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ANALYSIS

Valuing Health Impacts In Climate Policy: Ethical Issues And Economic Challenges

ABSTRACT Deciding which climate policies to enact, and where and when to enact them, requires weighing their costs against the expected benefits. A key challenge in climate policy is how to value health impacts, which are likely to be large and varied, considering that they will accrue over long time horizons (centuries), will occur throughout the world, and will be distributed unevenly within countries depending in part on socioeconomic status. These features raise a number of important economic and ethical issues including how to value human life in different countries at different levels of development, how to value future people, and how much priority to give the poor and disadvantaged. In this article we review each of these issues, describe different approaches for addressing them in quantitative climate policy analysis, and show how their treatment can dramatically change what should be done about climate change. Finally, we use the social cost of carbon, which reflects the cost of adding carbon emissions to the atmosphere, as an example of how analysis of climate impacts is sensitive to ethical assumptions. We consider $20 a reasonable lower bound for the social cost of carbon, but we show that a much higher value is warranted given a strong concern for equity within and across generations.

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Climate change will alter patterns of exposure to many important human health risks. In some cases, this will occur through relatively direct pathways—for example, by increasing exposure to high outdoor temperatures, which is associated with morbidity and mortality from a variety of causes.[1,2] Other health impacts will be more indirect. Vectorborne disease dynamics, for instance, may be affected through changes to vector survivability, habitat suitability, or biting rate.[3] Nutrition-related outcomes may be altered by similarly complex pathways, including through food production via changes in rainfall, temperature, pest dynamics, and carbon dioxide concentrations, as well as challenges to food storage and distribution.[4] Extreme weather events, which are projected to increase in many locations, bring both direct (for example, injuries from flooding) and indirect (for example, crop destruction, sitting water) impacts.[5]

There is a strong consensus in the literature on climate change that the aggregate health impacts will be adverse overall and, similar to many threats to human health, will disproportionately harm those who are already disadvantaged.[6,7] A number of recent studies have estimated health burdens under different potential future climate scenarios,[8–10] consistently finding that the health burdens will be larger at higher levels of warming and that the impacts will only peak many decades from now. The takeaway message is that enacting mitigation policies would be good for public health because reducing our emissions of greenhouse gases will also reduce many health burdens.

If mitigation policies were free, they would all be implemented immediately to prevent future climate harms. Unfortunately, achieving large reductions in greenhouse gas emissions will likely be costly. For example, investments are needed to electrify the vehicle fleet, improve agricultural practices, and build large-scale renewable energy infrastructure. These investments, in turn, will increase the prices of many products and thus affect people's everyday lives. Similar to the harms from climate change itself, the costs of mitigation policy, if it is poorly designed, may also excessively burden disadvantaged populations, who tend to spend more of their incomes on energy and food.

This tension between the costs of mitigation and the costs of climate change is the key tradeoff underlying the climate problem: How much should be spent now to reduce climate change later? Or put another way, what climate target should be pursued? Should the world hold warming to 1.5–2°C, as outlined in the Paris Agreement? Or is that too strict—or not strict enough?

If the policy were costless, decision makers would want to choose the lowest possible climate target, as it would prevent the greatest number of premature deaths. But climate change policy must strike a balance between avoiding premature deaths and the costs of the policy itself. The ongoing coronavirus disease 2019 (COVID-19) outbreak provides a salient example. The solutions—including social distancing, stay-at-home orders, and travel restrictions—entail massive unemployment, economic loss, and mental health burdens. Bad climate mitigation policy, or too much of it, could create a comparable situation by mandating stringent and costly economic and lifestyle changes.

If the health impacts of climate change were the only concern, the health benefits of different levels of mitigation—different climate targets—could be estimated in terms of cost per life or life-year saved, compare the options against each other and against other potential public health interventions, and choose the mitigation level that provides the most value for the least cost. But climate change will likely produce an assortment of impacts beyond human health, such as property damage from storms and sea-level rise, reduced labor productivity from heat exposure, yield changes in forestry and agriculture, and a cascade of ecosystem impacts.[11] To complicate matters further, the impacts will affect all countries in the world and will manifest over decades and centuries, affecting future generations of people not yet born. Setting a rational mitigation policy for climate change therefore requires an analysis that accounts for multiple dimensions of impact (health and nonhealth) across countries and subpopulations over long time horizons.

