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Benefit-Cost Analysis and Consideration of Distributional Effects and Social Equity

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1. Introduction

Using benefit-cost analysis (BCA) to analyze and consider government proposals began with the 1936 Flood Control Act, which mandated federal investments would be allowed only if "the benefits, to whomsoever they accrue, exceed the costs" (Andrews, 1984). Since that time, BCAs have become a standard practice for evaluating public investments and regulatory decisions. Methodologically, BCA sums all benefits that society accrues from an action and then subtracts all costs imposed by the action to derive net benefits (in dollars) to society. Maximizing net benefits is a measure of economic efficiency[1] and represents one of the fundamental criteria for evaluating proposed government actions. Positive net benefits indicate that the benefits of an action exceed the costs, therefore it can be considered an efficient use of resources. Prior to 1981, executive oversight refrained from asserting economic efficiency as the ultimate criterion for evaluating regulatory decisions. However, with the signing of Executive Order (EO) 12291 in 1981,[2] federal agencies were directed to evaluate economically significant rules to confirm benefits would exceed costs in all cases except when expressly prohibited by law.[3]

The challenges of implementing EO 12291 have been discussed in books, journal articles, forums, and newspapers since its inception. Within a few years of its signing, Smith's edited volume *Environmental Policy under Reagan's Executive Order* (1984), tackled many of the issues arising from the executive branch's focus on economic efficiency in the adoption of new federal regulations including the limitations to elevating BCA and economic efficiency as the ultimate criterion in regulatory decision-making and the need for a more detailed analysis of distributional issues. A little over a decade later, the role of BCA in environmental, health, and safety regulatory decision-making was reflected upon by a group of prominent economists offering their take on the principles that should govern its use, including identifying distributional effects and incorporating uncertainty of the costs and benefits (Arrow et al., 1996). Despite their belief in the utility of BCA in regulatory decision-making, Arrow et al. (1996) state, "…it should not be the sole basis for such decision making." More recently, BCAs in practice have been criticized for lacking a comprehensive evaluation of distributional effects, thereby obscuring who wins and who loses if a new policy is adopted (Robinson et al., 2014).

Distributional effects, as broadly defined by the Office of Management and Budget (OMB), are how the benefits and costs are distributed across society, disaggregated by characteristics of interest

Equality vs. Equity

While **equality** and **equity** may sound similar, it is important to understand how these two terms differ. **Equality** seeks to provide individuals with the same amount of resources or opportunities. **Equity**, on the other hand, recognizes that everyone is not endowed equally and thus allocates the appropriate amount of resources and opportunities needed to reach equal outcomes. Thus, equity can be a means for identifying and addressing systemic differences of social systems that are intrinsically biased toward/against

[1] Economic efficiency (or Pareto optimality) is the optimum allocation of resources, where no redistribution of resources can make someone better off without making someone else worse off.

[2] Exec. Order No. 12291, 46 Fed. Reg. 13193, 13193-94 (Feb. 17, 1981).

[3] EO 12291 defines economically significant or "major" rule as "any regulation that is likely to result in: (1) an annual effect on the economy of $100 million or more; (2) a major increase in costs or prices for consumers, individual industries, federal, state, or local government agencies, or geographic regions; or (3) significant adverse effects on competition, employment, investment, productivity, innovation, or on ability of the United States-based enterprises to compete with foreign-based enterprises in domestic or export markets."

or concern (e.g., income, race, sex, age, geography). Although OMB requires an analysis of distributional effects, this is rarely practiced. Reasons include a lack of federal guidance for performing an analysis of distributional effects, "discomfort" in applying different benefit values for different population groups, inadequate resources, and data limitations (Robinson et al., 2016). BCA can obscure who "wins" and who "loses" by aggregating the benefits and costs of a government action (e.g., public project or regulation). Analyzing the distributional effects after conducting BCA is imperative to understanding the significance of a government action on social equity, meaning whether the distribution of the benefits and costs is "fair."

This report focuses on current practices of applying BCAs to evaluate government actions and existing methods for evaluating distributional effects and addressing social equity. Section 2 provides an overview of BCA and current practices and requirements for using BCA to support government actions at both the state and federal levels. Section 3 discusses methods for identifying distributional effects. Areas in BCA that could be improved to address social equity are covered in Section 4 and Section 5 recommends next steps.

For those readers new to the concept of BCA, Appendix A offers a primer that describes the basic steps of a BCA. Appendix B offers more detail on the total economic value framework and how economists estimate the monetary value of goods and services not traded in markets. More detail on discounting and specifically intergenerational discounting is in Appendix C.

2. Benefit-Cost Analysis Overview

BCA is a pragmatic framework designed to enable the formal comparison of disparate benefits and costs using the same metric—money. Various methods, based in economic theory, can be used to monetize goods and services not sold in traditional markets. Monetary valuations of these non-market goods and services are useful for measuring the extent individuals are willing to exchange income for specific outcomes if they could be directly bought and sold. According to OMB, when quantification of a potentially important effect is not possible, then the benefits should be addressed qualitatively (OMB, 2003).

BCA is intended to evaluate the economic efficiency (maximizing scarce resources given the preferences of individuals) and magnitude of a proposed action by summing the effects across individuals. When multiple alternative scenarios are compared to the same baseline over the period of analysis, BCA can inform the selection of the alternative scenario that maximizes economic, social, and environmental benefits on a cumulative basis; however, using only aggregated outcomes from BCA does not identify who bears the costs and who receives the benefits and when. A distributional analysis is necessary to evaluate who "gains" and who "loses" because those that bear the costs may or may not equally receive the benefits.

