Valuing Ecosystem Services

by David A. Starrett

Abstract:

We develop the economist’s concept of value as opportunity cost and discuss the ways in which decisions imply values through revealed preference. We distinguish between the ideas of incremental and total value and argue that only the former is of importance in practical decision-making. The relationship between price and value is articulated and related to the distinction between public and private goods. Finally, we enumerate the various ways economists use to determine the value of ecosystem services—these include use of prices, methods of revealed preference, voting schemes and contingent valuation.

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In discussing economic valuation, one first needs to be clear on what the “value” is supposed to measure. It is possible to think of value in philosophical terms as the “intrinsic worth” of an object, which need not be related to its worth in an economic context. However, here I will restrict to discussion of measures that an economist could justify as relevant in making economic decisions. That is, value will be equated with the economist’s concept of “opportunity cost”—the value of the foregone alternative. For example in assessing the value of clean air, we will want to measure the amount of other resources society would be willing to devote to improving the quality of air (or preventing its degradation). Or in calculating the value of pollination services we would need to know how many resources would be enough to compensate for their loss.

Clearly in order to get a single measure of value in these circumstances, we need a way to aggregate the compensating resources and a precise statement as to how much air quality and pollination is “at risk.” In this paper, we will discuss ways of assessing these kinds of values. We begin with a general discussion of valuation from an economist’s perspective and later turn to specific issues that arise in connection with valuing ecosystem services.

I Objectives, values and tradeoffs

The central problem in economics is one of allocating scarce resources and the presumption is that our objective is to get the greatest possible “social benefit” from these resources. Most people would not criticize the economists’ agenda as just stated. Getting the most from what you have to work with seems like a worthwhile objective. Controversy comes from trying to get specific about the concept of social benefit. For example, if social benefit is equated with gross national product, then the objective becomes quite materialistic and can be criticized on many grounds. Economists frequently are identified with this materialistic view in the popular press, but this criticism is quite unfair. Our discipline has spent considerable time and effort identifying and trying to measure other factors that enter into social benefit. These include such diverse items as: the quality of life, clean air and water, sense of security, life expectancy, availability of parks and biological diversity. And as we will explain below, an economist’s concept of valuation for an item is, roughly speaking, its contribution to social benefit.

A. Necessity of tradeoffs
What does distinguish economists from others who think about social objectives is that we find it necessary to aggregate all these diverse items into a single measure. Put another way, we find it necessary to consider tradeoffs among these items and assign values to them. A simple example will be used to illustrate the considerations here. Suppose we are considering a nuclear power plant that would generate net output worth $10 million, but involves the risk of killing 100,000 people with a probability judged by experts to be one in 100,000. Here the benefit would enter into GNP and we have implicitly assumed that inputs and outputs can be correctly aggregated using prices (more on this later) so that net benefit is measured in dollars. However, the accident risk is in quite different units and it is not clear how, or even if, it can be aggregated.

All would agree that the necessary comparison is difficult and some would say that we should not try to make it. The economist’s position is that we cannot duck the issue even if we want to. A decision must be made. If we go ahead with the project there is a revealed judgement that one “expected” life was worth less than $10 million whereas if we don’t, we imply the reverse judgement. Since decisions of this type must be made all the time, we must find an acceptable way to evaluate associated tradeoffs.

One possible resolution is to take the position that human life is priceless and therefore categorically more important than any finite dollar amount. If this position is taken and used to guide decisions, the nuclear project is rejected as is any project that involves a risk of death, no matter how small. This position is philosophically respectable; indeed, there is a significant literature that attempts to identify values in ways unrelated to economic analysis. We do not denigrate this discussion but would argue that it is not appropriate or helpful when making decisions of the sort just discussed.

B. Principles of economic valuation

Most economists would insist that two principles be applied in evaluating tradeoffs: 1. Consumer Sovereignty and 2. Revealed Preference. According to consumer sovereignty, the tradeoffs used in making social choices should be derived from or at least linked to the tradeoffs held by individual citizens. And according to revealed preference we should, whenever possible, infer peoples tradeoffs from choices they actually make rather than what they say they believe in hypothetical situations.