This article describes how these issues are commonly approached in the cost-benefit climate policy models that are routinely used by governments in regulatory analysis, including to estimate the social cost of carbon. We describe the cost-benefit analytic framework and explain how a best-practices approach goes beyond simply adding up the dollar value of the impacts, which ignores their distribution. We discuss technical aspects of the cost-benefit analysis of climate change, including the thorny issue of how to convert deaths to dollars and whether it is defensible to assign different monetary values to avoided deaths in other countries or far in the future. We discuss the critical process of converting the monetized impacts into well-being. In the final section we provide an illustration of these concepts and their importance, using the example of the social cost of carbon, including a discussion of the extent to which health impacts are properly accounted for and evaluated. The main goal of this article is to provide a critical description of economic methods routinely used to recommend climate policies, and the role of ethics and health within that framework, to help decision makers and other interested parties interpret and use such analyses.

A Cost-Benefit Framework For Climate Policy Analysis

Cost-benefit analysis of climate policy is commonly conducted through the use of integrated assessment models. These models link economic projections to a climate module to capture feedbacks between the two: economic activity produces emissions, which cause climate change, which in turn harms the economy and nonmarket goods such as health and recreation. Several such models exist, but the three most prominent are the Dynamic Integrated Climate Economy (DICE) model (and its regional counterpart, RICE); the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model; and the Policy Analysis of the Greenhouse Effect (PAGE) model.[12–14] These models have been used by multiple governments, including in the US and the UK, to estimate the social cost of carbon. The ambitious nature of these modeling exercises requires a variety of inputs including atmospheric dynamics in the climate module, socioeconomic projections, estimates of the harms to health and the economy from climate change, and estimates of the costs of climate policy. In an effort to strike the right balance between complexity and simplicity, many of these features are represented in a reduced-form way. For example, many models separate the world into regions and thus do a poor job at capturing the distribution of impacts within a region. However, the models have many powerful features, including an ability to identify mitigation trajectories that maximize net benefits.

In evaluating the outcomes of different policies, the models take a consequentialist-utilitarian perspective, whereby an outcome is considered good only insofar as it contributes to the economic definition of well-being, which is measured by utility, or satisfaction of one's preferences. Because each additional unit of a good generates less well-being the more the recipient already has (as per the diminishing marginal utility of consumption), resources for the poor generate more well-being than the same resources for the rich. Notions of harm, right, and duty are excluded from the evaluation. Only the policy outcomes matter, measured in terms of well-being impacts, with the feature that policies that benefit mainly the poor generate more well-being than policies that benefit mainly the rich.

Suppose we want to assess whether the world should limit global temperature rise to 2°C. The predominant cost-benefit climate policy models[12–14] address this question in the following way: step 1, estimating all of the foreseeable avoided climate impacts if the temperature target is achieved; step 2, determining how the avoided impacts improve people's lives and converting the gains into monetary equivalents; step 3, estimating the economic burden that would result from implementing the policy; and step 4, comparing the costs and the benefits of the policy, taking into account when they occur (now or in the future) and to whom they occur (to poor or rich individuals or countries). These steps are presented diagrammatically in section 1 of the online appendix.[15]

Climate impacts (step 1) include how greenhouse gas emissions gradually increase average temperature and sea level, change rainfall patterns, and cause ocean acidification. Consequences of these climatic changes will include higher human mortality, property damage, biodiversity loss, reductions in agricultural production, and other negative impacts. Monetization (step 2) is essential because it converts all dimensions of climate impacts into a single metric, thereby making it possible to compare the different types of costs and benefits. Because cost-benefit climate models assume that greenhouse gas emissions fuel the economy, reducing them will generate economic costs, at least in the short term (step 3).

