversion, thus helping the market to maximize monetary value. Even if taxes did not exactly reflect the Cerrado's value, it would still be better than assigning no value, which is the current situation.

Our previous discussion of a demand curve can help us understand when such an approach might be appropriate. Region I, on the right hand side, is characterized by low marginal values and slow changes in marginal value. Though subject to the problems of profound uncertainty, plutocratic estimation methods and potential incommensurability of values, monetary valuation may be appropriate in this region of relatively abundant natural capital, and estimated marginal values are likely to be quite robust over a fairly large range of natural capital stocks. Under these circumstances, it may be possible to calculate some marginal values then feed them back to a central authority that internalizes them into prices of commodities or activities that lead to their degradation (e.g. through taxes or user fees), or to pay for activities that protect and restore them. Though the problems with valuation discussed above would still be relevant, even mis-estimation of values is unlikely to lead to irreversible damage, as the system is far from ecological thresholds.

However, the Cerrado is currently undergoing rapid rates of change, with deforestation rates exceeding those of the Amazon. Given the region's impressive levels of endemic biodiversity and the role of biodiversity in sustaining all ecosystem services, it would be safe to assume that the system plays a critical but not yet full understood role in sustaining welfare in Brazil and perhaps even at global level. While the Cerrado may have been in region I in the 1950s, this is probably no longer the case.

More than likely, the Cerrado finds itself in region II, the middle section, which occurs when natural capital declines to the point that demand becomes inelastic. The rapid degradation of the Cerrado may well be affecting critical system linkages, undermining the ecological resilience that sustains the system. If we set aside our concerns with uncertainty and incommensurability, it might still be possible to calculate marginal values in this situation. However, in the time it takes to move from a valuation study to the implementation of policies based on the study, much more of the Cerrado will have been lost, and the implemented policy will be based on outdated values. In a period in which rapidly changing food pricesis increasing the demand for conversion, internalizing externalities would require an army of technocrats to keep estimated values current as well as constant adjustment of taxes. While this might offer full employment to environmental economists, it would be quite impractical.

The closer we approach unknown ecological thresholds, the less appropriate this approach to internalizing externalities becomes. Markets work best when we have micro-flexibility in achieving macro level goals. The closer we are to criticality thresholds, the less flexibility we have – we must preserve all that is left, or risk unacceptable losses. While it is true that the Cerrado is being converted to food and biofuel, and the demands for these commodities are also inelastic, it is quite possible to substitute grain for meat, and in the wealthy nations, the lowest value use of biofuels is to drive enormous vehicles on unimportant errands. Furthermore, ecosystem services provided by the Cerrado almost certainly include climate regulation, pollination, water regulation and others essential for agricultural production. In other words, the negative externalities of conversion to agriculture are likely to reduce agricultural production. An individual farmer might gain from increasing more land to soybeans, but at the cost of decreasing yields for all farmers. Studies elsewhere have confirmed such outcomes (PANAYATOU; SUNGSUWAN, 1994; EHUI, 1989).

In region 2, rather than using prices (economic signals) to determine the appropriate level of resource use, it would be much simpler and more compatible with both free markets and democracy to fix supply based on ecological factors and moral obligations to future generations, and allow that to determine price. In other words, we would make our best estimate of critical natural capital, beginning perhaps with the criteria put forth by the Critinc project (EKINS et al. 2003), presumably adding a healthy buffer to account for uncertainty, ignorance and ethical obligations to future generations, and then allow the allocation of the remainder to be determined by market forces. As Daly has pointed out, frugality leads to efficiency, while efficiency does not lead to frugality. Under the status quo, efficiency improvements in soy bean production have led to ever faster rates of land conversion. A limit on land use is instead likely to lead to ever faster increases in per hectare productivity.

In region 2, the amount of conversion of an ecosystem would be price-determining, not price determined. In practice, Brazil is already following this policy, as it has put a cap on clearing of the Cerrado, limiting conversion to 80 % of a given territory. Unfortunately, such caps have been poorly enforced in recent years, and the cap does not appear to reflect any empirical study of whether 20 % of the ecosystem would be sufficient to sustain critical ecosystem services.