These two principles in conjunction rule out the categorical tradeoff proposed above. Everyone in society takes avoidable life-threatening chances, revealing that they put a finite dollar value on staying alive. For example, the fact that I am willing to drive to the airport on the freeway
rather than on city streets (where there would be less chance of being killed) reveals that I am willing to accept a risk of death in order to save a certain amount of time (which has finite value). I will have more to say below about the methodology of revealed preference, and as the reader will see then, it is quite imperfect and not always even helpful. However, it is the economist’s position that we have no choice but to do the best we can. The alternative is some form of paternalism whereby some “experts” decide what is best for the rest of us without regard for the latter’s preferences. Most of us find that view unacceptable.

To an economist, the problem of measuring value is the problem of determining these operational tradeoff rates. In particular, value is relative—we have no concept of absolute or intrinsic value. In assessing the value of an object, we ask what is its equivalent in terms of other resources we would be willing to give up in order to have it. The answer, sometimes referred to as opportunity cost is operational in that it can be used to determine which changes in social policy are in society’s best interests.

II Marginal Valuations

Much of microeconomic analysis focuses on marginal changes and from our viewpoint here, marginal valuations. That is, we ask how to measure the value of a change that is small relative to the size of items such as consumer income. The focus on marginal valuation has both strengths and weaknesses. The major strength is that under fairly weak assumptions (primarily that small changes in one part of the economy induce at most small changes everywhere else), these measures are additive; that is, if we assess the marginal value of clean air and pollination services separately the opportunity cost of a sufficiently small change in both can be computed approximately by adding measures. From a practical point of view this is important since it allows us to break up the overall valuation problem into simple component parts that are more easily contemplated than the overarching big picture.

However, the major weakness is that changes must be sufficiently small for the approximation to be very good and it is not always possible to be precise about the goodness of the approximation. And in any event we can be sure that many changes we may be forced to contemplate, such as a nuclear disaster or the melting of polar ice caps, are not small in the sense required. Once non-marginal changes are contemplated, the fact of one change will influence our valuation of another change, and additivity must break down. A simple example will illustrate this point. Suppose we were to ask what is the total value of atmospheric services. Since we would not survive if all these services were removed, this total must be more or less all the other resources we have. By the same token the total value of all water services is also pretty much everything.
Consequently measures cannot be additive since the total value (opportunity cost) of atmospheric and water services cannot exceed all the resources we have to pay with. The problem here is that once atmospheric services are gone, water resources no longer have value and vice versa.\(^1\)

Primarily for this reason, we would argue that focus on total economic value of ecosystem services is not very interesting—any collection of services that are indispensable to human life will give the same intuitively obvious answer. However, it is still important to know how to evaluate nonmarginal changes—changes that are not so large as to endanger our existence but are large enough to vitiate the additivity property. We will focus first on ways of measuring marginal willingness to pay and turn later to questions involving nonmarginal changes.

### A. Use of market prices

As suggested earlier, economists often use market prices as weights in determining relevant tradeoffs. For example, in computing the dollar benefits for our nuclear power project, the economist would weight hours worked by the wage rate and construction materials by the prices of steel, concrete, etc. The logic behind this choice involves an important “theorem” in economics; this theorem tells us that under certain restricted circumstances, allocation of resources through the market system is optimal. From our perspective here, there are two ways to think about this theorem. First it says that if you let markets run unchecked the resulting prices correctly reflect community preferences so the resulting allocation is “socially optimal.” Second it implies that when market goods (such as steel and concrete) are involved in publicly planned projects (such as the nuclear plant) market prices should be used for measuring marginal social valuation.

A thorough discussion of these results would take us too far afield, but we can gain some useful intuition for the second implication above by introducing a simple mathematical model of consumer behavior. It is assumed that individuals are able to aggregate in the manner discussed above and we represent the resulting preference by a utility function \(U(c_1, c_2, ..., c_n)\), where the c’s constitute a list of all items that affect a person’s well being.\(^2\) Let us suppose that the first “r” of these represent commodities that are sold through the market whereas allocation decisions for the other items are made in some other way (for example, through the political process). In choosing

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\(^1\)It is because nonadditivity was ignored that Costanza et. al. (1997) derived a number for the total value of ecosystem services that exceeded the world GNP (a proxy for total ability to pay). I would argue that their aggregate number is meaningless although the component estimates might still be useful in some contexts.