BCA results primarily used for decision-making are the present value of net benefits of the proposed action (benefits minus costs) and the benefit-cost ratio (BCR) (benefits divided by the costs). These metrics provide both the magnitude of the benefits and the extent to which they exceed the costs. Ideally, the benefits are sufficient for the gainers to potentially compensate the losers so that the individuals are not worse off based on the action under evaluation. However, this concept of the winners compensating the losers appears to be more theoretical than practical. Furthermore, BCA is limited in providing a full accounting of all the effects of a proposed action because some consequences may not be possible to monetize or quantify with a reasonable amount of certainty. See Appendix A for a more detailed explanation of BCA.

BCA has been widely used in the evaluation of proposed government funded projects, discretionary funding programs (both federal and state), and policies affecting transportation, public health, criminal justice, defense, education, and the environment. This report is focused on how BCA has been used to prioritize government actions.

2.1 Government Spending

The Flood Control Act of 1936, Public Law 74-738, requires the federal government to participate in flood risk management when "the [project] benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected." This Act authorized federally funded flood control projects and set the criterion of benefits exceeding costs and the consideration of social impacts in the decision-making process. Water resource development agencies, such as the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, Natural Resources Conservation Service and the Tennessee Valley Authority, are required to conduct detailed BCAs for individual project justification. Distributional effects are typically not identified, nor is a distributional analysis required.

Passed in 1977, the Federal Grant and Cooperative Agreement Act guides government agencies in their use of federal funds, such as grants and cooperative agreements. Grant-making federal agencies create agency-specific policies and procedures based on guidance from OMB.[4] Some of the grant-making federal agencies, such as the U.S. Department of Transportation (DOT), Federal Emergency Management Agency (FEMA) and Federal Aviation Administration (FAA), require grant applicants to perform BCAs for their proposed project. Grant-making federal agencies that require BCAs typically provide guidance for conducting the BCA, including specific methods and monetized values that are approved for use. A BCR equal to or greater than one is used to demonstrate a project is cost-effective. Usually, the distribution of benefits and costs is not explicitly quantified in applications; rather, affected populations may be identified (vehicle owners, residents, drivers and passengers, pedestrians, etc.) for each benefit category (e.g., travel time savings).

Using BCA to evaluate projects is a more common approach for federal agencies than at the state, county, and municipal levels of government. A study performed by DOT in response to Senate Report 113-182 to "evaluate the use of benefit cost analysis by State departments of transportation, and to issue a report to the House and Senate Committees on Appropriations"[5] found significant variation in the extent to which state departments of transportation use BCA, both across states and across different project types and planning stages, and that the use of BCA continues to be the exception, not the rule (DOT, 2016).

2.2 Federal Regulations

The use of BCA in federal regulations is influenced by legislative requirements and administrative guidance (Robinson et al., Hammitt and Zeckhauser 2014). When Congress enacts legislation for a new law, they delegate the implementation of the new law (including creation of regulations) to the federal agency as authorized in the statute. Hence, the agency's new regulations must follow the guidelines established by Congress. Congress can also direct federal agencies on the factors by which they can (or cannot) evaluate a new regulation. For instance, under the Safe Drinking Water Act, Congress required the Environmental Protection Agency (EPA) to consider

[4] https://www.grants.gov/web/grants/learn-grants/grant-policies.html

[5] https://www.congress.gov/congressional-report/113th-congress/senate-report/182

distributional concerns, including developing standards that protect those who may be most vulnerable (Robinson et al., 2014). Another example is the Clean Air Act (CAA), whereby Congress directed EPA to establish standards—the National Ambient Air Quality Standards—that are protective of human health while prohibiting the use of a cost analysis as criteria for determining the final rule. The CAA is unusual given the mandates by various presidents that direct federal agencies to use BCA in rulemaking. However, even if the regulatory decision cannot be made based on economic efficiency, administrative guidance requires the completion of a BCA (Robinson et al., 2014).

Administrative guidance can come from executive orders. In 1982, the executive branch formalized the inclusion of economic efficiency in the regulatory approval process with President Reagan's signing of EO 12291. The order requires demonstrating a need for regulatory intervention and that the chosen regulation maximizes net benefits to society (Smith, 1984). In 1993 President Clinton signed EO 12866, which modified EO 12291 by emphasizing the non-quantitative effects of rules but maintained benefit-cost requirements for all economically significant rules.[6] The key change introduced by Clinton was language that benefits "justify" costs (Petrolia et al., 2020).

The implementation of these executive orders consists of Regulatory Impact Analysis (RIA) for all major rules. An RIA is intended to include an evaluation of the need for and consequences of the proposed regulation. An RIA should include consideration of alternative regulatory approaches; quantification of the economic costs and benefits within a BCA framework; determination of economic impacts and distributional effects; and a discussion of costs and benefits that cannot be quantified, with an assessment of their importance relative to those that are quantified or monetized.

In *Circular A-4*, OMB (2003) has proposed guidelines for federal agencies in their treatment of uncertainty in the context of RIA. OMB stresses the importance of transparency in the sources of uncertainty. The RIA should include discussions about the quality of data, models used to analyze uncertainty, and the use of inference and assumptions in the analysis. In short, the analyst is encouraged to identify the strengths of the analysis as well as the uncertainties about the conclusions. When benefits and cost estimates are uncertain, then the analyst is encouraged to present the range of benefits and costs that reflect the full probability distribution of the potential outcomes.