If our knowledge of ecosystem function improved substantially along with valuation methodologies, so that valuation studies more accurately reflected actual ecosystem values, then valuation could help us decide when to shift from price determined conversion to price determining conversion. A rapid increase in non-market marginal values resulting from small decreases in quantity would indicate inelastic demand, and hence increasing essentialness and non-substitutability. This in turn would suggest we are nearing critical ecological thresholds, and should halt conversion. However, as monetary valuations can be no more accurate than the knowledge of the ecosystem that underlies them, it might be best to simply cap conversion as soon as the ecologists believe we are nearing irreversible thresholds.

Based on our previous description of the Brazilian Amazon, it too appears to offer an example of an ecosystem currently in stage II. Deforestation is rapid, and the forest may fail to regenerate itself if much more is lost. Brazil's forest code in fact mandates that 80 % of all holdings in the Amazon be maintained in a natural state as a legal reserve. Unfortunately, the law is poorly enforced and penalties for non-complianceare low. Complicating matters further, there are certainly interactions between the Cerrado and Amazon about which we know little. It is quite likely that deforestation in the Amazon will affect rainfall in the Cerrado, affecting not only soy production, but also the capacity of the ecosystem to reproduce itself.

Stage III occurs when depletion of natural capital passes the criticality threshold and either human welfare or the ecosystem is doomed to collapse in the absence of intervention. If we take the position that species survival is an imperative goal, then future generations have inalienable rights to ecosystem life support services, which therefore have infinite value. Monetary values simply cannot be measured in the same units as the rights of future generations; they are incommensurable. Marginal valuation is entirely inappropriate. The only appropriate response is the restoration of natural capital in the hope that this is still possible with sufficient intervention. The correct priority for policy goals is ecological sustainability first (restore natural capital beyond the critical threshold), just distribution second (those who caused the damage should bear the costs of restoration) and economic efficiency third.

While it is often difficult to determine precisely when an ecosystem enters stage III (and global climate change is likely to affect this profoundly) many ecosystems have almost certainly reached this state. Brazil's Atlantic Forest provides one example. Whether through a slow process of attrition or via rapid conversion to a fire prone ecosystem, the Atlantic Forest appears doomed unless something dramatic is done. We cannot say for certain what the impact will be on Brazil and the world, but the region's biodiversity almost certainly sustains an array of local, regional and even global ecosystem services whose loss would be unacceptable to humanity.

Under such circumstances, scientists should seek to estimate the quantity, quality and distribution of forest necessary for its self-reproduction. Working with conservation and restoration specialists along with local communities and decision makers, economists should dedicate their efforts to estimating supply curves, the marginal cost of restoring the forest. This tells us little about value, but it does tell us where the ecosystem can be restored most cost effectively.

Supply curves in this situation however will not exhibit the same behavior as supply curves for conventional commodities. There are three components to the marginal cost of restoration: transaction costs, opportunity costs and implementation costs. While opportunity and perhaps transaction costs are likely to increase with increasing restoration of natural capital, as expected of conventional supply curves, this is not true of implementation costs. When an ecosystem is too severely degraded, restoration can be very costly. For example, as forest loss results in decreasing humidity, increasing temperatures, and greater occurrence of fires, seedling mortality may be exceptionally high, and restoration exceptionally difficult. Restoration may in fact require a trial and error process to discover effective techniques and viable species that help recreate the microclimate essential for other species to survive. Only then can the original vegetation be restored. The basic point is that in many cases, the more forest that is restored, the cheaper it is to restore additional forest. When enough forest has been restored, passive restoration is possible, which means simply letting the ecosystem restore itself. A benefit of restoration is that it reduces the cost of future restoration.

Brazil has appropriately outlawed continued deforestation of the Atlantic Forest, and has mandated that 20 % of all land be kept forested. As occurs in the Amazon, the laws are poorly enforced. Active restoration is almost certainly required to conserve the system and the services it provides. In this case, all beneficiaries of the services an ecosystem provides should contribute to its restoration. Rather than attempting to estimate marginal values of ecosystem services, it becomes far more valuable to identify the direction in which they flow, and hence the beneficiaries who should contribute to their conservation.