\(^2\)The units of utility are not important. All we care about are ordinal properties—higher utility numbers mean greater well being, but the absolute differences have no further significance. Utility plays roughly the same role as “fitness level” in organismal ecology.
market consumption, the individual faces a budget constraint in which the value of purchases is constrained by the value of resources. We can represent this constraint mathematically as

$$\sum_{i=1}^{r} p_i c_i \leq Y,$$

where the $p$'s represent market prices and $Y$ represents the value of all resources (labor time, property, etc.) owned by the individual. The “rational” consumer is assumed to optimize, choosing market consumption to maximize utility subject to the budget constraint. In doing so, the individual is induced to equate the relative “marginal preference” for any pair of market goods to the corresponding price ratio. To see this, we use the method of Lagrange multipliers to analyze the consumer problem. Assigning multiplier $\lambda$ to the budget constraint, the first order conditions for optimal choice take the form:

$$\frac{\partial U(c)}{\partial c_i} = \lambda p_i, \quad i = 1 \ldots r.$$ 

Here the partial derivatives measure “marginal preference” and optimal allocation of the budget requires that marginal preference be proportional to price. The intuition here is as follows: The consumer wants to maximize benefits per unit cost so he trades off at the margin benefits (partial derivatives of utility) against budget cost (price), with the Lagrange multiplier serving as a normalization to make units comparable. Dividing equation $i$ by equation $j$ yields the corresponding statement in relatives:

$$\frac{\partial U/\partial c_i}{\partial U/\partial c_j} = \frac{p_i}{p_j}.$$ 

The left side of this equation represents the relative marginal preference (called the Marginal Rate of Substitution in the economics literature).

There will be a similar incentive for firms maximizing profits to equate relative marginal profitability to the price ratio. This entails equating marginal revenue (output price) to marginal production cost (market value of incremental inputs). In the market equilibrating process, prices adjust so that the relative demands by all households are equal to the relative supplies by firms. Thus, in a market equilibrium each agent “reveals” his marginal relative preference for the goods and further, agents are induced to have a common relative preference that is equal to the equilibrium

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3We implicitly assume here that the first order conditions are sufficient for an optimum. This will be true under reasonable assumptions about the utility function.
price ratio. Consequently, the principles of consumer sovereignty and revealed preference suggest that relative prices be used as weights in public decision-making.\(^4\)

It is critically important to understand the restrictions that must be placed on economic behavior in order that this “market efficiency” proposition hold. Economists agree on the required set of assumptions but there is a wide range of disagreement as to how closely these assumptions hold in the real world. All agree that the assumptions do not hold universally--indeed if they did, all activity could be left to the market and there would be no need for public intervention in economic policy. In particular, there are no markets that fully insulate people from the consequences of a nuclear disaster. And there is a long list of commodities and services for which markets do not exist. Indeed, many of the items grouped under the heading of ecosystem services are in this category.

### B. Public goods

Economists generally assume that the decision as to whether or not a particular good or service is allocated through the market is made rationally—that is items are marketed if and only if it is relatively efficient to do so. The biggest impediment to using markets for efficient allocation involve commodities or items that have a “public” character, by which we mean that any individual’s decision to consume the item necessarily has repercussions on others. In such situations, the social benefit from individual consumption is necessarily different from the private benefit.\(^5\) As a general rule, we find that such commodities do not have markets. Examples include national defense, public safety, clean air, fish in the ocean, endangered species and the Ozone layer. All of those items have an extreme “public” character—namely they must be “consumed” jointly—they cannot be subdivided into “private” chunks. Clean air is such an item; if it is clean for one person, it is automatically clean for everyone. Fish in the ocean have a similar public character: it is not possible to assign any particular fish to any particular consumer so the fish population must be treated as a public resource. Of course, once fish are caught they can be so assigned and take on characteristics amenable to market allocation. Note that other items on the list above have this same public character.