When conducting RIAs in support of rulemaking, federal agencies are essentially seeking to address issues of *efficiency* (maximizing net social benefits) and *distributional consequences*. BCA estimates the net benefits to society, whereas economic impact analysis (EIA) and distributional analyses examine the effects of the proposed regulation to various economic sectors or subpopulations, respectively. Specifically, an EIA estimates the impacts to industry, governments, and non-profit organizations, whereas a distributional analysis examines the effects on various sub-populations, particularly low-income, minorities, and children. A complete RIA comprises a BCA, an EIA, and an assessment of distributional effects (EPA, 2014).

All RIAs are sent to OMB for review as authorized by EO 12291. OMB is responsible for reviewing the regulation and accompanying analyses before they are finalized, and has issued guidance on "best practices" in preparing an RIA. The latest such guidance is *Circular A-4* (OMB, 2003). *Circular A-4* was designed to standardize the measurement and reporting of benefits and costs of

[6] Exec. Order No. 12866, 58 Fed. Reg. 51735, 51735, 51738 (Sept. 30, 1993).

regulatory actions. In addition to a BCA, OMB guidance directs agencies to provide an analysis of the distributional effects of the regulation.[7]

Explicit language to consider distributional effects and equity has been included in President Clinton's EO 12866 and EO 13563 signed by President Obama.[8] Despite the strong interest in distributive impacts, especially adverse impacts on disadvantaged or vulnerable populations, standard practice has been to document aggregated benefits and costs to whomsoever they may accrue (Banzhaf, 2011; Robinson et al., 2016). Further, it appears that OMB does not enforce their own guidelines for conducting an analysis of distributional effects (Robinson et al., 2016).

The latest attempts by the executive branch to incorporate social equity and the analysis of distributional effects in regulatory rulemaking occurred in the first month of the Biden administration. With the signing of EO 13990, President Biden instructs federal agencies to make recommendations for adequately accounting for environmental justice and intergenerational equity in calculating the social cost of greenhouse gases.[9] Furthermore, President Biden issued a memorandum dated January 20, 2021, which directs the Director of OMB, in consultation with representatives of executive departments and agencies, to develop recommendations for improving and modernizing regulatory review to "…promote public health and safety, economic growth, social welfare, racial justice, environmental stewardship, human dignity, equity, and the interest of future generations."[10] Two subsequent executive orders—EO 13985 and EO 14008—use nearly identical language in stressing the importance of addressing social equity and environmental and economic justice for underserved communities.[11]

2.3 State Regulations

The use of BCA to support regulatory decision-making varies greatly in form, quality, and effectiveness at the state, county, and municipal levels of government. A nationwide assessment performed between 2008 and 2011 found that state governments are increasingly mandating and conducting BCAs, although most of the 348 BCAs reviewed lacked at least some of the desired technical aspects of BCA (White and VanLandingham, 2015). States reported that resource and data limitations, timing considerations, and difficulty in gaining policymakers' attention and confidence as key challenges. Notwithstanding, a notable proportion of the BCAs had a reported impact on state policy and budget processes (ibid).

The Institute for Policy Integrity studied and surveyed all 50 states and found that most state agencies struggle to assess the basic costs of regulations and completely forgo any rigorous analysis of benefits or alternative policy choices (2010). Furthermore, broader and more balanced distributional assessments, beyond the distribution of costs and benefits to different sized businesses, were rare. The study found 38 states assess economic costs and benefits to private or regulated parties, and only 21 states require analysis of social costs and benefits (Ibid).

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[7] Circular A-4 states: "Your regulatory analysis should provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision makers can properly consider them along with the effects on economic efficiency. Executive Order 12866 authorizes this approach. Where distributive effects are thought to be important, the effects of various regulatory alternatives should be described quantitatively to the extent possible, including the magnitude, likelihood, and severity of impacts on particular groups." (P. 14)

[8] Exec. Order No. 13563, 76 Fed. Reg. 3821 (Jan. 21, 2011).

[9] Exec. Order No. 13990, 86 Fed. Reg. 7037 (Jan. 20, 2011).

[10] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/modernizing-regulatory-review/

[11] Exec. Order No. 13985, 86 Fed. Reg. 7009 (Jan. 20, 2011) and Exec. Order No. 14008, 78 Fed. Reg. 7619 (Jan. 27, 2011).

3. Analysis of Distributional Effects

Per OMB (2003) guidance, after quantifying and monetizing total benefits and costs for BCA, an agency should then undertake a separate analysis of distributional effects. Distributional effects, as broadly defined by OMB, are how the benefits and costs of the proposed regulation are distributed across society, disaggregated by characteristics of interest or concern (e.g., income, race, sex, age, geography). In the realm of environmental rulemaking, distributional effects are of concern when environmental degradation and human health risks are disproportionately high to a segment of society or particular life stage (EPA, 2014). For instance, if a proposed regulation would impose significant costs to low-income neighborhoods or communities of color compared to high-income, predominantly white neighborhoods. Distributional effects may also occur over time (EPA, 2014). For example, climate change regulations or government-funded resiliency projects and ensuing benefits may span several generations.

If the distributional effects are expected to be significant, OMB specifically calls for a description of "the magnitude, likelihood, and severity of impacts" on particular groups (OMB, 2003). EPA's *Guidelines* (2014) devotes a chapter to this subject and outlines the approach an analyst should take to address distributional effects quantitatively or qualitatively, including metric definitions, sources of data, and analysis methods. In general, EPA's chapter on distributional effects and environmental justice tends to focus on exposure or health effects; however, there are other effects of environmental policies, such as differences in product prices, wage rates, employment effects, and economic rents that are not addressed (EPA, 2014). Notably, EPA is the only federal agency to develop guidelines for conducting distributional analysis, however the guidance is limited to health impacts and does not adequately address the costs or other non-health impacts of regulation, such as ecosystem services. In fact, there is no guidance for assessing the distribution of costs across various groups (Robinson et al., 2016). Even with guidance available, federal agencies are disinclined to complete a distributional analysis because of the "discomfort" in applying different benefit and cost values for different population groups (Robinson et al., 2016).

