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Benefit-Cost Analysis of Environmental Projects: A Plethora of Biases Understating Net Benefits

Philip E. Graves

Abstract

There are many reasons to suspect that benefit-cost analysis applied to environmental policies will result in policy decisions that will reject those environmental policies. The important question, of course, is whether those rejections are based on proper science. The present paper explores sources of bias in the methods used to evaluate environmental policy in the United States, although most of the arguments translate immediately to decision-making in other countries. There are some "big picture" considerations that have gone unrecognized, and there are numerous more minor, yet cumulatively important, technical details that point to potentially large biases against acceptance on benefit-cost grounds of environmental policies that have true marginal benefits greater than true marginal costs, both in net present value terms. It is hoped that the issues raised here will improve future conduct of benefit-cost analyses of environmental policies.

KEYWORDS: benefit-cost analysis, environmental policy, decision making, choice behavior, public goods, willingness-to-pay, willingness-to-accept, precautionary principle, hedonic methods, sum of specific damages, health effects model, environmental perceptions, travel cost method

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I. Introduction

After several decades of research in environmental economics, it has become increasingly apparent that the methodological techniques employed in benefit-cost analyses of environmental policies and regulations are flawed. The methods used lead to systematic bias (in the sense of "systematic error" rather than "prejudice") against acceptance of those policies. The purpose here is to bring together in one place as many arguments as possible to establish this position in order to provide grist for discussion. It is hoped that such discussion will yield improved methods for the conduct of future benefit-cost analyses in the environmental area.

The nature of the biases against adoption of environmental policies are many, ranging from a potentially serious unrecognized theoretical problem of public good valuation to specific technical details of the valuation methodologies in use. Section II briefly discusses a flaw in public good valuation generally, noting that this flaw is likely to be of particular importance in the environmental policy setting. Special interest power is seen to be concentrated *against* potential environmental policies vis-à-vis other policies (e.g., national defense) where special interest power promotes policy adoption. This section presents a "big picture" argument for a bias against environmental programs/regulations.

Section III also deals with a big picture issue. This section examines the implications of the – potentially clashing – motives that underlie marginal willingness-to-pay for environmental quality, concluding that the commonly used valuation methods of economics are generally biased towards "use values" versus "non-use values."

Section IV turns to a host of "little picture" specific methodological problems with the major environmental valuation techniques (sum of specific damages, hedonic analysis, and travel cost) that collectively reinforce the big picture flaws that result in rejection of environmental policies that have true benefits greater than costs. In Section V implications of the fact that environmental policies have both equity and efficiency implications are taken up, along with some additional concerns. Section VI concludes, arguing that the criticisms here, when considered together, provide compelling evidence that environmental benefit-cost analysis is systematically biased against environmental policies and regulations.

II. Valuing Environmental Public Goods

As discussed in extensive detail in Graves (2009), a flaw in public goods valuation has gone unrecognized for over a half-century. Early in Samuelson's (1954) well-known paper characterizing the nature of optimal public goods provision, he notes that inputs are just like outputs except for a minus sign in front of the former – we want more outputs from fewer inputs. Later in this classic contribution, Samuelson recognizes that, in practice, it will be extremely difficult to observe the true demands for public goods, because individuals have an incentive to understate their demands from their given incomes, the so-called "free rider" problem. Samuelson saw that this demand revelation problem would render decision making about proper public good provision levels very difficult.

However, not recognized explicitly in that discussion is the fact that in any situation in which there is an incentive to free ride in output markets, there will also be an incentive to free ride in *input* markets. That is,[1] as we work to acquire the goods that we desire, if a class of goods (e.g., public goods) cannot be individually incremented from work effort, then that effort will not be undertaken because leisure is valuable. Individuals *will* work to pay for whatever amount of the public good happens to be provided, but is the proper amount of the public good likely to be provided?

For some public goods, such as national defense, special interest power is likely to promote the provision of battleships, tanks, aircraft, missiles, drones and the like. The potential providers have an incentive to portray their goods in a positive light and to lobby congress in various ways to obtain contracts making provision profitable. The amount of such goods provided might very well be the right amount or too much, the latter emphasized in public choice literature discussions of "special interest" power. Whatever amounts of such goods happen to be provided, the costs of provision, borne by working taxpayers, will result in individually optimal adjustments in work effort to pay for such goods along with the private goods households also desire.

However, the case for environmental public goods is somewhat different; indeed, for most environmental policies/regulations, special interests are likely to be aligned against policies that would raise the cost of producing goods. Illustrating with but one industry, automobile manufacturers have fought against seatbelt requirements, airbag requirements, and – notably for present concerns – catalytic convertors.

In such cases, regulation will only emerge when the growing demands of a larger and richer populace overcome resistance to government intervention by entrenched special interests and others who on ideological grounds desire limited government.[2] Any such intervention is likely to begin conservatively with very low provision goals, such as early EPA (Environmental Protection Agency)

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[1] See Graves (2009) for detailed discussion:
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1119316.

[2] I should perhaps point out that I am firmly in this latter camp, in general. I believe that government does so many things it should not be doing at all that it fails to do at all well the things that it *should* do.

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requirements for exhaust gas recirculation systems for more complete burning, reducing both unburned hydrocarbons (now VOCs) and carbon monoxide, CO.

At conservative initial provision levels, it is likely that a *properly conducted* benefit-cost analysis would favor many additional environmental policies. But there is an inherent inability to properly conduct benefit-cost analysis in this case – the non-optimally low initial provision levels will result in a non-optimally low initial work effort, hence income generated is also non-optimally low. And, critically, all of the ungenerated income *would* have been spent on the public good, abstracting from general equilibrium effects.[3] That is, benefit-cost analyses of environmental public goods are currently being conducted at the *wrong* income levels because of free riding in input markets.[4]

What this implies, from a policy perspective, is that the difficulty is not just attempting to solve the well-known demand revelation problem out of a given income. Rather, the initial income is itself inappropriately low because of the fully symmetric – but unrecognized – demand revelation problem in input markets. In some respects, that this observation has not been heretofore noted in the literature on public goods is surprising – it was widely acknowledged that incentive problems plagued the former Soviet Union, because the link between work effort and work reward was broken, creating incentives to work less. Yet, pure public goods provide an extreme example of a break in the link between work effort and work reward, hence it would be individually irrational to generate income to "buy" an increment in a public good, because the income generated would be negligible vis-à-vis marginal provision cost.

