The cost of carbon: Economic approaches to damage evaluation

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Abstract

This contribution discusses the valuation of climate damage through economic valuation methods, initially developed for valuating environmental damages and benefits from environmental protection. Damages from climate change have been quantified either at a macro level (global climate impacts) or at a micro level (impacts limited in time and/or location), with the latter being particularly relevant for climate litigation. This article first outlines the general background of economic valuation and explains the methods employed for monetising climate damages. It then outlines their use in policymaking and litigation and explains how climate damages have been evaluated with a particular focus on US practice.

1 Introduction

This chapter discusses the assessment of the damages from climate change using economic methods of valuation. These methods are not specific to climate change – they were developed mainly in the 1970s by environmental economists to value damages from pollution and benefits from environmental protection/restoration. Subsequently, they have been applied widely in other fields of economics. The methods are known collectively as non-market valuation. What they aim to do, what specifically they measure, and how, is described in section 2. Section 3 summarises how these methods have been used in environmental policymaking and litigation in the United States. Their use is now well accepted in the context of cost-benefit analysis for policy, but it is more checkered in the context of litigation for what is known as natural resource damages (NRDA). Section 4 reviews how damages from climate change have been evaluated. This has been done on two scales: a macro scale purporting to monetise all impacts globally, and a micro (local) scale evaluating particular impacts at particular locations at particular points in time. The macro scale analysis takes the form of a damage function in an integrated assessment model (IAM) – a postulated relationship connecting increases in regional or global average annual temperature to reductions in regional or global GDP postulated to result from the temperature increase. With their damage functions, IAMs have been used to calculate what is known as the social cost of carbon (SCC). The SCC estimate has been used in the US since 2010 for regulatory review of proposed major regulations. However, the IAM damage functions themselves, and the resulting SCC estimates, are probably

on too coarse a spatial scale and a temporal scale to be useful in climate-related litigation. The micro scale local impact studies are directly relevant for climate litigation. Section 5 offers concluding observations.

2 Non-market valuation in economics[1]

Value means different things in different discourses. We start by describing what economists mean by value and how that differs from other discourses. Moral philosophy identifies three distinctions: (1) anthropocentric versus non-anthropocentric (ecocentric) value, (2) utilitarian versus deontological value, and (3) instrumental versus intrinsic value. Anthropocentrism makes humans the ultimate source of value: things have value only to the extent that (some) humans assign value to them. Ecocentric value, in contrast, holds that organisms and biota can have value even if no human being thinks so. Utilitarian values stem from the ability to contribute in some way to human well-being. A deontological value stems from something that is required of humans as a duty. Finally, the instrumental value of a thing is derived from its role as a means towards an end other than itself; an intrinsic value is a value that exists independently of its usefulness for achieving a goal.[2]

Economics focuses on human interests, preferences and behavior. Thus, the economic concept of value is anthropocentric and is based on utilitarian principles.[3] While recognising that other concepts of value can have merit, I focus here on values that can be captured through economic valuation. This is a broader set of values than often presumed. A common belief is that economic value refers to the commercial value of items and exists only for items for which there is (or could be) a market with a market price. In fact, anything that people care for, from whatever motive, is subject in principle to valuation using economists' concept of value.

The economic concept of value rests on the notion that individuals have preferences for things and can make judgments regarding their own well-being. They can judge among options; they can compare alternative combinations of outcomes involving things that they care about; they can assess whether one combination is bet-

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1 This section draws heavily on the excellent discussion in National Research Council, *Valuing Ecosystem Services: Toward Better Environmental Decision-Making* (The National Academies Press 2005) Chapters 2 and 4.

2 The modern notion of intrinsic value of intrinsic value reflects the notion that rights should be extended beyond human beings, Christopher Stone, *Should trees have standing? Towards a theory of legal rights for natural objects* (William Kaufmann 1974).

3 A value for an item held by humans which is being measured by economists could be instrumental or intrinsic. If the item has an intrinsic value, this is because humans deem this so. If an item has an intrinsic value from a deontological perspective and it is lost, it is irreplaceable. From an anthropocentric approach, however, whether the lost item is irreplaceable depends on what humans think.

ter than another, or worse, or the same. Using these assumptions, economic value is defined in terms of a trade-off by an individual. When an economist states that, for some individual, X has a value of 5 units of Y, it means no more, and no less, than that the individual would be willing to exchange X for 5 units of Y.[4] The item Y is the metric, or *numeraire*, for measuring the value of X.

The numeraire for economic valuation, Y, must be something that the individual sees as having value. It also must be something the individual sees as commensurable with X (comparable to X).[5] Most commonly, Y is a currency, such as dollars.[6] This assumes that the item being valued is in principle replaceable with other things that are also of value and that money can buy.

