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Author(s): Geoffrey Heal

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Valuing Ecosystem Services

Geoffrey Heal

Columbia Business School, Columbia University, 116th Street and Broadway, New York, New York 10027, USA

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The services of natural ecosystems are clearly very important to our societies: we probably could not live without them. (For a review of the importance of ecosystem services, see Daily 1997.) Does this importance translate into economic value? Are these services very valuable in an economic sense? Intuitively it may seem that the answer must be yes. In fact, the matter is not so simple as our intuition suggests. Economics is more concerned with *prices* than with *values* or *importance*. To delve into these issues, we need to begin with a discussion of exactly what prices are and what they reflect. For a start, we need to be clear that the price of a good does not reflect its importance in any overall social or philosophical sense. Very unimportant goods can be valued more highly by the market than—have higher prices than—very important goods. The classic illustration of this is the diamonds and water paradox, which perplexed economists through the 18th and 19th centuries until its resolution by Alfred Marshall. The point here is that water is clearly more important to human society than diamonds, yet diamonds trade in the market at prices far in excess of those fetched by water. Why? Marshall's answer was simple and is by now part of common knowledge: price is set by supply and demand. The market price is the price at which the amount supplied is also the amount demanded. In the case of water, the supply (at least in Marshall's time) was so large as to exceed the amount that could possibly be demanded at any price. Consequently the price was zero; water was free. Now, of course, the demand for water has increased greatly as a result of population growth and rising prosperity, while the supply has remained roughly constant, so that water is no longer free. In the case of diamonds, because they are naturally scarce, the desire for ownership always exceeded that which

could be accommodated naturally. The market price was consequently high as a result of competition between rich people for the few diamonds available.

So, in summary, we should not expect that the fact that something is important will ensure that its price is high. If like water in 19th century England it is naturally abundant, then this will keep down its price. Food in industrial countries is another good example of this point. Agricultural systems are sufficiently productive that the needs of the populations of the industrial countries can easily be met, and consequently food prices are not high. Indeed, the problem with food in the more advanced countries recently has been too much rather than too little production with farmers complaining about prices being too low. But food is nevertheless essential to life.

For both water and food, it is likely that if the amounts available were to decrease, then their prices would rise a great deal. If there really were not enough food to go around in the industrial countries, we would all be willing to spend a large fraction of our incomes to try to get enough for our families, in which case there would be a lot of money chasing relatively little food, and prices would be very different. The same is true of water. So the present prices reflect present supply conditions. They tell us nothing about how things would be if much less were available. David Ricardo, a famous 19th century British economist, put this nicely. His comment was that

The labour of nature is paid, not because she does much, but because she does little. In proportion as she becomes niggardly in her gifts, she exacts a greater price for her work. Where she is munificently beneficent, she always works gratis (Ricardo 1817).

Of course in many developing countries food is not abundant; there are great food shortages. How is this compatible with low food prices? Because the populations of these countries cannot afford to

compete for food on world markets. Markets are institutions where, as a famous economist once put it, you vote with your dollars. The populations of developing countries, having few dollars, are disenfranchised in this vote.

This leads naturally to another important aspect of prices: they reflect the distribution of income, the existing social order. To continue with the same example, if the people of Asia and Africa were much richer, they would compete with you and me for the world's food output, and consequently food prices would probably be higher. Going back to diamonds, in a world without very rich people the prices of luxury goods such as diamonds would be a lot lower. The reason of course is that the distribution of income affects the demands for many goods and therefore their prices. In general, an increase in the income level of a group will increase the demand for goods that they like and so increase the prices of these goods.

What, then, does the market price of a good reflect? It reflects what the good is worth to what we call the "marginal buyer." The marginal buyer is the buyer who is on the verge of not buying the good, the buyer who would drop out if the price were to rise only a small amount. There typically will be many people buying a good for whom that good is worth more than they actually pay: the difference between the price that they pay and what they would be willing to pay is called their "consumer surplus." These people do not determine the market price: it is the buyers who might drop out of the market who do this. An analogy can be made with swing voters who determine an election outcome. The market price of a good does not tell us how important that good is to society, nor how much some of the people buying it might be willing and able to pay rather than go without. It tells us what it is worth to the "swing buyer," what economists call the marginal buyer.