It is likely that the costs of restoring the Atlantic Forest prove greater than Brazil is willing to bear. However, in a globally interconnected ecosystem many of the benefits of restoration will be global. Since we do not know what will happen to the Atlantic Forest if it is not restored, we can only speculate on the costs to other countries. More intelligent empirical estimates of costs of international funding area possible as measured by the impacts on the well-being of donors. Taking the United States as an example, we know from government records that per capita GNP in 1969 was less than 1/2 of what it is today (BUREAU OF ECONOMIC ANALYSIS, 2008) and poverty rates were lower (US CENSUS BUREAU, 2007). We also know that subjective assessments of happiness (LANE, 2000) and an alternative measure of economic welfare – the genuine progress indicator (TALBERTH et al., 2007) – were higher. While it is hard to estimate the benefits to the US from dedicating 1/2 of its national income to restoring critical natural capital around the world, we have solid empirical evidence that the costs, as measured in quality of life, would be negligible.

Adjusting national accounts

Another widespread use of environmental evaluation is to adjust national accounts. As currently measured, Gross National Product (GNP), among its other flaws fails to account for the loss of ecosystem goods and services. There are two potential ways to correct this problem. First, one could deduct the value of ecosystem services lost or destroyed in a given year from GNP, leading to a smaller annual estimate. Alternatively, it would be possible to measure the contributions of non-marketed environmental resources to GNP. In one way, the latter approach makes more sense, as GNP is intended to measure the annual flow of benefits generated by the economy. If an ecosystem being valued is in region I, it probably does not matter too much which approach we take, as long as we are consistent. However, if we are in region II, the approach we make matters a great deal.

The fact is that GNP has a fundamental theoretical flaw. It measures the total contribution of a good or service to the economy by multiplying marginal value by total quantity. While this does measure how much money was spent on a service, it does not measure the total value of the resource in question. Failure to pay attention to this basic point led Nobel laureate in Economics, Thomas Schelling, to state that losing 1/3 of agricultural production as a result of global climate change will have negligible impact on the US economy, as it only accounts for 3 % of GNP (SCHELLING, 2007). The fact is that demand for food is inelastic, and when food production declines, its price increases dramatically. A small decline in agricultural output along with a shift to biofuel production were driving forces behind the recent 80 % increase in global food prices (Erlanger, 2008). Less food obviously contributes less to our total well-being than more food, and fewer ecosystem services obviously contribute less to our well-being than more, yet when measured as price times quantity, the total monetary value increases as quantity decreases! It would therefore make no sense to add the value of ecosystem services flows to GNP. Instead, if we are to use valuation to adjust national accounts, we must subtract from GNP the marginal value of the service in question multiplied by the quantity of service lost. If we increase flows of ecosystem services, we can add the marginal value times the quantity added.

Costanza et al. (1997) estimated the total value of global ecosystem services by multiplying the marginal monetary value of services generated by a given ecosystem by the total quantity of the ecosystem, then summing across ecosystems. This study has been widely criticized, but the fact is that its authors were attempting to compare non-marketed environmental goods and services with gross world product, in which case it was appropriate for them to use the same methodology as GNP. One important reason Costanza et al. (1997) conducted this study was to call attention to the importance of nature's goods and services, arguably an entirely appropriate use of valuation, and in this endeavor they were very successful.

Summary and Conclusions

In summary, monetary valuation of non-market goods and services has been offered by many economists as an efficient solution to the macroallocation problem. Efficiency in this case has the narrow definition of the maximization of monetary value given initial distributions of wealth and income.

Valuation may be appropriate when natural capital stocks are abundant, and safely distant from critical thresholds beyond which they enter into spontaneous decline or are no longer able to provide vital life support functions. Even in this situation, we must recognize several serious problems. Valuation systematically gives more weight to the preferences of the wealthy, it is limited by our ignorance of ecosystem functions and the impacts of human activities on them, and it may not be possible to measure all types of value in the same units. In addition, when applied to non-rival resources, the rationing function of price creates artificial scarcity.