Some who affirm the intrinsic value of ecosystems and biota object to the notion of quantifying that value. This quantification is, by definition, anthropocentric since humans are doing it. It also implies a ranking (i.e., a statement of which items are 'more valuable,' and possibly by how much). There may be objections to one or both of these implications of quantification. However, as described in the next section, there are contexts in which quantification of values proves useful or even necessary by providing a systematic way in which the values being quantified can be factored into an administrative or judicial decision process.

The economic concept of value is something that is inherently subjective and idiosyncratic. When an economist states that, for some individual, item X has a value of $50, what is being asserted is that the individual would be willing to exchange X for $50. The trade-off necessarily depends on the person's preferences, outlook, and specific circumstances (including income) at the time.

Conceptually, there are two distinct ways to frame the exchange in terms of which an individual's economic value is defined. One framing is the willingness to pay (WTP). The WTP value of X is *the maximum amount* of numeraire, Y, that the individual would be willing to give up (pay) to obtain X. The other framing is the willingness to accept (WTA). The WTA value of X is *the minimum amount* of numeraire (money) that the individual would be willing to accept as compensation for foregoing X.[7] The exchange may not, in fact, be practical or feasible. But the WTP and WTA

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4 Note what is being compared is changes: having X versus not-X as compared to having 5 units of Y versus not having that. In a climate context, what is being valued is *a change* in climate.

5 If Y is seen as incommensurable with X, the individual cannot make a tradeoff between X and Y.

6 In less monetised communities, time has been used as the numeraire – e.g., how much of your time would you give up in order to have X? Some ecologists have recommended using units of energy as the metric for measuring value, e.g., Howard T Odum, *Environmental accounting: energy and environmental decision-making* (John Wiley 1996). This rejects the premise that value arises from the preferences of individuals and that the purpose of valuation is to estimate the tradeoffs that individuals are willing to make.

7 These definitions apply when X is something seen by the individual as beneficial. If X is something that is harmful, the WTP value of X is the maximum amount of numeraire that the

values of X are what the person would exchange for X *if this were feasible*. If not an actual transaction, it is a thought experiment on the part of the individual.

The WTP and WTA values of a particular item are generally not the same. When they are different, economic theory predicts that the WTP value is often likely to be smaller than the WTA value.[8] If the WTP and WTA values differ, which measure to use is a legal or moral judgment rather than a matter of economic theory. Suppose that X is something desirable. If the individual is not considered legally or morally to be entitled to X, then his WTP value for X is likely the more relevant. But, if the individual is considered entitled to enjoy X, then his WTA value is likely the more relevant.

This conceptual framework, measuring an individual's value for an item as either the most he would be willing to give up to obtain X or the minimum compensation he would be willing to accept to forego X, with money (or time) as the numeraire, is applicable in principle to many items that people may value, regardless of whether or not they gain access to the item commercially through a market. It has been widely applied to value many things not for sale in the marketplace, including health outcomes, cultural and historical artifacts, public goods, and social programs provided by governmental or non-governmental, non-profit organisations. The framework, first articulated by Maler (1974), is the logical extension to non-market items of how economists conceptualise the valuation of marketed commodities.

The economic value of any item is not the same as its price. First, the item may not have a market price but is still of value to the person experiencing it. For example, a person may place a value on living in a better place with better weather. In that case, the trade-off is a thought experiment – if I could exchange a quantum of my income to secure better weather, just how much income would I be willing to exchange? Second, even if the item does have a market price, the individual may be willing to pay *more* than the price, and this extra payment is part of its value to the person. The cost of an item and what it is worth to me are two distinct concepts, just as supply and demand are distinct concepts. Something may be expensive, but I place

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individual would be willing to pay to avoid X, and the WTA is the minimum compensation that the individual would be willing to accept to endure X.

8 The theory underlying this issue is laid out in Michael W Hanemann, 'The economic theory of WTP and WTA' in Ian Bateman and Ken Willis (eds), *Valuing the environment preferences: Theory and practice of the contingent valuation method in the US, EC and developing countries* (Oxford University Press 1999) and Michael W Hanemann, 'Willingness to pay and willingness to accept: How much can they differ?' (1991) 81 American Economic Review 635. The WTP value is smaller than the WTA value if the individual's preferences for the item display a diminishing marginal rate of substitution and the item has the property that the demand for it increases, rather than declines, with the individual's income. There is no difference between the WP and WTA values if the individual's preferences are such that income is seen as a perfect substitute for X.

a low value on it. Something may be cheap, but I place a very high value on it. Therefore, price does not, in general, measure value to the consumer.[9]

Economic theory assumes that people behave purposively and consistently and that they have preferences that both motivate their actions and are revealed through those actions, whether in the marketplace or another setting, including a survey or an experiment. While economics does not prescribe what preferences people should have, it does provide a framework for classifying different preferences according to their economic implications.