Determining how much of the benefits received or the costs incurred are associated with subgroup populations presents a challenge in analyzing distributional consequences. (Loomis, 2011). Loomis (2011) suggests the following three possibilities for obtaining information on how benefits might be distributed: (1) information on project financing can help inform the distribution of costs across categories of interest; (2) surveys can be used to estimate how benefits vary across demographic characteristics of interest; and (3) if benefit estimates are calculated using demand or supply functions, then these models can include demographic variables in the statistical analysis to determine distributional effects.

In the realm of regulations intended to reduce health-risks, the analysis of health benefits is considered a mature field with a strong conceptual foundation for quantifying inequality in health outcomes (Levy, 2021). In a review of the current state of the practice, Levy (2021) references multiple studies where authors have demonstrated numerous quantitative indicators that are suitable for measuring health risk inequality. As an example, Levy (2021) suggests a study involving criteria air pollutants, which typically calculates health benefits as a function of changes in concentrations, baseline disease prevalence, and relative risk, could be expanded to characterize both spatial and sociodemographic variability in baseline disease status. The results could then be used to inform risk-based control strategies that provide greater exposure reductions for the defined vulnerable populations (Levy, 2021).

Despite these techniques for quantifying distributional effects, very few RIAs include this type of analysis (Levy, 2021; Robinson et al., 2014 and 2016). In an OMB review of 24 major federal environmental, health, and safety regulations between 2010 and 2013, Robinson et al. (2016) found that only 3 of the 24 RIAs quantified the distribution of risk reductions across population subgroups, none included monetary values of risk reductions across subpopulations, and none assessed the distribution of costs of complying with a regulation.[12] Instead, federal agencies tend to address distributional consequences by indicating the regulation does not harm specific groups protected by EO 13045, which protects children from environmental risks and safety risks, and EO 12898, which addresses environmental justice in minority and low-income populations (Robinson et al., 2016).[13]

A core concern regarding distributional effects has to do with the potential for disproportional effects of government actions on minority, low-income, and indigenous populations.; children; and the elderly (EPA, 2014). EPA acknowledges distributional effects through identifying and addressing "disproportionately high and adverse human health and environmental effects …" from proposed policies on these groups (EPA, 2014, pg. 10-4). EPA (2014); however, does not determine whether the differences represent disproportionate impacts. EPA states the following, "The term disproportionate is neither defined in EO 12898, nor does the academic literature provide clear guidance on what constitutes a disproportionate impact. **Thus, the determination of whether an impact is disproportionate is ultimately a policy judgment** [emphasis added]**"** (EPA, 2014, pg. 10-7). OMB *Circular A-4* also does not indicate how distributional concerns should be weighted. Thus, EPA's analysis of distributional effects stops short of addressing issues of equity, a topic discussed in Section 4.

Current agency practice in preparing an RIA for OMB review appears to rely on economic efficiency, as long as certain groups are not harmed, while ignoring the required analysis of distributional effects (Robinson et al., 2016). The groups in question are those that are covered by environmental justice mandates (EO 12898) and the protection of children's health (EO 13045). Thus, this approach takes the normative position—implicit in these executive orders—in that these groups will be protected from adverse effects. However, Robinson et al. (2016) disavows this approach because it only focuses on avoiding certain losses while ignoring positive gains.

The controversy surrounding accounting for distributional effects within the BCA framework has been ongoing for decades (Grubb et al., 1984; Fisher, 1984; Arrow et al., 1996; Cole, 2006). An often-cited criticism is the use of willingness to pay (WTP) or willingness to accept (WTA) for estimating benefits of a new regulation or action.[14] WTP is measured as the maximum amount of money an individual would exchange (or accept to measure WTA) to obtain an improvement (or accept to avoid an impact for WTA), given their budget constraints. Therefore, income influences WTP/WTA estimates and consequently reflects the unequal distribution of income. Accordingly, higher income individuals can assign a higher WTP value relative to low-income individuals simply because the higher income individuals have more discretionary funds to spend.

As a demonstrative example, a new air quality regulation would reduce the risk of contracting lung cancer by 1 in 10,000. A carefully designed stated preference survey could elicit how much a

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[12] All 24 RIAs reported the costs to industry, a few provided data on how aggregate costs are distributed among consumers (higher prices), workers (lower wages), and producers (lower producer surplus), and none showed how the costs are distributed across subgroups (Robinson et al., 2016). The authors note that there is no comprehensive guidance for assessing the distribution of costs across various groups.

[13] Exec. Order No. 13045, 62 Fed. Reg. 19885 (April 21, 1987) and Exec. Order No. 12898, 59 Fed Reg. (February 11, 1994).

[14] See Appendix B for a more detailed discussion of WTP and WTA.

person would be willing to pay (both pecuniary and non-pecuniary) to reduce the risk of contracting lung cancer by 1 in 10,000 in the current year. The WTP value would be divided by the change in risk (1 in 10,000) to calculate the value per statistical life (VSL) for that individual.[15] The average individual WTP would then be multiplied by the number of affected individuals to estimate VSL for the impacted population. An analysis of distributional effects of the air quality regulation on the impacted population would proceed by disaggregating health benefits by income groups. Low-income individuals would have lower VSL estimates, which may be interpreted as this sub-population valuing health outcomes less than high-income groups and may lead to controversy over the intended regulation. However, without considering how the costs and benefits are distributed, it is difficult to fully understand the benefits and costs of a government action upon vulnerable populations and whether the government action favors higher-income populations over lower-income populations due to the biases and limitations inherent to BCA.