In spite of these qualifications, the market price of a good is a very important and informative number. It tells us how much society would gain if a little more of the good were made available. Why? Because a small increase in the supply would not change the price much: the new buyers therefore would be people who valued the good at about the present price. If they valued it at more than the present price they would already be buyers: if they valued it a lot less, then a small drop in price would not bring them in. In other words, if a bit more of a good were available to society, then in a market economy the extra would sell at the current market price and be consumed by people who value it at that price. Accepting the premise that the value of

the good to society is the value to those of its members benefiting from the good, this sets its social value at the market price. This of course rests on a utilitarian political philosophy. It sees the good of society as the totality of the well-being of its members. Society has no goals or values not reflected in those of its members. (For the more technically inclined, the price of a good is the partial derivative of social welfare with respect to the availability of that good. In the maximization of social welfare subject to constraints, it is the Lagrange multiplier associated with the constraint posed by the availability of the good.)

To go back to water and Marshall, if more water had been made available to the United Kingdom in the 19th century, there would have been no gain to society. Society already had enough. So extra water was of no value. Of course this does not mean that society could have survived the loss of a large part of its water supply. But if the water supply had been a lot less, then the price would not have been zero, and the market would have indicated a positive value for water.

A key aspect of this interpretation is that price tells us about the value of having a little more (or less) of a good. It does not tell us anything about the importance of having a lot more or a lot less. So the prices of water and food tell us about the values of having a little more or less of each, but emphatically not about the values of having a lot less. Why this focus on small changes, on what economists call marginal changes? The answer is that these are generally the kinds of changes that are under consideration when individuals or policy makers are making decisions. The decision made by a farmer in his crop planning will not have a big effect on the supply of food. His decision is typically whether to increase the output of one crop a little by cutting back on another. He is considering trade-offs between different crops and their impact on his earnings. For these decisions, which affect the availability to society only a small amount, prices convey the right information. They indicate the social values of small changes in the availability of goods. If farmers and firm managers use these as guides in choosing what to produce, then they will be aligning their choices with what is socially desirable.

Now we can return to the issue of valuation. If there are market prices for the services provided by natural ecosystems, then these prices provide an obvious basis for valuing them. So we could value the carbon sequestration services of forests or the water purification services of watersheds by using market prices for these. We also could place some value on their biodiversity support roles by looking

at the market prices of ecotourism and of bio-prospecting. From these numbers, we could try to compute values for the forest as a whole or for the watershed as a whole. Typically we value the asset that provides a flow of services at the present discounted value of the flow of services that it will provide in the future. Corporations, for example, usually are valued for acquisition or investment purposes at the present discounted value of their estimated future earnings. The present discounted value of the future services is a number computed by adding together the values of all of the future services that will ever be provided, after scaling down the values of the future services by numbers called discount factors. Discount factors allow for the fact that investments can earn interest. At 5%, 100 dollars set aside today will be worth 105 a year hence. Consequently, we can say that 105 dollars a year ahead has a present value of one hundred dollars and in present value calculations scale it down by a discount factor of 100/105. (For a review of the issues raised by discounting see Heal 1998a.) So we could on this principle value a watershed at the present discounted value of the flow of watershed services that it will provide in the future. We could likewise value a forest as the present discounted value of its carbon sequestration and biodiversity support services and its recreational services. Note, of course, that such valuations are likely to be incomplete. There are usually services provided by natural ecosystems for which there are no markets and so no market prices. These therefore will be omitted from the calculations. At best therefore we will compute lower bounds for the values of these natural systems. However, even these lower bounds can be strikingly high, high enough to generate action for conservation.

There are methods for attributing prices to services for which there is no market price. By using them, some of this omission may be eliminated. In fact, there are several quite ingenious ways of doing this. Perhaps the most convincing is the use of hedonic price indices. This is best explained by an example. Suppose we want to value the fertility of soil. Soil fertility is not a good that is bought and sold in a market, so we cannot just look up the price. However, farms are bought and sold, and we could collect data on farm prices, calculate the prices per hectare of the farmland, and then also collect data on the quality of the soil for these farms. Next we would correlate the land price per hectare with the quality of the soil to see how much the fertility of the soil adds to the price of the land. So indirectly we have estimated a price for soil fertility. We have found what it adds to the market price of land.

Securities analysts carry out the same type of analysis daily when they ask how the volatility of a stock's earnings affects its market price. There is no market for volatility directly, so they look for comparable stocks with different records of earnings volatility and then attribute the difference to the volatility differences. Indirectly they are placing a market value on volatility. The same techniques are used to place a value on intangibles such as a view. What is the value of a beautiful view? To answer this, find two comparable houses, one with and one without views, and compare their prices. The difference reflects the value of the view in the marketplace.