People can value a thing for multiple reasons and from multiple motives. The value a person places on an item overall, reflecting all her motives, is referred to as her *total economic value* for the item.[10] Economists make a distinction between two components of total economic value: *use value* and *non-use value*.[11] A person's use value for an item is the value that she places on the item from motives connected with someone's use of the item, whether her own use or that of someone else. Non-use value is the value she places on an item from motives not directly connected with the use of that item by anybody in any tangible way. I may value the preservation of the Grand Canyon in Arizona and be willing to contribute money to secure this because I want to be able to go there in the future, or I want my grandchildren to be able to go – those are examples of a use value. Alternatively, I may be willing to give money to protect the Grand Canyon because I see it as a wonder of nature and an iconic item in this country's natural heritage. For me, it has an intrinsic value, regardless of whether people visit it. This is a non-use value, also called an existence value or a passive-use value. Typically, use values involve some human 'interaction' with the item, whereas non-use values do not.

Both use value and non-use value are measured through an exchange – trading off a change in the amount of the item being valued, whether for its use value, its non-use value, or both (its total economic value) for an exchange of something else of value (money, time). But, the distinction has economic significance because the trade-off used to measure use and non-use value cannot be implemented in the same way; it has to be measured differently. The two methods of measurement are known as *revealed preference* and *stated preference*. Collectively, these are referred to as non-market valuation.

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9 Cost and value coincide only if I am making a fine-grained choice of how many units to buy. In that case, under the assumption of diminishing marginal utility, it is a plausible presumption that the marginal value to me of the *last* unit I purchased just equals the unit's cost, which is why I stopped buying with that unit. The earlier units that I bought would have been more valuable to me than their cost, which is why I kept on buying more units.

10 This may be measured as either a WTP value or a WTA value.

11 The distinction was originally due to John V Krutilla, 'Conservation reconsidered' (1967) 57 American Economic Review 777.

To measure economic value, economists need to find a trade-off. With the revealed preference approach, one finds data on choices that the individual (or others like her) have made that involve a trade-off between money (if that is the numeraire) and the item to be valued or something close to it. Those choices will typically have occurred in some form of market or commercial transaction. A researcher obtains transactions data and estimates a demand function that represents the choice behaviour observed in the data. With the demand function estimated, economic theory provides a pathway to infer the particular utility function that could have generated the estimated demand function, from which WTP and WTA measures can be estimated for various potential changes involving the item whose demand function has been estimated. The key is to have obtained an accurate and complete representation of the consumer's choice behaviour.[12]

With the stated preference approach, a researcher engages with a sample of subjects in the context of a survey or an experiment and presents them with one or more explicit trade-offs in which they reveal their WTP or WTA values, depending on the design of the trade-off. Econometric estimation of the responses permits WTP or WTA values to be extrapolated to a larger group. The key is to design and implement a survey in such a way that respondents see what they are offered as a real trade-off, understand it correctly, and respond thoughtfully and to the best of their ability.[13]

Thus, with revealed preference, the researcher finds choices that exist in the marketplace, or at least extrapolates from marketplaces choices, and uses assumptions to identify the underlying preferences from which WTP or WTA values can be inferred. With stated preference, the researcher creates choices trade-offs for subjects in a survey or experiment that more directly reveal their WTP or WTA values.[14]

Since non-use values are rooted in motives not connected with the use of the item in any tangible way, they cannot be measured through the revealed preference approach, since that is based on observed uses alongside observed market prices from which a demand function can be estimated. Thus, stated preference is required to estimate non-use values. Typically, the stated preference approach will be framed in such a way that it measures respondents' total economic value for the item in question, i.e., use value plus non-use value combined.

From my own experience in having contributed to the development of both stated preference methodology and revealed preference methodology, I would say that both

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12 This necessarily relies on assumptions and judgments made by the researcher, including the mathematical form of the demand function, as well as judgments made regarding estimation procedures. Such judgments crucially affect the valuation results.

13 As will be mentioned below, the NOAA Panel on Contingent Valuation (1993) specified strict requirements for a valuation survey to be deemed reliable.

14 Patricia A Champ, Kevin J Boyle and Thomas C Brown (eds), *A primer on nonmarket valuation* (2nd edn, Springer 2017) is an excellent guide to revealed and stated preference and their implementation.

approaches present challenges. Both can be done badly, and both can be done well. Both call for good judgment on the part of the researcher and attention to detail. To do either well can take a significant investment of time and resources. All the more so if data collection is required, regardless of whether this is revealed preference data or stated preference data.

Because of the cost and time involved, there is temptation to look for a shortcut. One shortcut, often used, is *benefit transfer*. Benefit transfer takes an existing estimate of economic value developed for a different population, at a different time, and perhaps for a different but related item at a different location, and attempts to extrapolate ('transfer') that estimate of value to the item in question. There are two ways of doing this. A value transfer takes a specific estimate of value and applies it, possibly with some adjustment. A function transfer uses an estimated equation to predict a customised value for the intended application. As with any extrapolation, the quality of the resultant value estimate depends on the validity of the extrapolation. This can often be a leap of faith.