Focusing on environmental public goods, as a practical matter, starting from the conservative initial environmental provision level, environmental projects should be accepted even if *apparent* costs exceed *apparent* benefits because the actual benefits will be inevitably larger than those perceived out of the given initial income. In other words, were regulators able to produce increments to environmental quality up to the point where *observed* marginal benefits equal

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[3] The point is not merely that the justifiable amount of public good provision will be larger if those conducting the analysis recognize that the optimal income generated will be larger at a higher provision level (see Flores and Graves 2008, on endogenizing income in benefit-cost analyses). Rather, the *initial* income level is wrongly presumed to be an appropriate starting point for the analysis when it is not, because of input market free riding.

[4] The more important environmental and other public goods are relative to private goods in the utility function, the less income will be generated, an extreme case being perhaps the "hippie drop-outs" of the sixties. The "lazy" person who desires little in the way of either private or public goods is observationally equivalent to the person who desires very large amounts of public goods and modest amounts of private goods – each might generate the same income, hence are indistinguishable to the benefit-cost analyst. This is important and should be read twice.

observed marginal costs out of current income, they would be underproviding environmental quality by some unknown, but possibly large, amount.[5]

Existing efforts (see, e.g., Clarke 1971, Groves and Ledyard 1977) to solve the demand revelation problem have been largely moot, requiring quasilinear preferences as but one limitation. The ungenerated income of interest here represents additional, but unobserved, marginal benefits for any environmental good under consideration – the apparent marginal rate of substitution between environmental and ordinary private goods becomes distorted, making environmental goods "look" less valuable on the margin than they are.

Expressed another way, individual A who is "lazy" in the vernacular, might generate very little income because that individual values leisure highly relative to either private or public goods. Individual B might care a great deal about public goods, and very little about private goods, but that individual – if rational – will know that his individual values are too small to make a difference. As a consequence, individual A will "buy" more leisure than he would prefer if public goods could be purchased like ordinary goods. Individuals A and B might well generate the same income levels, and to the environmental analyst they are *observationally equivalent*, despite the high but unobserved demands for public goods by the latter.

Is there any corroborative evidence to indicate that the theoretical problem discussed here may be of any practical significance? Yes. A body of experimental economic research reveals a large gap between Willingness-To-Pay and Willingness-To-Accept (see Horowitz and McConnell 2002 for a summary). There might be many reasons for such a gap.[6] However, the finding by Horowitz and McConnell that the WTA-WTP gap is by far the largest for public goods, suggests the possible importance of the arguments presented in this section.[7] For example, when contemplating small increments to air quality people will often express rather small marginal willingness-to-pay, but will claim to require order-of-magnitude larger amounts to compensate for equally-small decrements to air quality. The ungenerated income resulting from the input market demand revelation problem discussed here would add to the WTP, greatly reducing the gap, and suggesting that WTA might actually be a better proxy for *properly measured* WTP than are current WTP estimates.

[5] One might argue that those desiring environmental public goods can pursue other avenues to achieve their goals, perhaps volunteering or engaging in the political system to attempt to "make a difference." However, the same free riding incentive problem plagues these alternatives, hence too little of such efforts is forthcoming.

[6] See Kahneman et al. (1990) or Tversky and Kahneman (1991) for a discussion of psychological notions of "endowment effect" or "loss aversion." See also Boyce et al. (1992) and Hanemann (1991) for additional explanations.

[7] Plott and Zeiler (2005) argue that the gap is due to faulty experiments; however, their example to establish their position is a private good example, leaving the issue unresolved for public goods.

It should perhaps be emphasized that fairly small levels of ungenerated income can result in very large provision level distortions. Approximately 2%, or $300 billion, of an approximate $15 trillion current United States GDP (gross domestic product) is currently spent as a result of all EPA regulatory initiatives. If only 1% of income went ungenerated as a result of input market free riding, a nearly 50% increase in that spending could be justified, resulting in very large environmental gains, even in the presence of rising marginal provision costs.

The public good valuation flaw discussed in this section has further implications for the conduct of benefit-cost analysis beyond the expectation that the benefits in the numerator are understated. As with free riding at a point in time, free riding is to be expected for intertemporal decisions as well. Suppose that the bequest motive is composed of desires to make our offspring better off, both in terms of wealth comprising ordinary goods and wealth in the form of an improved environment. To the extent that the latter matters to those leaving bequests, free riding incentives again suggest that the savings rate will be lower than would otherwise be the case. Those giving bequests will realize that the portion of their bequests that they would like to have devoted to environmental improvement is likely to be negligibly small relative to marginal provision costs. Hence, smaller bequests will be made from lower saving rates.

The implication of this is that the social rate of discount in current use for public goods lacking strong special interest support is at least to some extent biased upward. The use of a lower social discount rate for benefit-cost analysis of public goods of this type would result in acceptance of more environmental policies. I suspect that this problem is not of great magnitude, but its importance is largely unknown for the same reasons it is difficult to establish how much free riding occurs in ordinary output or input markets.

III. The Psychological Underpinnings of Willingness-to-Pay for Environmental Goods

Economists seldom care “why” people like the goods that they buy, not caring, for example, whether the “ice cube motive” is more or less important than the “fresh produce motive” for purchasing a refrigerator. The only exception to this appears in the money demand literature (the medium of exchange, asset, and precautionary motivations for money holding), but even here it makes no practical difference – the money demand analyst still looks for price and income elasticities in exactly the manner that they would if they completely disregarded why people wish to hold cash.