Once all of the positive and negative impacts of a given policy have been identified, estimated, and turned into monetary equivalents, we can determine whether the benefits outweigh the costs (step 4). In cost-benefit climate policy models, costs and benefits are not simply summed up, which is often done in regulatory cost-benefit analysis. Rather, the aggregation accounts for two main factors: when the costs and benefits occur and who enjoys the benefits and pays the costs (and, in particular, if it is a richer or a poorer person or country). This reflects the fact that the assumed ultimate objective of the policy is to improve people's lives rather than to prevent climate change per se; therefore, the "who" and the "when" matter. This aggregation step, which converts the monetized costs and benefits into well-being impacts, distinguishes our framework from the crude method of comparing monetized impacts without regard for their distribution.

Formally, the "when" is captured by a term in the model, the rate of pure time preference, which attaches higher importance to benefits and costs occurring in the present rather than the future. The "who" is captured by the assumption of diminishing marginal utility, which assumes that benefits and costs accruing to a poor person or country should matter more than equal monetary benefits and costs occurring to a rich person or country. The reason is that the same benefit to a poor person improves their life situation to a greater extent than it does for someone who already has more. In contrast, harming a poor person worsens their life situation more than harming someone who has a lot.

Leading cost-benefit climate policy models often do not fully take advantage of diminishing marginal utility. Usually these models operate at a very high level of aggregation (the world, or continental scale regions), making them blind to the distribution of outcomes at the local or individual levels. Therefore, the models ignore the equity considerations that arise from them—for example, whether most of the costs fall on the poor or on women or on a particular minority group that is more disadvantaged.

If a policy's benefits outweigh its costs, it does not mean that it is the best policy. For example, even if a 2°C scenario produces net benefits, it is possible that 1.5°C (or 3°C) will produce more net benefits. A further capability of cost-benefit climate policy models is that they can identify the policy that maximizes global well-being through time.

Controversies: Monetization (Step 2) And Aggregation (Step 4)

Monetization (step 2) and aggregation of the monetary value of climate change impacts (step 4) that occur at different periods and to different people are sources of debate in the climate policy community.

MONETIZATION OF LIFE AND HEALTH It is relatively straightforward to estimate the cost, in dollar terms, of lost farming revenue or property damage after a hurricane, because markets for these goods provide a price that reflects their value in terms of how much people are willing to pay for them. For health impacts such as deaths, lost life-years, or years lived with disability, however, there is no market price. A fundamental challenge for choosing a large-scale mitigation response to climate change is how to value these nonmarket impacts, such as health, on the same scale—dollars—as the impacts that can be readily valued using market prices.

The problem of quantifying the monetary value of better health is not unique to climate policy. There is a long, sophisticated literature aimed at determining the value of a statistical life, which has become a key quantity that many governments use to inform investments and regulations that affect public health. The value of a statistical life is determined by estimating how much people are willing to pay to reduce their risk for death by some small probability (see appendix section 2 for an example).[15] The estimate may be based on the judgment of a regulatory agency or produced directly from individual-level information such as data from questionnaires or by observing how much compensation people will accept to do a dangerous job.

One challenge in determining the value of a life lost is how to account for deaths at different ages. It is common practice to apply a constant country-specific value of a statistical life to all individuals in a given country. This approach is problematic because it attaches the same value to the premature death of a twenty-year-old, who can expect to live for sixty or more years, as to that of a seventy-five-year old, who has fewer expected years to live. For example, malnutrition could kill many thousands of children, which would lead to many potential years of life lost per death; however, heat stroke could kill the same number of elderly people, but fewer life-years would be lost because the elderly are more likely to die of other causes relatively soon. Using the value of a life-year avoids this problem by allowing the model to specify policy impacts in terms of years lost rather than in terms of an entire life. Similar principles apply to morbidity or composite measures (for example, disability-adjusted life-years or quality-adjusted life-years). Thus, in evaluations of the health impacts of climate change, acknowledging the age structure of a population is important.

Another challenge in monetizing life is inherent in how the value of a statistical life is determined. People with higher incomes will have higher values of a statistical life because their willingness to pay depends on their ability to pay. For example, a recent analysis estimates the value of a statistical life for an average citizen of the US at around \$10 million and for an average citizen of Poland at around \$2 million.[16] There is some logic in having different values of a statistical life in different countries, as a government's regulatory decisions should be based on the preferences of its own citizens. However, a problem arises in cross-national analysis, where it would be clearly inappropriate to assume that the same investment would be warranted to save one life in the US as five lives in Poland. (That is, to save a life in the US, we would be willing spend five times the amount spent to save a life in Poland.)