3 How non-market valuation is used

As mentioned, non-market valuation incorporates the economic concept of value and the economic methods of valuation that are used for market commodities and extends them to anything that humans value, whether market or non-market. With both market and non-market valuation, there are several contexts in which the economic quantification of such values is useful or even necessary, such as informing public policy decisions, including cost-benefit analysis, improving private sector decision making, and supplying the information needed in litigation, including the assessment of compensation for damages.

In the US, the requirement for cost-benefit analysis in rulemaking began in 1981 with President Reagan's Executive Order 12291. That order directed cabinet departments (but not independent regulatory agencies) to refrain from taking regulatory action 'unless the potential benefits to society for the regulation outweigh the potential costs to society.' It also required agencies to prepare a 'regulatory impact analysis' for each 'major' rule, defined as any regulation likely to result in an annual economic impact over $100 million. This order was replaced by President Clinton in 1993 with Executive Order 12866, which established similar (but not identical) analytical principles and requirements. Agencies were directed to

> assess all costs and benefits of available regulatory alternatives, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures (to the fullest extent that these can be usefully estimated) and qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider. Further, in choosing among alternative regulatory approaches, agencies should select those approaches that maximise net benefits (including potential economic, environmental, public health and safety, and

other advantages; distributive impacts; and equity), unless a statute requires another regulatory approach.

Many of these principles were re-iterated in President Obama's 2011 Executive Order 13563, which required agencies, to the extent permitted by law, to 'propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs.'

The reference to 'unless permitted by law' highlights the fact that agencies implement laws passed by Congress. Some statutes have required cost-benefit analysis, other statutes have prohibited it, and yet others were silent and did not preclude it. For example, the 1990 Clean Air Act Amendments required the US Environmental Protection Agency (EPA) to develop periodic reports of the Act's benefits and costs, although it specifies that the costs any regulation promulgated should not be used to block the EPA from its central mission to protect 'human health and welfare.' A degree of equivocation regarding the proper role for cost-benefit analysis still persists. On one side, there is the view that regulation should be discouraged unless the quantified benefits exceed the costs.[15] On the other side, some hold that not all socially important benefits can be quantified adequately, nor should they be. The upshot is that, while cost-benefit analysis is now an established item in regulatory policymaking in the US, sometimes it serves more to inform decisions than to drive them.

While the use of non-market valuation for compensation of certain environmental damages commenced in the US around the same time, in the 1980s, it has experienced a more turbulent history.

But first: how were violations of US environmental laws handled before the 1980's? To the extent that environmental laws were being enforced, which, especially for the Clean Water Act, was not so much,[16] the main thrust was sending notices, issuing warnings and other informal efforts to bring violators into compliance. In the event of persistent non-compliance, there could then be administrative, civil, or, very rarely, criminal actions. In the case of administrative and civil judicial actions, penalties could be assessed up to prescribed maxima per violation per day. Aside from a monetary penalty, a violator might be required to make payment based on a spreadsheet model used by the EPA to estimate (very crudely) the amount of profit that might have been earned by not complying with environmental regulations. There was

15 President Trump held an extreme version of this view. His 2017 Executive Order 13771 directed agencies to 'cap' the total costs imposed by all their new regulations each year, regardless of benefits, and required that, whenever an agency proposed a new regulation, 'it shall identify at least two existing regulations to be repealed.' This order was rescinded by President Biden on his first day in office.

16 Clifford Rechtschaffen, 'Enforcing the Clean Water Act in the twenty-first century: Harnessing the power of the public spotlight' (2004) 55 Alabama Law Review 775.

no provision for any payment based on the amount of the environmental damage caused by the violations.

This changed for a particular type of pollution event with the enactment in 1980 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, Superfund Act) and its reauthorising amendments, the Superfund Amendments and Reauthorization Act (SARA) of 1986.[17] Prompted by the infamous Love Canal, a housing development located on what had been a dumpsite for 21,000 tons of chemical wastes, including a dozen known carcinogens, CERCLA covered the release of hazardous substances that could endanger human health and/or the environment. It gave specific authorisation for the federal government and state governments to intervene and manage the response to a release of hazardous substances, and it created a specific liability of the potentially responsible parties to pay the costs of clean-up and restoration, relaxing certain liability limitations, standards for establishing causation and common law evidentiary barriers. An additional provision, little noticed at first, made the responsible parties liable for damages to public natural resources, and it designated the federal government, or state governments as its delegates, to recover those damages as trustees for the affected natural resources. Both concepts – trusteeship and damages for injury to natural resources – were novel legal developments.