In the case of the environment, there is a very good reason for examining the various motives that underlie the marginal willingness-to-pay, because there are clashes in the underlying motives that have potentially important policy implications.

The critical distinction is between "use values" (e.g., snowmobiling in Yellowstone Park or observing the sandhill cranes in Nebraska) and "non-use values" (e.g., preservation of Yellowstone Park or leaving undisturbed the sandhill cranes). The non-use values are sometimes further subcategorized into (i) option to use, (ii) bequest, and (iii) preservation/existence. The reason that the distinction is critical for present purposes is that the methods used by economists to value environmental resources are best at valuing use values.[8]

By way of illustration, 318 snowmobiles and 78 multi-passenger snowcoaches (usually with 15 passengers each, or 1070 passengers per day) have been recently allowed into Yellowstone each day during the winter. Assuming the winter has 100 days of good snow cover, there would be 31,800 snowmobile and 107,000 snowcoach visitors. If each of the former had a WTP of, say, $1000/day and each of the latter a WTP or $200/day, the aggregate value of winter visitors to Yellowstone would be $53.2 million dollars ($31.8 million going to snowmobilers and $21.4 million going to snowcoach passengers). This is a rather large amount of use value; moreover, there is a fair degree of certainty around this number – it is unlikely to be an order of magnitude larger or smaller.

But the winter visitors also stress the park animals during the harsh winter period when food is scarce and their presence in recent years has resulted in relatively high winter park pollution levels. Continuing the example, suppose that each of the approximately 115 million households in the United States (US) would be willing to pay $0.50/household/year (approximately $0.20/person/year) to keep Yellowstone pristine in the winter, with cleaner air and less stress on the park animals. If true, the non-use value of the park is $57.5 million dollars. Were we equally certain about both the use value numbers and the non-use value numbers, the efficient environmental policy would be to not allow winter visitors to Yellowstone Park.[9]

We are, of course, not equally certain about the two numbers (I pulled the $0.50 preservation value from thin air with no justification at all other than that it seemed "plausible"), because non-use values generally come only from so-called "constructed market" experiments (contingent valuation, conjoint analysis, etc.).

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[8] As discussed in the following section, being "best" at valuing use values relative to non-use values does not mean that the methods employed by economists are very good at capturing use values.

[9] It should be noted that preservation values might well come from those in other countries, adding value that might be completely ignored by the country contemplating appropriate policy. For example, Americans might have a true willingness-to-pay of a fairly large sum to preserve the habitat of the panda in China or the mountain gorilla in Rwanda, but those values are unlikely to register in those countries; high transactions costs render the Coase theorem inoperable, although ecotourism provides a partial offset in some cases.

Such experiments attempt to elicit values from respondents for a wide range of goods and literally thousands of papers have been published purporting to value various goods, environmental goods being the focus here.

Real controversy about the constructed market approach did not develop until the Exxon Valdez oil spill in March of 1989. Because large amounts of damages were at issue, the debate about the validity of directly elicited valuations became somewhat heated.[10] A NOAA (National Oceanic and Atmospheric Administration) panel was convened, headed by two Nobel-prize winning economists (Kenneth Arrow and Robert Solow), with the charge being to determine whether constructed market methods were "capable of providing estimates of lost non-use or existence values that are reliable enough to be used in natural resource damage assessments."

After many meetings and wide-ranging testimony from experts on both sides of this question, the NOAA panel concluded in a January 15, 1993 Federal Register report that "CV studies [applications of the contingent valuation method] can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive use values." However, the report also made several specific recommendations about how constructed market surveys should be conducted that would be likely to result in "conservative" damage estimates, underestimating preservation values rather than overestimating them. The issue is still unsettled and it remains the case that economists and others are strongly divided over whether numbers derived from surveys can legitimately be employed in benefit-cost analysis.

For present purposes, however, there is one point that must be emphasized: the only method currently available for the determination of preservation/existence values is that of constructed markets. It is inevitably the case that there will be at least some circumstances in which preservation value will be large relative to use value and if constructed market valuation is not implemented, preservation/existence values will be ignored in environmental policy regardless of their magnitude.

Summarizing to this point, there are strong theoretical reasons to suspect that both use and non-use benefits are understated in environmental benefit-cost analyses (because a free riding suboptimal income is assumed to be optimal in benefit-cost analyses), and moreover use values are likely to dominate environmental policy, even when true preservation/existence values may be larger (because of the reluctance to accept constructed market valuations). Are there further reasons to suspect that even the use values themselves are measured with downward bias?

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[10] For an excellent lead-in to the history and methodology of contingent valuation, see Portney (1994). His overview piece is followed by several articles both pro and con by various experts.

IV. Valuation Methods in Common Use and the Role of Damage Perceptions

Apart from voting/referenda methods,[11] there are three primary valuation methodologies in widespread use in environmental benefit-cost analysis. The most intuitively obvious is referred to here as the "Sum of Specific Damages Approach" (sometimes this is referred to as "The Health Effects Model," because typically only health effects are analyzed). The second approach looks at relationships between environmental goods and ordinary goods to infer the former's value and is widely known as "The Hedonic Method."[12] The third approach is the "Travel Cost Method" which takes the view that expected benefits of a trip to an environmental destination must exceed the costs or the trip would not be undertaken. Within each approach there is substantial likelihood that important benefits will be ignored as these methodologies are typically applied. The primary focus here, however, is on the nature of the implicit assumptions underlying each approach and what those strongly opposing assumptions imply about true willingness-to-pay for improvements in environmental quality.

The Sum of Specific Damages (SSD) Valuation Method

The idea under the SSD approach is to first gauge how much an environmental policy will reduce physical damages, ΔD_i, of a wide variety. There are hundreds of studies relating various levels and types of pollution (e.g., particulates, sulfur dioxide, ozone, or lead) to physical damages taking many forms, such as asthma, cancer, cardiovascular disease, chronic bronchitis, hospital admissions, lead neurotoxicity and blood pressure effects, mortality, respiratory infections, and work loss. A dollar value, $\$V_i$, is then placed on each category of damage, with, for example, a prevented life lost being valued at perhaps $5 to $7 million, and the prevention of an asthma attack much less.