4. Accounting for Social Equity

Distributional effects quantify who gains and who loses and by how much. The "who" in the analysis represents some classification of the populations impacted, such as income levels, race, age, etc. Equity, on the other hand, asks whether the distribution of the benefits and costs is "fair" or "just." Thus, equity is a normative question.

Equity among individuals is a normative analysis and as such requires a decision maker or an elected official or society as a whole to determine how the well-being of one person is compared against the well-being of another. In 2021, the federal government that mandated agencies begin addressing social equity. The Justice40 Initiative, launched as part of EO 14008, directs federal agencies to distribute at least 40 percent of the overall benefits of federal investments in climate and clean energy initiatives to disadvantaged communities. While laudable in its acknowledgement of social equity concerns, new administrations in the U.S. government are known to overturn previous presidential agendas with the signing of new executive orders. Therefore, the adoption and implementation of methodologies to account for social equity within BCA frameworks and distributive analyses must continue forward.

One approach for considering social equity in the process of prioritizing government actions is the use of social equity indicators. Social equity indicators may consider environmental justice; equitable services and access; poverty prevention and alleviation; and/or civil and human rights. BCA begins with the definition of the objectives or goals and identification of one or more alternatives that meet them. Relevant social equity indicators could be identified in consultation with the affected communities to inform the formulation of various alternatives. The indicators would measure the current conditions and then track these indicators of social equity/inequity over time to evaluate if social equity goals are being met after the implementation of a government action. Indicators can be weighted according to the importance to the community, the difficulty of the actions required, and the impact to the community.

In the accounting of social equity, the economic principle at play is the diminishing marginal value of income, meaning the value of an additional dollar is worth more to a poor person than a wealthy person. The choice of how to incorporate the differential value of benefits between people of different incomes is sometimes referred to as "equity weighting" (Carleton and

[15] VSL is not intended to be the value of a person's life or the value of saving a life with certainty. VSL measures an individual's tradeoff between small changes in life expectancy or risk reduction and spending on other goods and services within a defined period.

Greenstone, 2021). Scholars have been writing about and endorsing the use of equity weights in BCAs since the 1950s (Adler, 2016). Adler (2016) provides a review of the key ideas relevant to equity weights, including a case study involving risk-reduction policies and VSL. For example, incorporating equity weighting into a BCA could mean increasing the weight of health effects (costs) incurred by residents in low-income neighborhoods from exposure to higher levels of pollution.

An intuitively appealing approach to develop equity weights is to empirically derive a distribution of weights that reflects the small change in well-being that people in different income groups receive from their net benefits. Utility is how economists operationalize an individual's well-being, where well-being is related to income, consumption, or wealth (Boardman et al., 2018; Lesser, Dodds and Zerbe 1997). The relationship between small changes in an individual's well-being (marginal utility) and small changes in income (marginal utility of income) is not linear but concave. A concave function indicates that the marginal utility of income decreases with increasing wealth. Figure 1 illustrates this concept, which is known as diminishing marginal utility of income. The bars show that an equal change in income (x-axis) produces differing increments in well-being (y-axis), depending on the initial level of income. This trend describes that $100 given to a poor person produces significantly more well-being than if a billionaire were to receive $100.

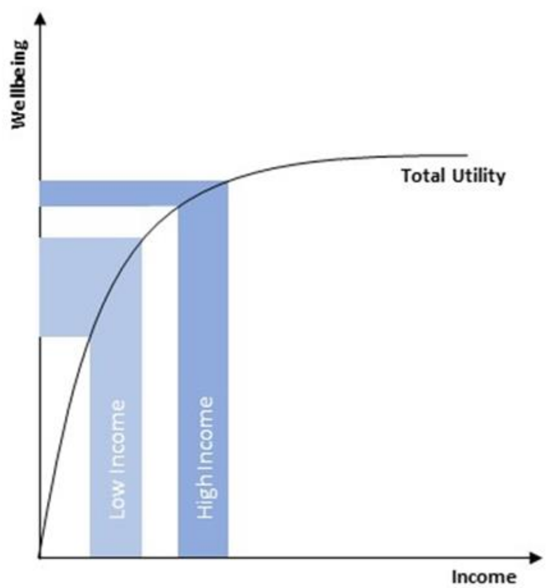

Figure 1. A utility function describing the relationship between income and wellbeing. An equal increase in income results in differing quantities of wellbeing depending on initial income levels.

The curvature of the utility function in Figure 1 establishes how much utility changes with changes in income. This curvature is called the elasticity of the marginal utility with respect to income. Using population surveys that measure happiness, Layard, Mayraz and Nickell (2008) were able to estimate elasticity of the marginal utility of income, which ranged from 1.19 to 1.34, depending on the survey and averaged 1.26. These estimates of elasticity trace out the differential value of benefits between people of different incomes and can be used in a distributional analysis to take social equity into account. Equity weights generated in this manner reflect the ethical theory called prioritarianism, which holds that "… improving a person's wellbeing contributes more to social welfare if the person is badly off than if they are well off"[16] (Kolstad et al., 2014). Kind, Wouter Botzen, and Aerts (2017) use marginal utilities of income in an analysis of flood risk management, which can also be applied to other climate risks, such as storms, droughts, and landslides. Their results indicate that the inclusion of equity weighting in a BCA can significantly alter the conclusions, leading to identification of who to target, what to do, how much to invest, and how to share risks, with increased emphasis on resiliency measures for population segments with low-income and high-social vulnerability.