The US Department of Interior (DoI), designated by CERCLA to develop regulations for assessing natural resource damages, was less than enthusiastic. The regulations, issued in 1987, restricted damages to market valuation of use values and stipulated that public trustees claim only the *lesser of* the diminution of use value resulting from the release or the cost of restoring the affected resources, thus precluding restoration if it cost more than the lost use value.[18] These regulations were invalidated by the Court of Appeals in July 1989 (the *Ohio* ruling) as inconsistent with what Congress had intended.[19] Trustees should claim for non-use value (which the Court called 'passive lost use value') using the suite of non-market valuation methods, and they were allowed to favour restoration unless the cost was 'grossly disproportionate' to the benefit.

The *Ohio* ruling came shortly after the *Exxon Valdez* oil spill in Alaska in March 1989, which had momentous consequences. CERCLA actually did not cover the Exxon Valdez spill since oil spills had specifically been excluded from its coverage.

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17 The enforcement situation has *not* changed for violations of the Clean Air Act and other environmental laws, or for violations of the Clean Water Act other than releases of hazardous substances.

18 CERCLA called for two types of assessment: 'Type A' involving a standardised procedures and minimal field observations for the case of a minor discharge; and 'Type B' involving a detailed site-specific, assessment following major events. My focus here is the rules for Type B assessments contained in 52 FR 9042.

19 880 F.2d 432 (D.C. Cir. 1989).

To remedy this, Congress passed the Oil Pollution Act of 1990. In a possible rebuke to DOI, this designated the National Oceanographic and Atmospheric Administration (NOAA) as the primary federal trustee for injuries to marine and coastal resources. It also expanded the range of liable damages, and it mandated that damage assessment be conducted along the lines prescribed in the *Ohio* ruling.

The Exxon Valdez spill triggered what has been called an 'assessment war' in which the federal government with the state of Alaska and Exxon each conducted competing damage assessments. For damage valuation, Exxon measured lost recreational use value while launching a full-scale public relations campaign against non-use values as measured by contingent valuation, featuring the inadequacies found in poorly-designed contingent valuation studies which it had sponsored (covering items unrelated to the oil spill). In contrast, Alaska's team (of which I was part) advanced the state of the art in designing and implementing a contingent valuation study focused on the oil spill. While this was going on, there was heavy industry lobbying of NOAA as it developed the guidelines it would promulgate for damage assessment. To buy time, in April 1992, NOAA convened a Blue-Ribbon Panel of distinguished economists to advise whether, and under what circumstances, contingent valuation could be used to measure non-use value for the purposes of natural resource damage assessment. The Panel's report, released in January 1993, upheld the application of contingent valuation for non-use value providing the study followed strict guidelines which largely followed the protocols that we had developed in our study for the State of Alaska.[20] Under those conditions, the Panel found that estimates of value developed through contingent valuation convey useful information which is reliable by standards used for assessment of other damages normally allowed in court proceedings.

While NOAA was gearing up to formulate its damage assessment rules under OPA, DOI was revising its CERCLA damage assessment rules to comply with the *Ohio* ruling. In April 1991, it had issued a notice of proposed rulemaking describing how it would proceed.[21] It noted that contingent valuation was expressly upheld in the *Ohio* ruling and, therefore, constraints on using that would be deleted. However, in January 1993, just days after NOAA's Blue Ribbon Panel's released its report and days before President Bush left office, DOI sent over to the Federal Register a set of rules for damage assessment that severely limited the use of contingent valuation. The rules were immediately withdrawn by the new Clinton administration. This was raised as an issue when DOI released its final rules in March 1994.[22] DOI's new rules accepted CERCLA's preference for restoration as the appropriate measure of damag-

20 One of the Panel's many recommendations was that, to be conservative, the WTP measure of value be used and not the WTA measure.

21 56 FR 19752.

22 59 FR 14262.

es. But, pending completion of the restoration, there will be an interval during which the resources would be partially unrestored. The DOI rules provided for monetary compensation for that interim diminution in resource value, independent of and in addition to the cost of restoration.[23] Monetary compensation for what is called *interim lost value* could include non-use value (measured through contingent valuation) as well as use value. Industry groups challenged these rules on several grounds, one being that they had been harmed by the rule withdrawal in January 1993 since the withdrawn rules would have lowered the compensatory damages to which they might become exposed. In July 1996, the Court of Appeals rejected those claims.[24]

Meanwhile, NOAA was changing its position rather along the lines proposed by industry (unsuccessfully) to the Court of Appeals. NOAA had released its proposed damage assessment rules in January 1994, which largely resembled the rules released by DOI in March 1994.[25] But it then 'fundamentally restructured' its approach to damage compensation. Whereas the purpose previously stated was 'to make the public whole' through a combination of restoration and monetary compensation, the new version, re-proposed in August 1995,[26] focused primarily on making *the environment* whole through restoration, including perhaps some natural recovery. Monetary compensation for interim lost value was largely replaced with some additional quantum of ecological restoration.[27] The final OPA rules, issued in January 1996, embodied the changes proposed in 1995.[28] In 2008, DOI revised its CERCLA assessment regulations to align them more closely with the OPA regulations, replacing the possibility of monetary damages for interim lost value with some additional quantum of ecological restoration.[29] This is where the CERCLA and OPA damage assessment rules remain today.