The marginal benefits of the policy are, then, the sum of all of the reductions in physical effects times their respective values:

$$\text{Marginal benefits} = \sum(\Delta D_i)\$V_i. \qquad (1)$$

[11] Because many environmental benefits (e.g., mortality and morbidity) are concentrated among a small number of individuals, their intensity of want fails to be picked up in a one person/one vote mechanism. Benefit-cost analysts attempt to aggregate benefits and costs weighting each individual by dollar willingness-to-pay not weighting each individual identically, so I forego discussion in the main text of, for example, California's green propositions.

[12] There are many detailed reviews of both of these approaches, but here are two recent ones: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1542074 (Sum of Specific Damages), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1542072 (The Hedonic Method).

The reduction in physical damages is usually further decomposed into:

$$\Delta D_i = b_i * POP_i * \Delta EQ \qquad (2)$$

where ΔD_i = change in population risk for health effect i,
b_i = slope of the dose-response function for health effect i,
POP_i = population at risk for health effect i,
ΔEQ = change in environmental quality, measured as pollution reduction.

Illustrating, suppose that an environmental policy is being contemplated that is expected to lower fine particulate pollution levels by 5 $\mu g/m^3$ in some populous region. Assume that the net present value of the benefits of this change in air quality is one life per million people and the elimination of 100 cases of chronic bronchitis per million people. If there are 8 million people in the region affected by the policy, then 8 lives will be saved and 800 cases of chronic bronchitis will be eliminated in present value.

Further assume that a saved life is "worth" \$5–\$7 million dollars, with a best point estimate guess of \$6 million and an eliminated case of chronic bronchitis is worth \$50,000 (perhaps based on contingent valuation or some other stated preference mechanism as discussed earlier). Then the policy would have present benefits of $8 \times \$6,000,000 + 800 \times \$50,000 = \$88,000,000$. If these are the only benefits of the policy and it can be put in force for a present cost of \$88 million or less, it would be efficient to adopt the policy because it would have marginal benefits greater than or equal to marginal costs, a positive net present value.

The preceding example can be used to illustrate all three major problems with the SSD approach. First, the physical effects due to the policy, ΔD_i, are highly uncertain; although we "supposed" that 8 people would not die and 800 would not acquire chronic bronchitis if the policy were put into effect, such estimates are very uncertain. In testimony prior to the implementation of the environmental policy, some experts will argue that the damages prevented might be very large, whereas others will argue that the damages prevented may be very small. In part, this stems from advocacy positions – an expert working for the American Lung Association is more likely to predict more bronchitis cases prevented by the policy than an expert working for the National Association of Manufacturers. The final determination of damages will probably depend on some mix of the credibility/credentials of the experts and the quality of the analyses they present.

Where do experts of either stripe get their information? There are three primary approaches (toxicological, clinical, and epidemiological) with epidemiological studies tending to carry the most weight. Clinical studies are used to address research questions that can be well examined in laboratory settings. In a human clinical study, scientists investigate the effects of individual air or water pollutant "doses" by measuring a variety of health effects (e.g., lung function, heart rate variability, blood component analysis). Clinical studies are themselves usually initiated in response to prior biological studies, either *in vitro* or *in vivo* in animal surrogates for humans. The latter provide information about the way pollutants generate their molecular effects, and such animal and *in vitro* studies are particularly important when human data are unavailable or when such data cannot be ethically obtained.

Epidemiological studies, although less rigidly controlled, offer more natural settings through the statistical analysis of data from human populations or by field studies. In some cases, researchers follow fairly large groups of individuals and use detailed questionnaires to relate the incidence of various disease endpoints to pollutant levels. Field studies involve fewer individual observations and employ repeated assessments of health effects of pollution exposure. The smaller numbers of subjects involved in field studies allow researchers to extend the information obtained in large-scale epidemiological studies by including measurements of clinical health endpoints. Various epidemiology studies have, for example, implicated particulate matter in premature death among elderly individuals with cardiopulmonary disease and to increased use of medications, doctor visits, and hospital visits for individuals with pulmonary disease such as asthma.

Toxicology studies attempt to identify and study the specific properties and constituents of various pollutants that are responsible for causing adverse health effects. Toxicologists test the molecular, cellular, and systemic effects of pollutants in experimental settings using cell and tissue cultures, animals, and computer models. As already indicated, findings of dose-response effects from a toxicology study might prompt the initiation of either or both clinical trials and epidemiological investigations.

Knowledge is gained from the various approaches, but there remains great uncertainty at the policy level about how physical effects relate to pollution exposures. This is particularly so for *chronic* pollution effects, such as perhaps a long-latency cancer, vis-à-vis the more immediate *acute* effects. When certain physical effects are difficult, for various reasons, to tie to pollution, they will tend to be ignored in the SSD approach, leading to understatement of damages. Death or cancer at least have clear definitions, but certain forms of pain, dermatitis, neurological effects, various endocrine disruptions and the like are difficult even to quantify, let alone relate to pollution, and hence are likely to be ignored in practice.

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Returning to the example of how Eq. (2) might be used (or misused), the second source of uncertainty is on what values to place on the physical effects that are predicted to occur. Is the "value of statistical life" (VSL) $6 million? Or, is it one-tenth or ten times that? Could the value of a chronic bronchitis case be an order of magnitude greater or smaller than the $50,000 used in the illustration? One might argue that values such as these are at least plausible, and one could make a fairly strong case for the argument that there is greater uncertainty regarding the physical effects estimated by the epidemiologist than there is regarding the values placed on them by the environmental economist.