Publicness does not entirely preclude the use of markets but does imply that if employed they will work very poorly at best. For example, suppose we try to sell community safety through the

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\(^4\)This proposition does depend in subtle ways on the concept of optimality. It is exactly true only if agents on both sides of the market are counted equally in the social accounting. We will have more to say about this when issues of equity are raised later.

\(^5\)Note that we took for granted that consumption commodities in the previous section did not have this feature since we implicitly assumed that consumption by one individual affected only his or her own utility function.
market. That is we allow citizens individually to purchase police time for patrolling the town streets. It is possible that there would be some purchases on this market but we argue that these will be lower than desirable for the overall social good; when any particular citizen purchases police time, most of the benefits go to others who will benefit equally from the police presence. Here (in contrast to the case of privately divisible goods such as bread or steel) the private benefit from purchase is much lower than the social benefit. Since market price can only reflect the private benefit, the arguments made for efficiency of markets do not hold for goods with these public characteristics. In the economics literature, the problem here is sometimes referred to as one of externalities. When one agent purchases services he confers external benefits (or costs) on others who will also be affected. He therefore has what is called a free rider incentive to undersubscribe.

C. The mixed economy and marginal willingness to pay

The simplest paradigm to use in measuring valuation is one in which we divide the list of goods and services into two mutually exclusive and exhaustive categories: those that can be optimally allocated by the market (we label these private) and those that are allocated entirely outside the market system through the political process (we label these public). Obviously market prices are to be used to reflect marginal valuations of private goods and the remaining issue in valuation is to determine the tradeoff between each public good and a private goods aggregate, the latter now being measured in dollars using the price weights. Such a measure is referred to as marginal willingness to pay.

In the next section, we discuss ways of measuring marginal willingness to pay for ecosystem goods and services in this paradigm. Later, we will address complications that arise when some goods that are marketed are nonetheless not allocated optimally by those markets.

III. Valuing Ecosystem services

The science (and art!) Of measuring economic valuation is quite complicated and generally rather imprecise. Here, we will not try to give a comprehensive treatment of the subject, but rather give a flavor of how things can be done and where the major impediments lie.

In our current paradigm, the first question to ask of a particular ecosystem service is whether or not it is allocated through the market. If yes, then its marginal willingness to pay is given by market price; if not we must look further. Some of these services are marketed, either directly or
indirectly. Agricultural land is marketed directly in most of the world and rental rates can be used in these cases. These rates should reflect different qualities of the land including, richness, resistance to erosion, nutrient balance etc, since farmers are willing to pay more for land, the more productive it is in farming. Many raw materials such as metal ores, gems, and other minerals are mined privately and traded on markets. In some cases the rental rate on mine property may be directly observable. However, when the mine owns the land, it must be inferred from the market value of the mine. Here, there are some legitimate questions as to whether some of these markets are “efficient” in the required sense, and we will address these later. At a more indirect level, pollination services are marketed. Some fraction of this effort is generated commercially by private beehives. These are in direct substitution for naturally provided services and the price earned will reflect marginal valuation that can be applied to those natural services.

There are a few other examples of this type, but a large number of ecosystem services possess the publicness qualities which force them outside markets. These would certainly include atmospheric and oceanic services, estuaries, lakes and wetlands. How are we to determine the correct marginal valuations to use for public goods? This is an old and vexing question with many proposed solutions, none of them entirely satisfactory. There is a long literature on the design of mechanisms that could provide incentives for participants to truthfully reveal preferences and thereby determine values. These typically involve the sending of messages and a schedule of monetary payments as a function of messages sent, with the understanding that the associated allocation decision will be a known function of messages and payments. The best known success story here is the “second price auction” for allocating a single item. In this scheme, people bid for the item and it is sold to the highest bidder for the second highest bid price. This mechanism is efficient in that it induces bidders to bid their true valuations and therefore guarantees that the item is sold to the person who values it most.

Unfortunately however, the class of allocation problems for which efficient mechanisms can be constructed is quite limited and generally do not include allocation of items with pure public characteristics (in particular the auction item discussed above does not have public characteristics). Most practical schemes, such as those where citizens vote on public projects together with the tax increases to pay for them fail this test, largely because they cannot overcome free rider incentives. And when such mechanisms do exist, they are generally too complicated to implement from a practical point of view.