In all of these examples, I have oversimplified to make the point clear. In practice one would rarely find two houses identical except for the view that you want to value. In this case, we do the same thing but by a more roundabout route. We will relate the prices of many houses to the attributes of those houses, including size, view, quality, neighborhood, and other variables. We will use statistical techniques that will tell us how much of the variation in house prices is due to the variation in each of the characteristics. From these we will separate out the part of the variation in prices that is due to differences in views. Indirectly, we put a price on the view. The same holds true for analysis of stock prices and farm prices. There is a general principle at work here. The price of a good reflects the valuations people place on all of its characteristics: in the case of a house, these will include size, location, quality, views, and many more. An important area of economic research is the study of how each of these characteristics contributes to the value that consumers place on the overall package. These techniques sometimes allow us to value properties for which there is no market. However, for this approach to work, there has to be a product for which there is a market and in which the characteristic at issue is embedded. So if we want to use this as a way of valuing nonmarketed ecosystem services, then we can only apply it to cases in which these contribute directly to something that is marketed. (For more details, see Rosen 1974.)

Another possibility, perhaps less general, is the use of replacement costs as a way of valuing a natural service. This can work even if there is no marketed service to which the natural service contributes. Again, the best way to start is with an example. Consider the case of New York's decision to preserve the Catskills watershed. In that case, the city had an alternative to restoring the watershed: replacing it with a filtration plant. (see Chichilnisky and Heal 1998 for details) This would have cost about \$6 to \$8 billion, plus operating costs and

eventually replacement costs. Call the total \$9 billion for simplicity. Can we say that because the cost of replacing the watershed would have been \$9 billion, this is its value? Certainly this is a tempting strategy.

There are pros and cons to this approach to valuation. Note that as in the cases in which there are markets for some of the services of an ecosystem, we can reach at best a partial valuation of the watershed via this route. The point is that that the filtration plant replaces only a small part of what a watershed does. A filtration plant does not sequester carbon or support biodiversity or provide recreational opportunities. It does not even purify water as well as a natural watershed. So at best, we again could reach a partial, a lower bound estimate of the value of the services of the ecosystem.

In this case, there is another argument that goes in the opposite direction. We will not always choose to replace something that is defective: the cost of replacement could be too high. In the New York watershed case, nonreplacement was not an option: the city needs drinking water. Suppose instead that the Catskills had just been providing recreational services to the city, and that the replacement of these services was at issue. And suppose that this replacement would cost several billions of dollars. In all probability the city would have decided not to replace the recreational services of the Catskills; it would have decided that at the cost of several billions these were a luxury that they could do without. In this case the replacement cost would not be a proper indicator of the value of the service. Replacement cost can only be a good indicator if it is a cost that will be incurred if a replacement is needed. The same principle operates in many other contexts: we often decide not to replace something that is lost or broken because it is not worth the cost. Again in the case of a watershed supplying a critical life-support service, nonreplacement is not a possibility. However, even in the New York case we cannot legitimately say that the value of the watershed is \$9 billion, because in fact the city never chose to pay this amount: it restored the watershed at a much lower cost of between \$1 and \$2 billion. We can say that the city saved \$9 billion by environmental conservation; that is clear. Perhaps we can even say that environmental conservation enriched the city by \$9 billion minus \$1.5 billion, the cost of watershed restoration. This is a net enrichment of \$7.5 billion. But this is not the same as placing a value on the watershed; it is valuing the consequences of a conservation policy.

In summary, assessing the replacement cost is not a convincing way of valuing natural ecosystems and

the services that they provide. Replacements rarely replace all of the services coming from the original system, so that this could capture only a part of the value. But more fundamentally the replacement cost is not a proper estimate of the value unless this cost is incurred. There will be cases in which this does not happen: these are cases in which the replacement will be too expensive to make sense. Replacement costs are certainly interesting, indeed essential, information in the context of evaluating conservation policies, particularly for essential services for which a replacement would surely be needed were the original system to fail. The replacement cost is a benchmark that the decision makers have to keep in mind as they evaluate conservation and restoration options. But, again, this does not make it a good estimate of the economic value of a system or service. To clinch this point, let me take one more example, oil. Oil is close to essential to industrial economies. If all oil were to vanish tomorrow, it could (with difficulty) be replaced. We could, for example, extract oil from coal by complex industrial processes, at a cost of about \$40–\$50 per barrel (a barrel is 42 US gallons). Or we could extract it from shale or from tar sands, at similar prices. Currently the price of oil is approximately \$18 per barrel. Since its replacement cost is at least \$40 per barrel, does this mean that its value is \$40 per barrel? Clearly not: its value is its market price. Currently, the supply is abundant, and there is no prospect of having to pay the replacement cost. However if the supply were to start running out, then the market price would rise towards the replacement cost, which would become more relevant as an indicator of value.