Neither of the uncertainties discussed to this point would seem to point to any obvious downward bias in damage estimates. There are two important reasons to suspect that such a downward bias exists, however. First, the physical effects should be *all* of the physical effects that will occur as a result of the policy, not just (a portion of) the health effects. If a policy cleans up the air or water, it will have physical benefits of a wide variety, not just mortality and morbidity benefits. There will generally be ecosystem improvements, agricultural crop yield benefits, material damage reductions (e.g., house painting with less frequency), benefits for pets, as well as aesthetic effects (e.g., smells, visibility). Because we get all of those effects as a result of the policy they all should be counted, yet in practice they never are under this approach.

There is an additional theoretical and practical problem with the SSD approach that strengthens the claim that too little environmental quality will be produced if this approach is used to estimate the benefits of environmental policies. For this method to "work well" as a measure of pollution damages, people have to be *unaware* that pollution has any impact on the damages they experience. That is, the impact of pollution on, say, health has to either be unknown to households or they must be unable to determine where it is clean and dirty. The environmental source of the damages has to be *unperceived*.

If the damage and its cause were perceived by individuals, they would be expected to engage in costly mitigating behavior[13] (sometimes referred to as "averting" behavior), to the point where marginal benefits of mitigation were equal to marginal costs of mitigation – and the saved mitigation costs should be added to the estimated marginal health benefits (damage reduction) of the environmental policy. Because such mitigation costs never are added to environmental benefits calculated by the SSD, analysts are at least implicitly

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[13] We might not, for example, exercise outside on high pollution days, we might install dust filters or air conditioning in part to avoid air pollution, we might move to a less-preferred but cleaner location, and so on. In the case of water, we might buy distilled water, or install water filters, as a means of avoiding damages from polluted surface reservoirs or aquifers. In all of these cases, scarce resources are expended *to avoid* a damage that otherwise would have happened.

assuming that such costs do not exist, i.e., that individuals do not perceive the causes of their health damage.

We turn now to an approach to valuing environmental improvements that relies on a *polar opposite* assumption, namely, that damages from environmental pollution (hence benefits of environmental pollution clean-up) are perfectly perceived.

The Hedonic Valuation Method

Two ways that people can avoid pollution damages are by locating in cleaner towns and/or by locating in cleaner parts of a given town. The appropriate use of this method is taken up in some detail here, because the hedonic method is commonly misused and that misuse generally leads to downward-biased estimates of environmental values.

The fundamental notion underlying all hedonic methods is merely that people like to make themselves as well off as possible, exactly the assumptions that we make about their behavior in ordinary markets. *Other things equal*, we would all prefer to live in a cleaner town or live in a cleaner part of a given town. The idea with hedonic methods is to examine how much households are willing-to-pay in land and/or labor markets to live in cleaner locations, because they will in general *have* to pay, as we shall see. The main ideas are really very simple, but to gain a clear understanding of this method we shall first consider wage and rent compensation separately (as is often done, although this is in general incorrect as we shall see). An "integrated" model that was first formally presented by Roback (1982) and later implemented empirically by Blomquist, Berger, and Hoehn (1988) is then described in some detail.

(A) Hedonic Methods: Wage Compensation

Some labor market regions are more polluted than others, and households will have to receive compensation for the pollution they experience to be willing to work in dirtier cities. That is, if city A (one of two otherwise identical cities) has higher pollution levels than city B, residents would move from A to B reducing the labor supply in A (raising wages) while increasing the labor supply in B (lowering wages). The movements would continue to occur until the wage differential just compensated people for the higher average pollution in city A. One extremely desirable feature of this approach is that it gives us exactly what we want, the net present value of marginal willingness-to-pay in dollar terms, which can then be compared to the marginal costs of policies yielding that amount of cleanness.

The actual process requires as much data as possible on individual wages as well as the determinants of wages for people at various locations (education, experience, age, occupation, region, union, etc.) to which are added measures of environmental quality levels in those locations. With this information at hand a regression analysis is then performed to statistically relate the wage (as the dependent variable) to those determinants. There is little theoretical guidance on functional form – degree of linearity, interactions among variables, and so on. This raises the possibility that researchers inadvertently, and advocates deliberately, might distort environmental values by their choices along several dimensions.

The coefficients on the environmental quality variable will indicate how much impact a given change in environmental quality has on wages, holding constant other wage determinants. In this way, the trade-offs between environmental goods and other goods that people also value can be directly measured. Because higher levels of environmental quality are a desirable trait of a labor market area, we would expect that wages would be *lower* in the high-environmental quality locations because the supply of labor would be greater to such areas. If environmental quality differences across labor market regions are not perceived or if people do not know how environmental quality affects them, the true benefits of cleaning up will be understated by this method – one would not expect households to accept wage cuts for unperceivable benefits. However, a large number of wage studies (see Bockstael and McConnell 2007, for a good review in the present context) indicate that households are willing to give up wages to live in cleaner locations.

(B) Hedonic Methods: Property Value or Rent Compensation

The property value/rent compensation method of hedonic valuation translates the logic that underlies the labor market studies to the housing market. How much a house will sell or rent for is clearly related to the nature of the traits that the house possesses. Some of those traits are "structural," such as whether it is constructed from stone or wood, square footage, number of bathrooms, size of lot, presence of pool or tennis court, type of heat, and so on. Other traits are related to location such as "neighborhood" variables (school quality, freedom from crime, access to various destinations, and so on). These latter traits are "location-fixed" public goods whose prices end up being bundled together into the price of the house along with its structural traits. Environmental quality, viewed from this perspective, is just another location-fixed trait that is desirable from a household's perspective.

Assuming perceptions are perfect and that we have a competitive housing market, the value of clean air must be paid for in higher prices for houses in areas having higher air quality. If we can determine how much people are willing to pay for an otherwise identical home in a clean location versus a dirty location, we will again have a measure of exactly what we would like – the present value of the marginal dollar willingness-to-pay for environmental quality, which can then be compared to the present dollar marginal cost of environmental quality.