In climate policy cost-benefit analysis, this objectionable conclusion can be corrected by modeling diminishing marginal utility, which reflects the varying value of a dollar to different populations. However, how much to correct for this variance is a source of disagreement.

AGGREGATING DOLLARS: ACCOUNTING FOR HETEROGENEITY The aggregation step allows us to translate dollars into well-being, as it is not actually dollars that we are concerned with but, rather, the amount of well-being that those dollars represent.

The aggregation step in cost-benefit analysis sums up monetized impacts in a way that accounts for diminishing marginal utility—the fact that a dollar confers more well-being to a poor person than to a rich person. The aggregation step also accounts for time preference—that a unit of well-being in the distant future is worth less than it is today. In this way, cost-benefit aggregation requires, and is sensitive to, a number of normative assumptions.

▶ **DIMINISHING MARGINAL UTILITY:** Diminishing marginal utility is included in the best-practices cost-benefit analysis through a model term that reflects the elasticity of marginal utility, or the rate at which a dollar is less valuable to increasingly rich recipients. The effect is that, dollar for dollar, more priority is given to poorer people, which is hugely consequential considering that the poor will bear the brunt of future climate impacts. For this reason, the elasticity of marginal utility is interpretable as the degree of aversion to inequality and can compensate for the lower monetary value of lives or life-years assigned to lower-income populations. It also means that when policies are being compared, one that is relatively more costly can still be rated as preferable if the distribution of the impacts is less harmful to the poor.

The results of a cost-benefit analysis are highly sensitive to the selected elasticity, with larger values giving higher importance to the distribution of costs and benefits. Values between 1 and 2 are common, but the exact number is hotly debated. Setting the elasticity to 1 implies the value judgement that a person two times richer experiences one-half the well-being from the same monetary gain or, in other words, that the same health impact (converted into monetary terms) on someone half as rich is twice as important. In this way, the best-practices cost-benefit analysis can value the lives of different individuals the same even if they have very different levels of income. (See appendix section 3 for a brief discussion of the interaction between the value of a statistical life, income, and the elasticity of marginal utility.)[15] An elasticity of 1.5 reduces the well-being benefit to a person two times richer to one-third that of the poorer person. An elasticity of 2 makes it one-fourth (exhibit 1).

In a climate policy analysis, two key dimensions of inequality are influenced by inequality aversion. The first is intragenerational inequality, meaning that within a given time period, some countries and populations are richer than others. The second is intergenerational inequality, meaning that across time periods, some generations are richer than others.

The usual assumption is that, on average, even with climate change, the world will get richer, which means that in the whole of the climate challenge, the present generation is the poorest of all (and the poor of today in particular). Because of diminishing marginal utility, this automatically implies that the same health impact in monetary terms is worth less in the future than it is today. (This conclusion is weakened if there is a significant chance that a catastrophic event will undo the assumed economic progress.) A second concept, known as time preference, also acts to discount future impacts.

▶ **TIME PREFERENCE:** The rate of pure time preference quantifies the extent to which the analyst assumes that an equal well-being impact is worth less simply because it is in the future. It is introduced in cost-benefit analyses as an annual rate, usually 0–1.5 percent per year. This seemingly small range will have an enormous impact over the generational time scales associated with climate change. Because of exponential cumulation, at 1.5 percent the impact of a death in fifty years would be considered about half as important as one today (exhibit 1).

Because of its quantitative importance, the rate of pure time preference is another fiercely debated number, both in economics and in philosophy. Some follow the economist and philosopher Frank Ramsey, who argued that impacts occurring in the future are nearly as valuable as those of today. He stated that any value significantly over 0 is "ethically indefensible and arises merely from the weakness of the imagination."[17] This camp usually applies a value in the range of 0.1 percent, representing the small probability of extinction, in which case future impacts become irrelevant. Others, most prominently the recent Nobel Prize winner William Nordhaus, claim that discounting the future is partly an empirical matter that can be observed in the economy through how people save.[18] Compared with people who save a lot, people who save a little place a lower importance on impacts that occur in the future relative to the present. The observed average saving behavior suggests that people have a rate of pure time preference much larger than 0.1 percent.