In today's world however, increasingly few ecosystems are safely above critical thresholds. When there is any threat we are nearing critical thresholds, sustainability takes precedence over efficiency. We should dedicate our efforts to identifying critical natural capital, then implement polices to ensure its protection, leaving a healthy buffer to account for our profound uncertainty and our ethical obligations to future generations. Prices can adjust to ecological constraints much better than ecosystems can adjust to economic factors. Herman Daly summarized this point best when he stated that scale (defined as the size of the economic system relative to the ecosystem that sustains and contains it) should be price determining, not price determined.

If research reveals that we may have already encroached upon critical natural capital, sustainability requires restoration to a point safely beyond critical thresholds. In this case, economists should focus on estimating supply curves, so that we can achieve our restoration goals as cost effectively as possible.

Distribution issues are also important. Those who benefit the most from ecosystem services and those responsible for threats to critical natural capital should finance restoration and conservation. It may therefore be more important to understand the spatial distribution of ecosystem services and the sources of harm to the ecosystems that generate them than to estimate their marginal values.

In spite of the proliferation of valuation studies, and the growing number of decision makers who request the results of such studies, there may be few circumstances in which monetary valuation of ecosystem services is scientifically appropriate. But valuation studies only matter in any practical sense when they influence on the ground decisions. Even when valuation studies have dubious economic and scientific validity, however, they may serve to attract the attention of decision makers and the public, and lead to positive change. For policy and decision-makers, hard science is often less influential than good storytelling (STONE, 2002), and monetary valuation can help tell an important story about environmental values.

References

BROMLEY, D. Entitlements, missing markets, and environmental uncertainty. **Journal of Environmental Economics and Management,** San Diego, v. 17, n. 2, p. 181-194, 1989.

BRUIJNZEEL, L. A. Hydrology of tropical montane cloud forests: a re-evaluation. In: INTERNATIONAL COLLOQUIUM ON HYDROLOGY OF THE HUMID TROPICS, 2th., Panama City. **Proceedings...** Panama City: ATHALAC, 2000.

BUREAU OF ECONOMIC ANALYSIS. **National income and product accounts table 7.1**: selected per capita product and income series in current and chained dollars. Washington, DC., 2008.

CONSERVATION INTERNATIONAL. **Ecosystem profile**: atlantic forest. 11 Dec. 2001. Available in: < http://www.cepf.net/xp/cepf/where_ we_work/atlantic_forest/ full_strategy.xml> . Aceess in: 5 Nov. 2007.

COSTA, L. P.; LEITE, Y. L. R.; MENDES, S. L.; DITCHFIELD, A. D. **Mammal Conservation in Brazil**, v. 19, n. 3, p. 672-679, 2005.

COSTANZA, R.; D'ARGE, R.; GROOT, R. D.; FARBER, S.; GRASSO, M.; HANNON, B. The value of the world's ecosystem services and natural capital. **Nature**, London, n. 387, 253-260, 1997.

EHUI, S. K.; HERTEL, T. W. Deforestation and agricultural productivity in the Côte d'Ivoire**. American Journal of Agricultural Economics**, Ames, v. 71, n. 3, p. 703-711, 1989.

EKINS, P.; FOLKE, C.; DE GROOT, R. Identifying critical natural capital. **Ecological Economics**, Amsterdam, v. 44, n. 2-3, p. 159-163, 2003.

FARBER, S. C.; COSTANZA, R.; WILSON, M. A. Economic and ecological concepts for valuing ecosystem services. **Ecological Economics**, Amsterdam, v. 41, n. 3, p. 375-392, 2002.

FARLEY, J.; ERICKSON, J.; DALY, H. **Ecological Economics**: a workbook in problem based learning. Washington, DC: Island Press, 2005.

FOLKE, C. Resilience: the emergence of a perspective for social-ecological systems analyses. **Global Environmental Change:** human and policy dimensions, v. 16, n. 3, p. 253-267, 2006.

FREEMAN III, A. M. **The measurement of environmental and resource values:** theory and methods. Washington, DC: Resources for the Future, 1993.

GOMBE, S. Epidemic, What Epidemic? **New Internationalist Magazine**, Farmington Hills, 2003.

GOWDY, J. The value of biodiversity: markets, society and ecosystems. **Land Economics**, Madison, v. 73, p. 25-41, 1997.