The process is fairly similar to the wage hedonic approach, first requiring as much information as possible about the traits – structural, neighborhood, and environmental quality – of all houses (in what is hopefully a large sample), along with their property values and/or contract rent. In an ideal world, the property value (the dependent variable) would be the actual sale price, but sometimes information is used from multiple-listing books, scaled up or down by the going ratio of list price to exchange price. The property value is next regressed against its structural and neighborhood determinants. The empirical analysis involves many possible functional forms, with non-linearities, synergisms, and the like possibly being important. As with the wage hedonic approach, there is little theoretical guidance on the nature of the functional relationship between property values and their determinants which enables researchers accidentally – and advocates intentionally – to publish very different conclusions, even from *identical* raw data. The coefficients on the environmental quality variables reveal how much impact a given change in environmental quality will have on property values for average households. That is, the trade-off between environmental quality and other goods can be directly measured, and because higher environmental quality is a desired trait, we expect to observe *higher* house prices or rents in cleaner areas, other things equal.

As with wage studies, property value studies suffer from problems stemming from the assumption of perfect information. Suppose that people do not fully perceive the impact of pollution on their health and well-being or how the pollution levels vary across locations or both. The first possibility is somewhat plausible, because even the "experts" have widely varying opinions about the amount of physical damage, particularly health damage stemming from pollution, as discussed in the section on the SSD approach. As to the second possible perceptual difficulty, many pollutants are odorless, colorless, and tasteless in ambient concentrations commonly encountered, so it might be difficult for the average person to even know whether a particular house is in a high-pollution or low-pollution location. If buyers do not properly perceive all of the damages from pollution or if they cannot tell which locations are dirtier, the benefits estimated by this approach will be understated. As with the case of wage compensation, people will not be expected to pay for something without tangible benefits. Many studies, however, show strong positive relationships between property values and environmental quality as was the case for wage studies.

(C) Wage and Property Value Differentials Are Not Alternatives

Until fairly recently, the preceding hedonic approaches to valuing environmental improvements were viewed as "alternative approaches." That is, it was thought that one could find out what clean air was worth *either* by examining property value variation in land markets or by examining wage variation in labor markets. The approaches were viewed as alternative ways of measuring the same environmental preferences. Indeed, if the values happened to be similar under the two methods, greater confidence was placed in either as a measure.

It turns out that this is incorrect under plausible assumptions about rational peoples' behavior when evaluating locations. Indeed, for this view to be valid, it must be the case that people follow a two-stage procedure in picking a location. First, only looking at wages (and average pollution levels), they pick a location among alternative labor markets; only then, having settled on a labor market, do they select a location within that labor market based on housing price and pollution variation within that area. This would clearly be irrational because households would do much better in general by looking at the combination of wages, rents, and amenities available in all locations prior to selecting their location.

Another way to think about this is that, between two otherwise identical locations, the one that is more polluted will be less attractive, so people will move from the more-polluted to the less-polluted location until they are equally well off in both locations. But, as they move into the less-polluted location they both increase the supply of labor (driving down wages) and increase the demand for land (driving up rents). Hence, the "true" value of the less-polluted locations is the *sum* of what is being paid for reduced pollution in both the labor and land markets.

At the level of theory, the preceding has been known since at least 1982, with convincing empirical verification being provided by 1988.[14] Yet many recent studies continued, and continue at this time, to be conducted employing a single-market compensation methodology. This is perhaps partly because the data for such studies are typically easier to come by when only one market is employed,

[14] Roback (1982) first presented the theoretical arguments for multimarket amenity compensation in a convincing way, while Blomquist, Berger, and Hoehn (1988), in a large study funded by the EPA, demonstrated empirically that proper valuation of environmental goods requires the summation of compensation in both labor and land markets; moreover, they found that there is wage variation even within large labor market areas using county-level data. In an excellent recent empirical study, Kuminoff (2007) finds, in a nested analysis comparing results from a traditional property value approach, that his "new 'dual-market' framework increases estimates for the average per/household marginal willingness-to-pay by as much as 110%."

but also partly because it is *possible* that compensation for specific environmental amenities can occur in either the land or labor market separately.[15]

Clarifying, what is an amenity to households might be a disamenity to firms (e.g., a city introducing an expensive pollution control policy that helps households but harms firms). In this case, wages will definitely be lower (households enter increasing labor supply, whereas firms exit reducing labor demand), and the effect on property values/rents is ambiguous, depending on whether the city becomes larger or smaller as a result of the policy. Similarly, if an environmental policy happened to be good for both firms and households (e.g., reductions in fine particulate that improve health and perhaps lower production costs of microchips), the benefits to households would appear largely in property values, with perhaps negligible impact on wages – whether wages would rise or fall would depend on whether the amenity was relatively more important to households or to firms.

It seems very likely that hedonic methods would *understate* the value of environmental quality improvements, even if a properly conducted multimarket methodology was employed. The most obviously damaging observation is that the benefits of environmental quality must be *fully perceived* by households for them to be willing to pay more for cleaner locations. As indicated earlier, even the world's foremost health experts have spirited debates about the role various pollutants play in human disease and death. It seems implausible that ordinary people would be able to accurately perceive such things – moreover, because many pollutants are not detectable by our senses in normal ambient concentrations, it is likely that ordinary people would be unable to even distinguish the clean places from others.

Why do hedonic property value and wage studies show such large environmental effects then? It is certainly the case that people *will* perceive localized smells, bad visibility, and other impacts of pollution that are inevitably revealed by our five senses. Yet, it is precisely such perceived damages that are *ignored* in the SSD approach discussed earlier. The SSD environmental valuation method assumes that damages (typically a subset of health damages) are *unperceived*, merely occurring to people at greater rates in dirtier locations than in cleaner locations.

Given the nature of the assumptions about preferences, the two approaches clearly cannot be viewed as alternatives, as is implicitly the case when one methodology is selected in preference to the other. A much stronger case can be made for *adding* together the damages estimated from an SSD study to those of a hedonic study to get the true damages, those both perceived and unperceived.