To summarize, a best-practices cost-benefit analysis will account for time discounting and diminishing marginal utility and therefore allow a policy analyst to transparently explore the impact of several different ethical assumptions on decisions about how much to mitigate climate change, and when and where to do it.

EXHIBIT 1

Common values for elasticity of marginal utility and the rate of pure time preference

Value	Underlying assumption
ELASTICITY OF MARGINAL UTILITY	
Elasticity = 1	For each dollar, a person 2 times richer experiences one-half the well-being
Elasticity = 2	For each dollar, a person 2 times richer experiences one-quarter the well-being
RATE OF PURE TIME PREFERENCE	
0.1% per year	100 units of well-being in 50 years is worth 95 units today
1.5% per year	100 units of well-being in 50 years is worth 47.5 units today

SOURCE Authors' definitions.

An Example: Social Cost Of Carbon

The most high-profile example of where these concepts intersect is in the calculation of the social cost of carbon, which is widely used in regulatory cost-benefit analysis to value the impact of carbon emissions. The social cost of carbon is defined as the net damage, or cost, to society that results from one additional ton of CO_2 added to the atmosphere. The social cost of carbon, which changes over time, also reflects the optimal carbon tax level to apply in a carbon tax regime: the higher the social cost of carbon, the higher the carbon tax and the more climate mitigation that would result.

To illustrate the influence of both scientific information and normative choices in decisions about how much carbon to mitigate, we computed the social cost of carbon through time for seven different scenarios, each of which results in a corresponding temperature pathway (the higher the temperature, the greater the impact from climate change). To summarize the results, we report only the 2030 social cost of carbon and the peak temperature increase from each scenario. All results are based on modifications to the RICE model,[12] which our team has reported in prior work[19–21] (also see appendix section 4 for more details on this model, and the analyses).[15]

Exhibit 2 reports the results for all seven scenarios. The scenarios are independent of each other and use the marginal utility and time preference assumptions from scenario 1 unless otherwise noted. The scenarios are as follows.

Scenario 1 uses standard assumptions of the RICE model, setting the elasticity of marginal utility at 1.5 and time preference at 1.5 percent per year.

Scenario 2 doubles the climate change impacts in the RICE model. Recent empirical evidence suggests that the health burdens from climate change will be larger than originally thought, are likely to be a dominant type of impact, and could be as large as nearly all other impacts in the RICE model combined (that is, roughly doubling total climate impacts).[22]

Scenario 3 incorporates near-term health co-benefits.[20] We incorporate the expected health benefits from improvements in air quality that would result from reducing greenhouse gas emissions, valuing avoided deaths using the value of a statistical life.

Scenario 4 is the same as scenario 3 but uses the value of a life-year instead of the more uniform value of a statistical life. Benefits are captured as avoided life-years lost.

Scenario 5 allows for inequality within the twelve world regions and for proportionally distributed climate impacts. We divide income groups into quintiles within regions and adopt the standard assumption in climate policy models that climate impacts are distributed proportionally to income.[19] The RICE model and the other leading cost-benefit models ignore inequalities within regions.

Scenario 6 is the same as scenario 5 except that climate impacts are inversely proportional to income, meaning that they disproportionately harm the poor, as many expect.

Scenario 7 is the same as scenario 1, but the elasticity of marginal utility is set at 1 (meaning that a population twice as wealthy as another experiences half the well-being conferred by a dollar) and time discounting is set at 0.1 percent per year (meaning that impacts in the present are valued about the same as impacts in the future).