HEINBERG, R. **The party's over**: oil, war and the fate of industrial societies. Gabriola Island, British Columbia: New Society Publishers, 2003.

KOPP, R. J.; SMITH, V. K. (Ed.). **Valuing natural assets**: the economics of natural resource damage assessment. Washington, DC: Resources for the Future, 2003.

LANE, R. **The loss of happiness in market economies**. New Haven: Yale University Press, 2000.

LIMBURG, K. E.; O'NEILL, R. V.; COSTANZA, R.; FARBER, S. Complex systems and valuation. **Ecological Economics**, New York, v. 41, n. 3, p. 409-420, 2002.

MACARTHUR, R. H.; WILSON, E. O. **Island Biogeography**. New Jersey: Princeton University Press, 2001.

MARTINEZ-ALIER, J.; MUNDA, G.; O'NEILL, J. Weak comparability of values as a foundation for ecological economics. **Ecological Economics**, New York, v. 26, n. 3, p. 277-286, 1998.

MILLENNIUM Ecosystem Assessment. **Ecosystems and human well-being**: synthesis. Washington, DC: Island Press, 2005.

NEPSTAD, D.; TOHVER, I. M.; RAY, D.; MOUTINHO, P.; CARDINOT, G. Mortality of Large Trees and Lianas Following Experimental Drought in an Amazon Forest. **Ecology**, v. 88, n. 9, p. 2259–2269, 2007.

PANAYATOU, T.; SUNGSUWAN, S. An Econometric Study of the Causes of Tropical Deforestation: The Case of Northeast Thailand. In: BROWN, K.; PEARCE, D. (Ed.). **The causes of tropical deforestation**: the economic and statistical analysis of factors giving rise to the loss of the tropical forests. London: UCL Press,1994.

SALATI, E. The forest and the hydrological cycle. In: DICKINSON, R. (Ed.). **The geophysiology of amazonia**: vegetation and climate interactions. New York: John Wiley and Sons, 1997.

SALATI, E.; VOSE, P. B. Amazon basin: a system in equilibrium**. Science**, New York, v. 225, n. 4658, p. 129-138, 1984.

SCHELLING, T. C. **Greenhouse effect**. Available in: <http://www.econlib.org/library/Enc/GreenhouseEffect.html.>. Aceess in: 2 Nov. 2007

SMITH, A. **An inquiry into the nature and causes of the wealth of nations.** 1. ed. Oxford: Clarendon Press, 1776.

STONE, D. **Policy paradox**: the art of political decision making. New York: WW Norton, 2002.

TABARELLI, M.; PERES, C. A. Abiotic and vertebrate seed dispersal in the Brazilian Atlantic forest: implications for forest regeneration. **Biological Conservation**, Essex, v. 106, n. 2, p. 165-176, 2002.

TABARELLI, M.; PINTO, L. P.; SILVA, J. M. C.; HIROTA, M.; BEDE, L. Challenges and Opportunities for Biodiversity Conservation in the Brazilian Atlantic Forest. **Conservation Biology**, Cambridge, v. 19, n. 3, p. 695-700, 2005.

TALBERTH, J.; COBB, C.; SLATTERY, N. **The genuine progress indicator 2006**: a tool for sustainable development. Oakland, CA: Redefining Progress, 2007.

UNEP. **2006 Antarctic ozone hole largest on record**. New York: United Nations Environment Program, 2006.

US CENSUS BUREAU. **Historical poverty tables**. Available in: < http://www.census.gov/hhes/www/poverty/histpov/hstpov2.html>. Aceess in: 2 Nov. 2007

VATN, A.; BROMLEY, D. W. Choices without prices without apologies. **Journal of Environmental Economics and Management**, New York, v. 26, p. 129-148, 1994.

WORLD HEALTH ORGANIZATIONS. (WHO). **African trypanosomiasis**. Available in: < http://www.who.int/topics/trypanosomiasis_african/en/>. Aceess in: 2006.

WTRG Economics. **Oil Price History and Analysis**. Available in:< http://www.wtrg.com/prices.htm>. Aceess in: 2 Nov. 2007.