[15] Indeed, it is the case that the compensation shares are not even bounded by zero and one. That is, depending on how important the amenity is for firms relative to households, it is possible to have +150% of the amenity value occur in one market and –50% occur in the other.

Such a procedure might result in some double counting, because an area that is unhealthy might also smell bad, but it is likely that the two methods pick up largely unrelated damage categories, those perceivable and those that are not perceivable by households. Moreover, in light of the discussion suggesting that each of the SSD and hedonic methods separately underestimate damages, any double-counting is likely to be more than offset by those underestimates.

This point is fairly important in practical environmental situations, whether in regulatory rulings or in court testimony. The benefits of environmental clean-up are estimated *either* from an SSD type of approach or a hedonic type of approach, but the estimates are never added together which in many cases would greatly increase the estimated benefits of clean-up.

An additional reason for expecting the hedonic method to understate true benefits is that the hedonic method – even properly conducted – only captures *use* benefits of the environmental resources of concern, because the amenities are bundled with housing and jobs. As discussed in Section III, non-use benefits might well be of greater magnitude in particular environmental settings, and policies allocating the environmental resource should, on efficiency grounds, encourage highest value allocation – even if that results in "non-use" of the environmental resources. Illustrating, is the California Coastal Commission properly allocating scarce ocean locations? It is clear that in the absence of this regulatory authority virtually the entire coast of California would be lined with high-rise condos, looking much more like Miami's South Beach area than at present. But, the scenic Pacific Coast Highway has value to all who drive it, and to a large extent that value has been perceived as being of greater importance than the (admittedly very large) benefits households would receive if the coast were opened to unrestricted development. Similar observations would apply to Central Park in New York City.

The final reason why hedonic methods might be expected to understate the benefits of environmental clean-up stems from the relative supplies of clean locations relative to the demands for clean locations. The behavior underlying the hedonic method results, at least in principle (for homogeneous agents), in *zero* spatial consumer surplus. That is, if one location is "nicer" than another location, households will continue to move to the nicer location, until it is no longer nicer – until identical locations have identical full compensation. There will be no consumer surplus over space, and indeed this is one of the reasons the hedonic method is desirable in that the *full* benefits that are perceived are measured. Were people all homogeneous, as the "representative agent" models of economics typically assume, zero consumer surplus over space might well be a reasonable expectation.

But, the fact that people are very different means that understatement of environmental benefits (damage reduction) is likely to occur when there are more locations with the amenity than there are people strongly desiring the amenity. Suppose, for example, that there are very few households containing really sick individuals, individuals with weakened cardiopulmonary systems who would be highly damaged by pollution. Such households might be *willing* to pay a great deal for a very clean location, but they might only *have* to pay a much smaller amount, if the number of "clean" locations is large relative to the number of these households. They will get consumers' surplus over space. Inferring the value of cleaning up the environment from the average person in this case would ignore the high marginal benefits received by these households. When one considers the very large number of traits that can matter to a heterogeneous population with very diverse preferences, it becomes clear that a great deal of consumer surplus can remain in the hedonic equilibrium – households are not indifferent to where they locate. In the case of incrementable environmental goods, the unobserved consumer surplus corresponds to a higher marginal value that might – if observed – justify a policy intervention to increase levels of the public good.

The Travel Cost Method

The travel cost method of valuing environmental amenities was invented by Harold Hottelling, a brilliant economist who would have won the Nobel Prize were he alive when it was originated. The notion is that the (expected) benefits of a trip to an environmental destination have to be higher than the (expected) costs of that trip or the trip would not occur. There are two serious criticisms of this method in the literature. One is that this method presumes that the trip is for a specific destination of interest, and the analyst must figure out how to deal with multi-destination trips. For example, virtually everyone who visits either Mt. Rushmore or Devil's Tower visits the other (and, often, Crazyhorse and Deadwood, to complicate matters further). Attempts have been made to resolve this issue (e.g., asking respondents to state the proportion of their travel cost attributable to the destination of interest to the researcher) and those attempts are likely to achieve success at isolating values. The second criticism, in common with most commonly used environmental valuation methods, is that non-use values are ignored by this approach.

There is a third criticism of the travel cost methodology. As far as I know, this observation is not currently in the environmental economics literature, even though I think it should be. Many environmental destinations are rather desirable and often remote from substitute destinations. If an individual or household is strongly attracted to such destinations, they will be expected to move closer to them to reduce the travel costs of enjoying those destinations. The movements will be expected (harkening back to the hedonic discussion) to raise property values in the desirable destination and to lower the wages available at that destination. The travel cost literature views those living nearby (think "ski bums" here, for concreteness), as merely having lower travel costs to the destinations that they are interested in. But, critically, those who live close to the desirable amenity are likely to be (i) paying more for housing than in other places and (ii) working in jobs that pay less, perhaps because their human capital has lower value in the places they prefer to live. This means that the travel cost method is likely to undervalue the location-specific amenity because the method ignores any other prices being paid to experience that amenity by those living close to it. A properly conducted analysis – admittedly difficult in practice – would add the prices paid in land and labor markets to the travel costs as one moves closer to the destination amenity. This has never been done in the environmental economics literature.

V. Policy Implications of Equity/Efficiency Trade-Offs and Additional Concerns

Environmental policy, at least as practiced in the US, is regressive. There are many arguments as to why this must be the case, but I will briefly enumerate a few. The rich have a larger amount of ordinary goods and are limited in their consumption of public goods, the environment being of concern here, to the levels politically determined to be the "social optimum," a political average below their optimal levels. So, on the benefits side the rich come out on top for environmental improvements. The cost side is equally clear…the poor spend a higher percentage of their income on manufactured goods whose price will rise with the institution of environmental controls. The practical implication of this, in a world where there is genuine concern for those less fortunate, is that efficient policies are not adopted when they are viewed as clearly inequitable. As was noted in a recent California study cited by the *New York Times*, cars that are 13 years old or older cover only 25% of the miles driven, but cause 75% of the air pollution. The dirtiest 10% emit 59% of hydrocarbons and 47% of all carbon monoxide, states the California Air Resources Board.