Borrowing from risk analysis, Farrow (2011) models equity using a measure of income inequality to characterize the economic impacts of proposed policies across groups with differing incomes. Farrow employs the Atkinson income inequality index, a measure related to income inequality aversion ranging from 0 to 1. The Atkinson index explicitly incorporates a normative perspective about social welfare—weighing the wellbeing of one subpopulation against another (Levy et al., 2006). Assuming declining marginal utility of income across groups, the model is consistent with welfare economic theory. Farrow advocates employing alternative values of the Atkinson index of inequality as a way to conduct sensitivity analysis of BCA. Other researchers have also used the Atkinson index to analyze the distribution of health impacts from pollution. Levy, Chemerynski and Tuchmann (2006) found the Atkinson index to be the best indicator for addressing the needs of inequality assessment (distributional effects) in health benefits analysis.

Another approach involves applying the Lorenz curve to a proposed government action. The Lorenz curve is a graphical representation of the distribution of income or wealth in a population by plotting the cumulative percentage of income against the cumulative percentage of the population (Maguire and Sheriff, 2011). If income were equally distributed, the resulting line would be straight with a slope equal to one. When income is not equally distributed, the line may be curved like a hockey stick, depicting a small segment of the population holding the majority of the wealth. In this way, the Lorenz curve is a relative measure of inequality (Maguire and Sheriff, 2011). The Gini coefficient is the ratio of the area between perfect equality (straight line) and a line demonstrating perfect inequality (i.e., one person has all the income/wealth). The more dispersion in the data, the higher the Gini coefficient.

The estimation of the Lorenz curve and Gini coefficient involve ranking the units of observation based on some quantity of interest and then estimating cumulative proportions. However, when there is error or variation in the measurement of the quantity of interest, an analysis that does not account for this error or variation may incorrectly rank the units and result in upwardly biased estimates for the concentration in the Lorenz curve and Gini coefficient (Moskowitz et al., 2008). The data needed to generate a Lorenz curve can come from single market or multiple market analyses, or broader, simulation models such as computable general equilibrium (CGE) models (Loomis, 2011). Groot (2010) applied the Lorenz curve to carbon emissions and abatement policies across countries.

Most practitioners suggest that in the absence of equity weights or a formal ranking of whose utility is more important, the results of a BCA should be presented with a range of inequality indicators, like the Atkinson Index or the Gini index,[17] along with a discussion as to whether policy alternatives are sensitive to the choice of indicator, and if so, what drives that sensitivity.

The quantitative accounting of social equity through the use of indicators, weights or indexes of inequality, although necessary, is not sufficient in addressing issues of equity. First and foremost,

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[16] Social welfare is a function that aggregates the lifetime wellbeing across people to determine an overall value for society.

[17] The Gini index is derived from the Lorenz curve and reflects the inequality among values of a frequency distribution.

rulemaking and public project selection must also include conversations with the communities that will be affected. Equity, to be meaningful, should be addressed through community engagement at all stages of rulemaking and public project planning. President Biden echoes this need in his January 21, 2021, memorandum indicating that recommendations for improving and modernizing regulatory reviews should be informed by engagement with stakeholders. While model outputs can identify the geographic locations or segments of the population that will be disproportionately affected (either positively or negatively) by a government action under consideration, the communities themselves must be engaged in the process for social equity to be fully addressed. EPA defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA, 2014).

5. Summary and Recommendations

Social equity is receiving considerable attention with the recent issuance of President Biden's Justice40 Initiative, launched as part of EO 14008, which mandates the distribution of at least 40 percent of the overall benefits of federal investments in climate and clean energy initiatives to disadvantaged communities. There are also the additional directives outlined in EO 13990, EO 13985, and the memorandum dated January 20, 2021, which all stress the importance of addressing social equity and environmental and economic justice for underserved communities. Although OMB guidance (2003) directs agencies to provide an analysis of the distributional effects in conjunction with a BCA, a comprehensive distributional analysis and subsequent assessment of social equity is rarely performed in practice. Even when a distributional assessment is performed, only the aggregated benefits and costs are reported, which obscures who wins and who loses. There are various methods that can be applied to consider social equity and analyze the distributional effects of proposed governmental actions. We provide three recommendations to improve methods used in BCA and subsequent distributional analyses to properly address social equity.

First, develop a step-by-step methodology for performing distributional analyses. This methodology could vary in scale from simple and basic to comprehensive. A simplified methodology may be more appropriate for smaller scale government actions, such as small public projects where the BCA may be performed by state, county, and municipal levels of government applying for federal grant programs. Although this type of approach would not be comprehensive, it would move the needle towards the consideration of social equity instead of omitting it completely. A comprehensive approach would be appropriate for widespread federal regulatory policies. A threshold could be developed for when each type of approach is warranted. The methodology should point to existing sources of data and there may be opportunities to develop or modify data sets to address gaps and facilitate implementation.

Second, how to incorporate social equity into the BCA framework should be further investigated. The BCA framework would need to be expanded to address social equity both within BCA and throughout the planning process. Equity is best addressed through multiple lenses. How these weights should be developed and used could be determined through the elicitation of expert opinion and stakeholder engagement with a neutral third-party as the lead organization.

Third, test the methodology developed with government partners by preparing various case studies, ideally using proposed government actions that are currently under consideration. A use case after a government action has been implemented could also be helpful for understanding whether the intended outcomes materialized.

Acting on these recommendations will create a pathway for the federal government to comply with OMB requirements (*Circular A-4*) and six EOs dating back to the Clinton Administration (i.e., EO 12291, EO 12866, EO 13563, EO 13990, EO 13985 and EO 14008) that specify the need for identifying and analyzing the distributional effects in conjunction with BCA and considering the implications for social equity.