I will mention briefly another approach to valuing environmental services that are not marketed. This is the travel cost method (see Clawson 1959 for details). The idea is to estimate how much people value an environmental asset by seeing what costs they will incur to visit it. It typically has been applied in the cases of national parks and ecotourism facilities. The basic idea is simple: if I am willing to incur costs of say \$500 to visit a forest and spend time there, then being there must provide me with benefits that I value at least this much. It must be worth at least \$500 to me. We can think of the access costs as a price that people pay to get to the forest. Across all visitors there will be many different access costs, so that different people are in effect paying different prices for access to the forest. Some may live locally and incur costs of only a few dollars: others may live far away and have to travel for hours at great expense to get there. If there are many different implied prices, then which do we

use to value the facility? Which can act like a market price? Recall that the market price tells us the value of having a little more or less of a good. In fact, there is no exact equivalent of this for a park: a park is a public good, and there generally will not be a single price that represents its social value. In such cases, we have to add up the values attributed to it by all of its users and take this sum as the valuation of the services that it provides. So the sum of the travel costs incurred to visit it would be the natural indicator of the value of providing slightly more of the services of the park.

Market prices, hedonic prices, travel costs and replacement costs as methods of valuing the services of natural systems have an important feature in common: they are based on actual transactions. Hedonic prices are derived from market prices. Travel costs reflect real transactions. And replacement costs, used properly, reflect a cost that will be incurred in the case of a need for replacement. The remaining method of valuation, used when none of these is possible, is called contingent valuation. It is a survey method. In essence it involves asking a carefully structured sample of people what value they place on a natural asset and then using this data to extrapolate to the population as a whole. The questions posed have to be carefully designed for the answers to have any validity. With this caveat, such methods have been widely used for estimating the value of loss of natural amenities, particularly in high-profile lawsuits such as the Exxon Valdez case. I think it is fair to say that most economists feel more comfortable with valuations based on actual transactions rather than those given in response to hypothetical questions, however carefully constructed. Intuitively there seems to be a big difference between completing a questionnaire on what you would be willing to pay for something, and actually paying for it. In spite of such reservations, this approach has given quite good predictions of what people might pay in the occasions when it has been possible to compare contingent valuation estimates of what people might pay with what they have paid subsequently for the same service. (For a detailed exposition see Mitchell and Carson 1989.)

In summary, economists ideally would like to value ecosystem services by attaching market prices to them, or by deriving prices for them from market transactions. There are relatively few cases in which this can be done. But even when this is possible, the market-based valuations resulting need not reflect the social importance of the services or the extent of the losses that we would suffer if these services were removed. The market-based prices tell us the value

to society of a small amount more or less of a service and do not indicate the overall contribution of the service. Operationally, this is usually fine because it is usually small changes in availability that are at issue.

Unfortunately some of the human impacts on important ecosystems are far from small. Overfishing is radically changing marine food chains. Nitrogen fertilizers have already more than doubled natural nitrogen concentrations. We have increased significantly atmospheric concentrations of carbon dioxide and other greenhouse gases. We are driving species extinct at perhaps 1000 times the natural rate. (For a review of these issues, see Arrow and others 1995; Vitousek and others 1997; Lubchenco 1998.) In such cases, market prices even if they exist will seriously underestimate the economic value lost by this destruction. Why will market prices give an underestimate? Because typically the price of a good or service rises as it becomes scarcer. This is particularly true of goods and services that are essential to human welfare, such as food, water, and clean air. As I noted above, if food or water were scarce in the rich countries, then most of us would spend a significant fraction of our incomes assuring adequate supplies for our families. In such a world, prices of food, water, and access to clean air would rise dramatically, and the prices of other goods would fall as there was less left to spend on them.