Another possibility is to learn something about preferences for public goods from observable behavior, typically behavior on related private goods markets. For example, one can presumably learn something about the value of clean air by observing differences in rents on clean versus dirty
sites. Or one can learn about the value of job safety by observing the differences in wages between safe and risky jobs. These procedures of indirect revelation are known as hedonic methods and there is a large literature on their theoretical foundations as well as attempts at empirical implementation. Again, the areas of success are limited. The class of public items for which hedonic methods are amenable is limited and even when available, the practitioner generally faces problems of identification. For example, in the case of clean air, land rents vary across locations for many reasons other than ambient air quality (view, convenient access to shops, work, etc) and the method works only if one can identify which parts of the rent difference are due to which cause.

When all else fails, there is still the option of conducting surveys in which people are presented with a hypothetical situation involving a change in public goods and asked how much it is worth to them. Such methods have become more and more popular over time and are now grouped under the heading: contingent valuation. As long as participants believe the situation described is strictly hypothetical, they have no incentive to lie and one might hope would therefore reveal their true preference (even though they have no incentive to tell the truth either). However, experience with these methods is mixed at best. It is clear that responses are quite sensitive to the way in which questions are asked. Furthermore, research has shown that responses tend to be biased in a number of ways. Part of the difficulty with contingent valuation may be that when questions are strictly hypothetical, respondents do not think very hard about them and consequently do not give the more accurate answers they would if money were on the line. However, as we have suggested above, when money is on the line, incentives generally become distorted, so contingent valuation methods frequently are the only game in town. Much work is currently going on to design contingent valuation methods that will better elicit correct information.

IV. Implications of Market Distortions

The argument for using market prices as proxies for marginal social preference rests on a number of assumptions concerning the workings of markets. When any of these fail to hold, market price must be modified in an appropriate way. Among the various causes of market failure, the two most important for us are externalities and inequities.  

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^6^Standard treatments of “market failure” would include a discussion of monopoly power. When one firm dominates a market, it has substantial control of its output price and an incentive to raise that price above marginal social cost. Evidence suggests, however, that even if monopoly power were prevalent (debatable) the distortions in market price would be relatively small so the issue is of minor concern from our current perspective.
In any market, there is the possibility that some benefits (or costs) of the associated activity accrue to people not engaged in the activity. We saw that this happens naturally if we try to allocate public goods through a private market, but it may happen more generally. For example, when coal is burned it emits particulates that dirty the air and greenhouse gasses that may contribute to global warming. If we treated the particulates and gasses as separate commodities, they could in principle be assigned their own (negative) marginal social valuations, but this is rather difficult to do in practice for the same reasons we have difficulties in valuing pure public goods. Otherwise, the price of coal understates the true marginal social cost of use and we must add something to reflect the cost of the externality. An implication of this is that such markets ought to be regulated, for example by imposing a tax to reflect the externality cost. Unfortunately, computing the appropriate tax requires the same kind of information as in the previous section and is consequently an inexact science. When, for whatever reason, the correction is not made in the market, then market price alone is not a correct measure of marginal valuation.

Another type of externality is generated by so called existence values. An item has existence value to someone if that person gets satisfaction out of knowing that the object is there whether or not they directly take advantage of its presence. This is distinguished from use value which represents the value they get out of using the item. As an example, consider the case of a national park. I get use value out of making visits to enjoy its attributes directly and this use value potentially can be recovered and identified through entrance fees. However if I value having the park there quite apart from any use I make of it, this existence value is a public benefit (note that everyone who cares will get the benefit if we decide to have the park at all) that cannot be captured through market charges. To the extent that existence values are important we could not rely on the market alone to reveal willingness to pay.

As a third example, consider resources such as cattle and oil. One might think these could be treated like mining operations; that is we could infer the value of the grazing and extraction rights from profits made by cattle and oil companies. However, in many places this would be wrong because grazing and extraction rights are not allocated privately. For example, in open rangeland where grazing rights are not rationed, one company’s grazing generates externalities by reducing the quality of grazing for others. Consequently, land will be overgrazed and grazing rights will be undervalued at the margin (in the literature, this situation is referred to as the problem of the common). In some circumstances the same argument might be made with respect to mining rights, although these are generally more localized and therefore immune to this externality.