Most damage assessments conducted under CERCLA and OPA since 1996 have followed the spirit of the OPA regulations, focusing on restoration and eschewing monetary compensation for interim lost value. However, there have been exceptions

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23 Restoration would be to conditions as they would be but for the release/incident.
24 88 F.3d 1191, 1220 (D.C. Cir. 1996).
25 59 FR 1061.
26 60 FR 39804.
27 If needed and judged reliable, contingent valuation or conjoint analysis could be used, but only to scale the level of compensatory restoration for interim lost value – not to monetise compensation for damages. With contingent valuation, respondents would be given a tradeoff between expedited restoration at a cost to taxpayers versus slower, natural recovery at no cost. With conjoint analysis, respondents would be making a tradeoff among alternative ecosystem services or attributes; they would not be trading off ecosystem services against money. If compensation for damages were monetised, the funds recovered would still have to be spent on restoration. But, the new version of the rules encouraged direct calculation of the additional restoration needed to cover interim lost value, and the cost thereof, rather than explicitly calculating the value to the public of the interim lost value.
28 61 FR 440.
29 73 FR 57266.

where interim lost value was monetised for use values and/or non-use values, using contingent valuation for the latter, including several in which I have participated for state and federal trustees. By far the largest example is the damage assessment following BP's Deepwater Horizon in the Gulf of Mexico in 2010, in which I participated. There, revealed preference was used to monetise interim lost recreational use value and contingent valuation to monetise interim lost non-use value for ecosystem services. But, this was an exception to the general practice.

In summary, monetising non-use value by stated preference in the US is a standard feature of the landscape in cost-benefit analysis for policymaking and regulatory analysis but not for the assessment of compensation for natural resource damages. The use of contingent valuation was upheld by the Court of appeals in its Ohio ruling in 1989 and in its Kennecott ruling in 1996, and by NOAA's Blue Ribbon Panel in 1993. Yet, its use for damage assessment under OPA and CERCLA is now limited almost as strictly as under the original 1987 CERCLA regulations that prompted the *Ohio* ruling.

Conducting a stated preference survey to the meticulous standards prescribed by the Blue Ribbon Panel is expensive, and this certainly would not be reasonable for smaller incidents. But, the aversion to deploying stated preference goes beyond that. Why?

One factor is the common preference on the part of government attorneys to avoid trial and obtain a settlement of their damage claims. From my own experience, I know that, psychologically, it is easier to persuade a responsible party to make a payment of $X million because there is this set of restoration actions that need to be undertaken, and their cost amounts to $X million, rather than because some economist has conducted a measurement exercise which shows that the public values the loss at $X million.

Another factor is a strong preference for restoration, which is hardly inexplicable or unreasonable. In addition, there is some animus against monetising nature. An example is Seevers (1996), who lauds NOAA's decision to 'sideline' monetary valuation in favour of compensatory restoration which, he asserts, better accounts for 'the diverse ways' in which people value natural resources and promotes a more satisfactory balance 'between protecting the environment and promoting commercial activity.' Damage assessment, he concludes, quoting NOAA, is 'not about collecting money.' To the contrary, in my view, damage assessment *is* about collecting money since restoration costs money, and all the money collected for natural resource damages is required to be used for restoration. The real questions are: (1) How much money should be collected? (2) How does one determine that amount, especially with respect to interim lost value?

Some critics of economic valuation have asserted that compensation for interim lost non-use value should be determined by a judge or jury as the fact finder, which is done in all tort cases that allow plaintiffs to be compensated for noneconomic

injuries.[30] This overlooks a fundamental conceptual distinction between the injury suffered by a plaintiff in those cases and the interim lost non-use value of a public natural resource. The non-economic injury suffered by the tort plaintiff, while a non-market good is conceptualised in economics as a *private good*, it is both rival and excludable. The lost non-use value of a public natural resource is a *public good*; it is both non-rival and non-excludable.[31] The implication is that if harm to a public natural resource reduces the well-being of one member of the public, it can do so also for other members of the public.[32] While a tort plaintiff can offer testimony about a non-economic injury and be cross-examined before a judge or jury as fact finder, this is not possible for injury to a public good. In fact, the closest thing to such testimony is the documented responses collected from a survey of the public designed and implemented according to the strict standards set forth by the NOAA Blue Ribbon Panel.