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Appendix A. Benefit-Cost Analysis Primer

BCA allows for a comparison of disparate impacts using a common metric—money. Although another metric could be used, money is a convenient and well-established measure of exchange. Figure A-1 displays the general framework and steps for conducting BCA.

The BCA begins with the definition of the objectives or goals that need to be met. BCA can be used to evaluate one or multiple actions or alternatives that meet the same objectives and goals. The actions may be proposed public projects, policies, or regulations.

Figure A-1. BCA Framework

The actions or alternatives are compared to the baseline or the status quo conditions that are anticipated in the future. The baseline should reflect the world without the proposed scenario (action/alternative). The baseline is sometimes referred to as the "do nothing," "no action," or "business as usual" scenario. The baseline should incorporate population growth, economic growth, demographic shifts, migrations between urban and rural areas, and climate change. To determine the incremental costs and benefits, the baseline scenario is compared to one or more alternative scenarios that depict the expected state of the world with the proposed action, policy, or regulation in effect. Effectively, a BCA provides a systematic framework for evaluating the likely outcomes of alternative choices. Determining the baseline, therefore, is an essential component of a BCA because the results of the analysis are reliant on its specification.

The next step is to estimate the incremental benefits and costs of a proposed action. There are multiple different methods based in economic theory that can be used to monetize benefits and costs. Some of these methods are described in more detail in Appendix B. Monetizing benefits and costs allows for a direct comparison using a common metric.

Economic, social, and environmental costs that can be avoided by a proposed action are considered benefits in a BCA. For example, favorable outcomes such as improved air or water quality, reductions in the risk of contracting cancer, or reductions in the emissions of greenhouse gases are defined as benefits. Monetized benefits associated with the proposed action, regulation or policy are compared with the costs in the BCA. Besides investment costs, other economic costs (or opportunity costs) can be defined as opportunities not taken or investments not made, or the goods and services not consumed for agencies, firms, or individuals to comply with a proposed action.

Often, the benefits and costs of a proposed action occur at different times. The period of analysis may be specified by the federal agency or may correspond to the type of action. For example, a BCA evaluating a highway project intended to last 40 years would use a 40-year period of analysis. Typically, when BCAs are used to evaluate proposed rules, the BCA covers decades. Policies designed to address climate change, hazard waste disposal, or groundwater contamination, for instance, will likely involve significant impacts over very long time horizons involving multiple generations.

To compare future benefits and costs in a meaningful way, economists discount all values to present terms. In short, discounting reflects an individual's preference to receive a dollar today as opposed to receiving that dollar in the future (time value of money). The choice of the discount rate will determine the overall reduction in value as will how far into the future the benefits and costs are discounted. More detail on discounting is provided in Appendix C.

The result of BCA may include net present value (NPV), benefit-cost ratio (BCR), and internal/economic rate of return (IRR/ERR). NPV is calculated as the present value of benefits minus the present value of costs. The BCR is calculated as the present value of benefits divided by the present value of costs. A BCR greater than one indicates cost-effectiveness. IRR/ERR is the discount rate at which the NPV of costs would equal the NPV of benefits and can be used to compare the profitability of investments. Generally, the higher the rate, the more desirable.

Uncertainty can take several forms within the BCA framework. The estimated values of benefits and costs are often uncertain. Sensitivity analysis can be conducted to cope with this problem. In some cases, a proposed regulation may suggest novel activities or changes the economic incentives or choices faced by consumers and firms (EPA, 2014). In these cases, unless new information is generated, it may be difficult to do more than speculate about the benefits and costs that may result. Uncertainty can also exist in the provision of outcomes (supply side uncertainty). This is especially true in climate-related outcomes. The inherent complexity in linking greenhouse gas emissions to changes in global surface temperatures across multiple generations makes prediction difficult and uncertain.

A recurring argument against using BCA to evaluate low-probability, high-impact events like those associated with climate change projections is BCA's inability to handle infinite, expected utilities (Kunreuther et al., 2014). Infinite utility occurs when income is zero (Ingham and Ulph, 2003). In modeling climate change outcomes, income can become zero in some regions, in some time periods, because the random variable that underlies the process may have "fat tails," so that there are relatively large probabilities of extreme values (Ingham and Ulph, 2003). In these situations, more robust techniques are required.

One approach would be to specify a threshold probability and a threshold loss for low-probability, high-impact events. In determining what policy to adopt, the analyst removes from consideration events that are below these critical values. Insurers and reinsurers use this approach to determine the amount of coverage that they are willing to offer against a particular risk. A portfolio of policies is then created that diversifies the insurers risk to a pre-specified level of concern (e.g., 1 in 1,000).

The precautionary principle, a proposal for dealing with serious uncertain risk to the natural environment and public health, coupled with robust decision making is another alternative framework for climate-related decisions. Developed in the 1970s and 1980s, the precautionary principal advocates for the protection of the environment or public health if a proposed policy or action may cause harm, even if some causal effects are not well understood. Robust decision making operationalizes the precautionary principle (Kunreuther et al., 2014). Using plausible probability distributions, robust decision analysis describes uncertainty and evaluates the performance of different policies with respect to different outcomes arising from the probability distributions. This process results in a series of tradeoff curves that allow decision makers to evaluate the risks and benefits of different policies.

Expected value analysis or expected utility theory is the standard quantitative approach to benefit-cost evaluation under uncertainty (Kunreuther et al., 2014). To conduct an expected value analysis, a probability distribution of the outcome is necessary. For instance, the outcome might be the probability of a degraded water body or harm to human health and safety. Expected value is equal to the effect of the regulation on net social benefits times the probability (or distribution of probability) of occurrence.