Given the high-marginal costs of reducing emissions for new automobiles, it is likely that requiring old automobiles to meet emissions standards would be an efficient policy – but such a policy would be cleaning up the air on the backs of the least fortunate Americans because those are the owners of the highly polluting cars. As a consequence of this concern for the poor, cars that fail the inspections are required to be tuned up, but are then "passed," regardless of how dirty they remain. Hence, this equity/efficiency trade-off provides additional support for the position that environmental policy is biased against achieving efficient levels of environmental quality, because attempts to offset any undesirable equity implications of a policy are seldom built into environmental regulations.

There are additional benefit side reasons, perhaps slightly speculative, for suspecting that benefit-cost analysis of environmental projects is biased against their acceptance. Expected future population growth and likely increases in income have impacts that are generally ignored in environmental benefit-cost analysis. Many environmental policies will confer benefits over long time periods into the future (e.g., it took many years for the catalytic converter equipped automobiles to predominate on American roads; long-lasting stationary source controls such as baghouses, scrubbers, and the like provide clean air for many years after their introduction). If population growth is occurring at 1% a year[16] and per capita income is growing at 2% a year, the numerator benefits of environmental improvements would be growing at 3% a year under a conservative assumption that the income elasticity of demand for environmental quality is unity (most economists who have studied this issue would argue that environmental quality is a superior good, with income elasticities of perhaps 1.5). Building these considerations into benefit-cost analyses would greatly increase the net present value of the benefits.

There are cost issues as well. Traditionally, many analysts, partly tongue-in-cheek, state that the actual costs will end up being twice what they were predicted to be *a priori*. But, these casual observations are normally directed at projects (e.g., dams, airports, and the like) that have substantial special interest support and which are, furthermore, usually eligible for federal cost-sharing. Federal cost-sharing creates incentives to pursue projects with *local* benefits greater than *local* costs, regardless of overall project efficiency. These projects are politically preferred to typical environmental projects, despite the latter offering learning-by-doing cost savings along with scale economies in provision, suggesting that cost estimates are likely to be overstated for environmental projects.[17]

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[16] For some countries currently, and many others in the future, population growth may well be negative, which would reverse the text argument. The growth of income is likely to more than offset population declines, however, in the overall growth of numerator benefits from environmental policies.

[17] The recent arguments of Hahn (2010) provide an at least partial offset to those of the main text. I would argue that the very pronounced downward bias in benefits discussed here are likely to more than offset any cost side concerns associated with the regulatory process. Moreover, it is very easy to find examples of policies in which the costs were *a priori* argued to be rather high, but were found later to be much lower (e.g., an elaborate 4-point race car seat belt can be acquired for $10–$14 each in quantity and even the less-expensive old-fashioned lap belt reduced traffic fatalities by 30–50%). As another example, automobile manufacturers expressed great concern about the cost of required catalytic converters on cars built after 1974. Catalytic converter production technology has been systematically improved [e.g., laser welding instead of conventional TIG (tungsten inert gas) welding] and prices now range from $70 to perhaps $300 in various configurations. The catalytic converter has had a huge impact on urban air quality, particularly in rapidly growing Western cities.

The primary reason that the observations of this section have environmental policy importance is that benefit-cost analyses of environmental policies tend to be only infrequently conducted. A rejection on benefit-cost grounds of an environmental policy at one point in time does not mean that a rejection would occur a decade later when both population and income are larger and when technological advance might lead to lower costs. The optimal timing of an environmental project is itself a "policy" with benefits and costs, and projects with current negative net present values might well have substantially positive net present values in the near future.

VI. Conclusion: Environmental Valuation as Practiced is Biased Against the Environment

As an initial observation, it was argued that some public goods – such as many environmental goods – will tend to not only lack special interest support but will actually have powerful special interests aligned against their provision. Hence, initial provision levels are likely to be rather low relative to optimal provision levels. Regardless of initial provision level, rational individuals will not generate income to increment a class of environmental goods that is not individually incrementable. These observations imply that benefit-cost analysis of environmental public goods is being conducted at the wrong income levels and, furthermore, all of the ungenerated income would have been spent on environmental public goods, apart from general equilibrium effects, which could lead to substantial resource misallocation.

We then went on to observe that the non-use values, preservation and existence values in particular, are poorly captured by the methods in widespread use by economists. The methods of economics – the sum of specific damages method, the hedonic method, and the travel cost method – all concentrate exclusively on use values, when it will certainly be the case that at least some environmental amenities will have a higher value to society collectively if preserved.

Moreover, damage estimation methodologies in common use understate damage as they are typically conducted. The hedonic approach requires perfect perceptions of environmental benefits along with perfect knowledge of how environmental quality varies over space. Moreover, it remains the case that expert legal testimony and typical regulatory practice still typically employ *either* a property value study or a wage study, despite knowledge available for more than two decades that compensation for environmental amenities and disamenities will generally occur in *both* land and labor markets.

The SSD approach requires zero damage perception to be accurate and, moreover, tends to omit many hard to measure health and other effects (e.g., material damage, minor health effects, views), while emphasizing acute damages rather than the more difficult to study chronic damages.

A strong case can be made for applying *both* methods to specific environmental policies being evaluated in a benefit-cost analysis and adding the benefits of a properly conducted hedonic analysis to the benefits obtained from the SSD approach. There might be some double-counting in this process, but it is unlikely that this source of bias would offset the biases within each methodology that lead to understatement of environmental values.

The travel cost method ignores any compensation paid in land and labor markets as one gets closer to the destination amenity, an observation that is completely ignored at this time in the environmental economics literature.

When all of the arguments presented here are considered as a whole, it seems difficult to deny the strong likelihood that benefit-cost analysis, at least as applied to environmental projects, is biased against acceptance of those projects. While the specifics here have dealt with environmental policies, it is likely that the central concerns would apply to many other areas of benefit-cost analysis (e.g., safety, health, or natural hazards).

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