However, because interim lost non-use value is a public good, it is susceptible of large damages. Far more people may be affected by an injury to a public good than the number affected by the same injury to a private good, rendering the potential compensation correspondingly larger. You can say that the need to restore an injury to nature is the same regardless of whether a small or large number of people care for the resource. But, as a public good, the interim lost non-use value – the loss to the public before nature is restored (assuming that it can be restored) – is *not* the same regardless of the size of the public.[33] This accounts for the unrelenting industry pressure on DOI and OPA to limit or exclude monetisation of interim lost non-use value.[34]

Industry has succeeded in propagating the view that measuring non-use value by contingent valuation is too controversial to be a practical option.[35] It has established a

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30 Allan Kanner and Tibor Nagy, 'Measuring loss of use damages in natural resource damage actions' (2005) 30 Columbia Journal of Environmental Law 417.

31 By contrast, interim lost use value is a private good.

32 This does not imply that all members of the public lose wellbeing when a public good is damaged. Preferences vary, and some people may not care at all for that public good. Generally, the only way to determine what economists call the extent of the market for a public good – the number of people who place a non-zero value on it – is through a survey.

33 Interim lost value is inherently an anthropocentric concept, not an ecocentric one.

34 Richard B Steward, 'Evaluating the present natural resource damages regime: The lawyer's perspective' in John Daniel Ballbach and Richard B Stewart (eds), *Natural resource damages: A legal, economic and policy analysis* (National Legal Center for the Public Interest 1995) described the use of contingent valuation is the single most controversial issue in natural resource damage assessment, and that accords with my own experience.

35 As an example, having mentioned critics who would forego reliance on contingent valuation evidence because it is controversial and subject to claims it is grossly unreliable; Robert Force, Martin Davies and Joshua S Force, in 'Deepwater horizon: Removal costs, civil damages, crimes, civil penalties, and state remedies in oil spill cases' (2011) 85 Tul L Rev 889 add the observation that they are unaware of any reported decision that has based damages on evidence from contingent valuation. While the statement is correct, it overlooks the fact that almost every natural resource damage case ended through settlement rather than through the de-

dogma that monetising non-use value will fail in court.[36] The government trustee attorneys are often not experienced as trial lawyers, and this makes them risk-averse. They have largely been intimidated by industry into shying away from monetisation of damages in favour of a tally of restoration costs. That would not matter if the restoration adequately compensated for the damage to the public, but it is unclear that this is the case.

4 Damages from climate change

To an economist, monetising damages from climate change is in principle no different than monetising other outcomes that change people's level of well-being - it is no different with regard to the type of impacts involved, the type of data needed, or the methods of economic measurement deployed. Climate change may affect people in diverse ways, benefiting some people but harming others. In some cases, it is their livelihood that is affected; in others, it is their health, access to food or clean water, the amenity of life, or the natural environment around them. The changes that affect human well-being can be classified as market and non-market. The market effects involve changes in market prices, changes in revenue and net income, changes in the quantity or quality of market commodities, or changes in the availability of commodities. Non-market changes are changes in the quantity, quality or availability of things that matter to people, even though they are not obtained through the market.

A given change in a physical or biological system can generate both market and non-market impacts on human well-being. For example, an episode of extreme heat in a rural area may cause heat stress for exposed farm workers and dry up a wetland that serves as a refuge for migratory birds, while killing some crops and impairing the quality of others that survive. From an economic perspective, the damages would be conceptualised as a loss of income for farmers and farm workers; an increase in prices of crops for consumers and/or a reduction in their quality; and non-market impacts, including the impairment of human health (though some of these effects may be captured in the wage of farm workers) and ecosystem harm.

While valuing these things in the context of climate change impacts is no different than valuing them in other contexts, whether cost benefit analysis, project appraisal, or assessment of natural resource damages, the spatial and temporal scales on which these things are being evaluated can be utterly different, depending on the focus of the analysis. Thus, the valuation of damages from climate change has been conducted

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cision of a judge or jury following a trial, Karen Bradshaw, 'Settling for natural resource damages' (2015) 40 Harvard Environmental Law Review 211.

36 This is true whether non-use value is monetised by contingent valuation or by conjoint analysis trading off ecosystem services against money.

on two scales: a macro scale purporting to monetise all impacts globally, and a micro (local) scale evaluating particular impacts at particular locations at particular points in time.

The macro scale analysis takes the form of a damage function embedded in an integrated assessment model (IAM), the main versions of which are the DICE model developed by William Nordhaus, and its regionally disaggregated sibling, RICE; PAGE, developed by Chris Hope; and FUND, developed by Richard Tol. These models were developed in the 1990s[37] and, while they have undergone various refinements and updates, their general structure has remained the same. They combine three main components: (1) a model of economic activity in a region at a point in time, which culminates in the generation of greenhouse gas emissions; (2) a model of the global carbon cycle which tracks how those emissions accumulate in the atmosphere, leading to a change in radiative forcing and from that to a change in the global climate, typically summarised through the global average annual temperature in a given period; and (3) a damage function, or set of damage functions, which translates the change in global average annual temperature to an overall economic impact or sectoral economic impacts, represented as percentage reductions in annual GDP. The IAMs march through time, typically on a multi-annual time step, from, say, 2000 through 2300. The spatial unit of analysis in DICE and PAGE is the entire world; in RICE and FUND the world is divided into broad regions (12 regions for RICE, 16 for FUND).