In scenario 1, the model recommends that under standard assumptions, the global temperature should be allowed to reach 3°C above preindustrial levels. In this scenario, additional mitigation costs required by stricter temperature targets outweigh the extra benefits, but at higher temperatures the climate costs are too burden-

EXHIBIT 2

The social cost of carbon in 2030 under different scenarios, and the resulting increase in peak temperature

Scenario	2030 social cost of carbon (\$/ton CO_2)	Peak temperature increase
Scenario 1: moderate concern for the poor and future generations	22	3.0°C
Scenario 2: more climate impacts	43	2.7°C
Scenario 3: health co-benefits with value of a statistical life	107	2.1°C
Scenario 4: health co-benefits with value of a life-year	46	2.6°C
Scenario 5: within-region inequality and climate impacts proportional to income	30	2.7°C
Scenario 6: within-region inequality and climate impacts inversely proportional to income	56	2.1°C
Scenario 7: more concern for the poor and future generations	139	1.7°C

SOURCE Authors' analysis, based on prior publications (see notes 19–21 in text). **NOTE** As a point of reference, the Obama-era 2030 social cost of carbon estimate ranged from \$16 to \$73.

The level of mitigation society chooses to undertake to address climate change is as much an ethical question as it is a scientific one.

some. However, as we modify assumptions to provide a more comprehensive representation of the climate issue, the recommendations change.

The existing models, including the RICE model, do not fully account for the most recent knowledge of the health benefits of mitigation, from either the avoided future climate impacts or the near-term co-benefits.[23] As we add these benefits, there is a push toward a higher social cost of carbon and lower associated temperature rise. This is the case in scenario 2, in which we model much higher health burdens from climate change by assuming that the total health impacts are roughly the same size as all other impacts combined.[22] Greater mitigation also results from scenarios 3 and 4, which add the health co-benefits from improved air quality. Co-benefits are particularly important because they occur in the near term and thus are less subject to time discounting. A value of a statistical life–based estimate (scenario 4) provides much more incentive to mitigate than a value of a life-year–based estimate because many of the avoided air pollution–related deaths occur in older people.

Representing the poorest people within countries or regions, as in scenarios 5 and 6, makes it more important to protect these highly vulnerable populations from future climate impacts (as well as from mitigation costs).[19] This is particularly evident in scenario 6, where the climate damages disproportionately harm the poorest people. Fully accounting for the distributional implications of climate impacts may be especially important for the evaluation of health impacts, given the positive correlation between ill health and preexisting socioeconomic inequities.

Despite all the important elements of scenarios 2–6, what is remarkable is that the most stringent recommendation results from changing the ethical parameters (scenario 7). In this case, we care about the future almost as much as the present, and we also do not worry as much about the current poor as in the other scenarios, so we are willing to enact stringent mitigation. This highlights the enormous influence of ethical beliefs about how to treat the poor and future people.

Embedded within these calculations is the question of how policy makers should assess the climate impacts that accrue to citizens of other countries. In the past (and in all scenarios presented here), US estimates of the social cost of carbon accounted for climate impacts in all countries; however, the Trump administration reversed that perspective and now considers only the climate impacts for the US. This decision alone deflates the social cost of carbon by more than 80 percent since it ignores the lost lives and economic harms expected from climate change in the other 95 percent of the world.[24,25]

Conclusion

The level of mitigation society chooses to undertake to address climate change is as much an ethical question as it is a scientific one. It is therefore necessary for analysts and policy makers to include ethical dimensions in their analyses and decisions and to explore their assumptions rigorously and transparently. Methods exist for doing so.

One domain in which ethical assumptions are highly apparent is in the calculation of the social cost of carbon, which several governments use to assign costs to carbon emissions. In the US, for example, the current 2020 social cost of carbon is \$1–\$7,[25] a fraction of what it was previously,[26] primarily as a result of decisions by the Trump administration to devalue future people and people in other countries. Implicit in this decision is a very high rate of time preference and no concern for intragenerational inequality or for the distribution of impacts. We consider this perspective to be inappropriate and consider a social cost of carbon of about \$20 per ton (similar to scenario 1) a reasonable lower bound of what should be used. However, we have shown that an even higher social cost of carbon is warranted, given a strong concern for equity within and across generations. If combined with the latest evidence on the potentially large health co-benefits of climate action and on the expected harms of climate change itself, the social cost of carbon could reach hundreds of dollars per ton, a level likely to be sufficient to meet the climate targets outlined in the Paris Agreement. We believe that such numbers are defensible, based on a robust conception of ethics and assuming proper protections for those most at risk from high energy prices and related impacts. ■

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