Are there any economic measures that would capture better the impact of the loss of a significant amount of a natural life-support system? For example, can we talk sensibly of the value of preserving the climate system intact, or of the value of preserving biodiversity? There are in principle ways of doing this, and recently there have been attempts to apply them and assess the economic value of the biosphere in a comprehensive way. However, we should note immediately some limitations here. It will never make sense to ask about the value that we would lose if an entire and irreplaceable life-support system were to be lost. The point is that if it is indeed a life-support system then its loss would lead to the end of all human life, and to put an economic value on that would seem foolish and inappropriate. (The numbers resulting from a recent attempt to do just this were described by one economist as "a serious underestimate of infinity.")

Could we value instead the loss of a significant part, but not all, of a life-support system? In principle we might be able to do this, but it is very difficult. Take a concrete case, water. Suppose we are concerned to assess the economic costs of a change in the hydrological cycle that would result from a change in the climate system. Assume that

this would reduce substantially but not eliminate water supplies to large regions of the earth. Could we value this change by economic techniques? We would have to know how much the price of water would rise as its supply falls, that is, in economic terms we would have to know the demand curve for water. This is not easy: as the price of water rose due to scarcity, many other things would change: food production, food prices, income levels, and many other economic variables would all change as the price of water rose in response to a sharp drop in availability. All of these other variables would affect the demand for water, so that estimating how its price would move along a trajectory of declining supply would be immensely difficult. To date, there have been no convincing studies of the economic value of preventing the loss of significant parts of any global life-support systems, although in principle we know how to do this.

The conclusion that emerges from this analysis is that economics probably cannot really value the services of the earth's life-support systems in any way other than by using market prices, which value them in the sense of indicating the value of a small change in their availability. We should not be disappointed with this limited ability to value ecosystem services. If our concern is to conserve these services, then valuation is largely irrelevant. Let me emphasize this: *Valuation is neither necessary nor sufficient for conservation. We conserve much that we do not value, and do not conserve much that we value.*

What then is the economic prerequisite for conservation? It lies in incentives: to conserve systems we must give their owners incentives to conserve them. We must make conservation more attractive than any other uses. Conserving forests must be more attractive than clearing them to plant coffee or bananas or cocoa beans. To do this, we have to translate some of the social importance of ecosystem services into income and ensure that this income accrues to the owners of the ecosystems as a reward for their conservation. This is the key theme, the single most important theme, in the conservation of the ecosystems that support human societies. Providing the right incentives is not the same as valuing the services: we can provide the incentives without valuing the services, and we can value the services without providing incentives for conserving them. In fact, valuation may sometimes be a by-product of providing the incentives. If we manage to establish a market in an ecosystem service, then we have a price for it and thus a basis for valuing it. And markets are probably the best ways of providing conservation incentives. So logically incentives come before valuation: *Incentives are critical for conservation;*

valuation is not necessary for establishing the correct incentives.

To give a concrete example, suppose that when implemented the Kyoto Protocol contains a provision under which owners of tropical forests can be paid for the carbon sequestration services that they provide. Then this will greatly increase the economic returns to forestation and to the preservation of existing forests. I have argued elsewhere (Heal 1998b) that it could lead to payments as high as \$100–\$150 per hectare per year, considerably in excess of the earning potential of land from which tropical rainforests have been cleared. Such a provision would generate strong incentives for the preservation of tropical forests and would radically change the economics of forestry. It would be a major step towards ensuring the preservation of forest ecosystems. The key step would be the provision of incentives, not valuation of services. In this case, valuation would be a by-product: the market price for carbon sequestration would allow us to calculate a lower bound on the values of forests by computing the present value of their carbon sequestration earnings. In the same vein, suppose that owners of forests were paid for their services as watersheds. These, like carbon sequestration, have great social importance and provide a product, water, for which people are increasingly willing to pay. For the forests that play this role, the economics of conservation versus clear-cutting would be changed radically in favor of the former. We would have established a powerful incentive for conservation without valuation, although again the potential to value partially would arise as a result of the provision of incentives. There is one exception to this general statements that valuation is neither necessary nor sufficient for conservation: this occurs in the context of cost-benefit analysis of conservation decisions that are being made via the political process, rather than through economic institutions such as markets. A cost-benefit analysis requires the enumeration and evaluation of the benefits from conserving a natural ecosystem and in this process placing values on the services provided by the system is a necessary step. It is important to remember always that the values that result are likely to be underestimates of the total value provided to society by the system under review.

To conclude, the emphasis on valuing ecosystems and their services is probably misplaced. Economics cannot estimate the importance of natural environments to society: only biology can do that. The role of economics is to help design institutions that will provide incentives for the conservation of important

natural systems and will mediate human impacts on the biosphere so that these are sustainable.

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