In DICE, there is a single damage function for the reduction in overall global GDP. In PAGE, there are four separate global damage functions for different categories of global damage. In FUND, there are eight sectoral damage functions for each world region. These IAMs have been deployed to calculate what is known as the social cost of carbon (SCC). The SCC measures the economic value of the marginal global damage associated with an increment in CO_2 emissions in a specific time period (regardless of the location of the emissions). Specifically, the SCC is the discounted present value of the stream of annual economic values measuring (via the damage function) the increment in annual damages due to the change in global annual average temperature resulting from the initial one-time increment in emissions. An estimate of the SCC based on averaging DICE, PAGE and FUND has been used in the US since 2010 for regulatory review of proposed major regulations. Since it monetises impacts occurring over a long span of time (through 2300, say), the numerical value of the SCC depends crucially on the discount rate used to calculate present value. The Obama Administration used discount rates of 2.5%, 3% and 5%, with 3% as the central value; the Trump Administration used discount rates of 3% and 7%, with 7% as the central value; the Biden Administration restored the Obama

37 DICE was first published in 1993, PAGE in 1993, FUND in 1995 and RICE in 1996.

discount rates.[38] In addition, the Trump Administration allowed only climate damages in the US to be counted, which lowered the SCC value by about 85%.

However, the IAM damage functions are problematic. They are a postulated relationship connecting changes in regional or global average annual temperature with changes in regional or global GDP. This is a long-run relationship, and a global one. There is no historical data from which it could meaningfully be estimated. Instead, the existing damage functions are speculation on the part of the individual IAM model developers. When the IAMs were first developed in the 1990s, the developers drew on the extant literature, which then contained about thirty economic micro scale studies monetising particular types of climate impacts at particular locations, from which they then extrapolated to a global damage function. Since then, the economic literature on climate change impacts has mushroomed. In 2013, almost 400 studies monetising climate change impacts were listed in the Web of Science under the search terms 'climate change', 'economic' and 'damage'. Today, over 2,000 such studies are listed. However, the IAM developers have not kept abreast of this literature, and the IAM damage functions no longer reflect what is found in micro-scale case studies of damages.[39] Over time, the IAM developers have idiosyncratically adjusted their IAM damage functions by themselves. They have done so, in my opinion, in a manner that seems, at best, ill-informed and, at worst, highly erratic. Consequently, it is not clear to me that the IAM estimates of the SCC would stand up well in litigation.[40]

Another problematical factor is the uncertainty pervading IAM projections – not the uncertainty about climate change per se but rather the myriad uncertainties in projecting the future trajectory of global emissions over three centuries, future technology, future adaptations, future physical and biological impacts, and future anthropocentric valuations of those impacts. Moreover, because discounting is involved, the specific timing and pace of future impacts greatly affect the calculation of SCC.

Thus, plaintiffs in litigation for damages for climate change are better served by focusing on specific impacts at specific locations in a near-term time frame that are well documented in – or amenable to reasonable extrapolation from – micro-scale studies monetising local impacts. In fact, these studies are highly similar – in methodology if not in their topical focus - to the studies conducted for the cost-benefit analysis of government regulations and investment, and to monetise natural resource damages from oil spills or releases of hazardous substances.

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38 The discounted present value today of $100 in 2100 is $13.87 using a 2.5% discount rate, $9.40 using 3%, $2.02 using 5%, and $0.45 using 7%.

39 In my view, the damage functions are likely to understate the overall impact of global warming.

40 I had some experience of this in 2015 when I testified in defence of the Obama SCC estimate before the Minnesota Public Utility Commission.

5 Conclusion

To summarise: monetising damages from climate change draws on concepts and methodologies that have now been used and accepted in economics for more than fifty years. In the US and the EU, these are commonly used for policy assessment and investment appraisal. Their use in litigation for natural resource damages resulting from oil spills or the release of hazardous substances is more constrained. Instead, the main thrust of damage assessment in that context has been to focus on restoration of the injured natural resources. In the context of climate change, however, focusing on compensatory restoration would quite often be a lost cause. A different strategy will generally be needed to value the damages from climate change that entails squarely facing up to the challenge of deploying stated preference to monetise losses to public goods. I believe that, when needed, this can be done successfully to the high standards laid down almost thirty years ago by NOAA's Blue Ribbon Panel.

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