Another example will illustrate the controversial nature of this subtopic. Consider the provision of primary education. Some would argue that such education is a private commodity--those doing the learning get the benefits and we should allow private choice in how much and what
kind of education to purchase. In their view, a freely functioning private market would generate a price that correctly measures marginal social benefit and no government interference would be justified. The counter-argument involves externalities to some degree but is mostly driven by issues of inequality. In the market system a person’s command over resources is proportional to income which naturally leads to inequality in outcomes. If primary education were strictly left to the market, people would have correspondingly unequal access. Many would argue that there should be equality here--children should start out in life with “equal opportunity.” Consequently, they argue for public provision of primary (and even secondary) education.

The issues here are quite separate from those of efficiency raised earlier\(^7\), and the reader should see that egalitarian beliefs militate against reliance on markets generally; indeed they are at the heart of the debate about capitalism versus socialism. Since the crux of this debate involves a value judgement there is no right or wrong answer and different societies resolve the conflict between efficiency and equity goals in different ways. In the U.S. economy, a large percentage of allocation decisions are made through the market with varying degrees of regulation through taxes, standards and the like. At the same time there is a widely (but not universally) held belief that the resulting market outcome is inequitable to some degree. There is in principle a way to modify marginal valuations to account for equity considerations but it is difficult to implement and rarely done in practice.

V. Nonmarginal Changes

The methodology of marginal willingness to pay is powerful but can never be comprehensive because it can never deal effectively with large divergences from the status quo. For example, suppose we wanted to consider a policy of curtailing all energy production from nuclear and coal powered plants. What price should we use to evaluate the lost energy? There is no obvious answer since the price of energy surely would change (rise) as a consequence of the policy. Further, the policy would cause other prices (or marginal valuations) to change as well and thus have indirect effects throughout other sectors of the economy. Consequently when large changes are considered, we cannot avoid looking at the big picture.

Eliciting the necessary information for deciding on large changes therefore becomes much more difficult. Without going into detail, we indicate some of the new impediments. 1) With complete information for consumer demands as a function of price and income, it is possible to

\(^7\)The efficiency “best served” by markets is called Pareto Efficiency. An outcome is Pareto efficient if there is no way of making one person better off without making someone else worse off. This concept ignores equity considerations as it pays no attention to the relative well-being of citizens.
measure consumer willingness to pay for large changes in market variables. However, the information needed is almost never available, particularly at the individual level and the best we can do is construct crude approximations. 2) Hedonic methods can sometimes be generalized in similar ways but the identification problems are much more demanding on the data. 3) The types of questions we would have to ask in contingent valuation surveys now will involve the simultaneous change in many variables, requiring respondents to think about much more complicated hypothetical situations. 4) Nonadditivity implies that studies cannot be conducted independently without the danger of making mistakes. For example we may find that two changes are desirable separately but not jointly. This means that studies need to be done in sequence, and the correct sequence is not identifiable at the outset.

Faced with these and more daunting impediments, the best we can do is rely on certain kinds of approximations. Among the most useful of these are upper and lower bounds. For example, in assessing the costs of a nuclear disaster, we can get a lower bound by adding up the expected hospital and funeral costs from those who become sick or die, and the expected cleanup costs at the plant, at fixed prices for the services. This will surely understate the full cost, but if it already exceeded the expected net benefits of the nuclear power we would need no further information and should abandon the project. Similarly, we could use the market cost of coal as a lower bound on its true social cost, assuming only that we would be sure that all its externalities were negative. Such methods can be really powerful in helping us to accept the "really good" changes and reject the "really bad" ones. And, of course, getting those decisions right is extremely important. Unfortunately, for changes in between our current methodology is not powerful enough to give definitive answers.

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8Intuitively, each unit of the item gained (or lost) in the large change is valued at the marginal value it would have if it were the last such unit and the incremental willingness to pay (or be paid) is computed as the sum of these values. Such measures are sometimes referred to as consumer surplus or compensating variation.
REFERENCES