In addition to these approaches to evaluating uncertainty, several more frameworks exist that have been developed for evaluating alternatives and making choices in a systematic manner. The advantages and disadvantages of these frameworks have been described in Kunreuther et al. (2014). These authors also provide a thorough review of uncertainty and its affect on climate policies.

Appendix B. Total Economic Value Framework

The term "value" has a very specific meaning in economics. Value is a measure of what individuals are willing to give up in order to get something else. For instance, if an individual is willing to give up $100 to purchase a pair of running shoes, the value of those shoes to that individual must be at least $100. For some goods or services, such as bottled water or timber, a competitive market exists in which many people have the opportunity to exchange money for goods. In these situations, economists can use data from these market prices to estimate the value of the last bottle of water bought or board feet of lumber sold. These types of goods and services are commonly called market goods.

Many other valuable goods and services, particularly environmental ones, are not traded in markets. Because costs are usually measured in dollars, the benefits must also be measured in dollars if they are to be in comparable units. Economists use the total economic value framework to estimate the monetary value of goods and services not traded in markets.

The economic concept of value reflects four important principles: (1) the values that individuals assign to outcomes depend on their preferences for those different outcomes, which are assumed to be stable and consistent; (2) some level of substitutability exists between what is being valued and other things individuals care about; (3) values are assigned to *changes* in the provision of the goods being valued; and (4) in addition to preferences, economic values are dependent on willingness and ability to pay.

The total economic value provided by market and non-market goods and services can be broken down into several components based on the particular ways humans choose to use the resource (Kroeger and Manalo, 2006). Use values are composed of direct use value and indirect use value. Non-use values, also referred to as passive-use values, comprise existence value, stewardship value, and bequest value. The total economic value of a resource is the sum of use values and non-use values. For example, when pollution is allowed to degrade ecosystems, then the benefits enjoyed by society are diminished in value. Economists view this decrement as a cost to society. Hence, EPA's regulation of air, water, and soil quality are motivated, in part, by the societal benefits of protecting or enhancing environmental quality.

B.1 Direct Use Values

Use values are all the direct and indirect ways that people currently expect to physically exploit the resource (Mitchell and Carson, 1989). Direct use can either be consumptive or non-consumptive, depending on its effect on the resource in question. Consumptive uses, such as hunting, fishing, or the extraction of food, fiber, water, or minerals remove resources to satisfy human use. Consumptive use also includes cases where the public's use of a place changes the structure and function of the ecosystem, for example, the use of off-road vehicle trails may cause erosion of topsoil and impacts to species. Non-consumptive uses leave the ecosystem relatively intact and unchanged. Examples include bird watching, photography, hiking, and canoeing, as well as the enjoyment that property owners receive from living in close proximity to natural areas.

B.2 Indirect Use Values

Indirect use values relate to the use by humans of various goods and services produced by ecosystems (Dailey, 1997). For instance, water supply and edible fish are direct use values that are provided by river ecosystems. Streams and rivers also provide the important service of waste assimilation. Society relies on a river's natural processes to assimilate waste to avoid having to treat all point and nonpoint discharges to undetectable levels of contaminants, a daunting and expensive undertaking. As such, rivers and streams *indirectly* contribute to our economy by keeping treatment costs down, protecting human health, and supporting recreational and aesthetic enjoyment. This example illustrates the activities of ecosystems commonly referred to as ecosystem services (Daily, 1997). Many of the ecosystem services that are provided by nature are reduced in quality and quantity if emissions of pollutants are not curtailed by government intervention. This pollution results in a diminution or loss of valuable ecosystem services, and thus represents a foregone benefit or cost of allowing polluters to pass on their costs of production to society. Because ecosystem services are not traded in markets, they are not easily valued. Although economists have developed the theory and application for valuing non-market goods and services, EPA and other agencies face limited budgets and time constraints to conduct the studies required to value these services. In a review of environmental policy decisions at EPA, Petrolia et al. (2020) found the inclusion of monetary estimates of ecological benefits was rare and, in most cases, received only a qualitative discussion. Failure to recognize and include environmental values, such as ecosystem services, biases policy decisions against conservation (National Research Council, 2004) and potentially may result in inefficient overuse of our natural world (Boyd and Banzhaf, 2005).

B.3 Non-use or Passive Use Values

Even though an individual may not directly or indirectly use a resource, they may still hold a value for it. This value is referred to as non-use or passive use value. For example, researchers have shown that individuals would be willing to pay for the preservation of unique natural areas, like Grand Canyon National Park, even though they have not visited the park nor have any intention of visiting in the future (Kroeger and Manalo, 2006).

Freeman (2003) identifies three categories of passive use values. Existence value is the value individuals assign to simply knowing that particular landscapes, habitats, or species exist. Stewardship and bequest values are the values that arise from the preservation of these places for current and future generations, respectively. Federal policy allows passive use values to be included in BCA for all major government initiatives (OMB, 2003: 5519). In some cases, particularly for resources of unique character like Yellowstone National Park or charismatic fauna like grizzly bears, passive use values can be quite large, and often dwarf use values. A classic example is the damage assessment from the Exxon Valdez oil spill in 1989, which included $2.5 billion in lost passive use value alone (Carson et al., 1992). An example of the major direct, indirect and non-use benefits that are derived when people use goods and services from ecosystems is provided in Table B-1.

Table B-1. Example of categories of values & associated benefits provided by ecosystems

Value category	Benefit
Use values	
Direct use values	• Non-consumptive recreation (e.g., canoeing, wildlife viewing, scenic views) • Consumptive recreation (e.g., hunting and fishing) • Consumptive non-recreation uses (e.g., extraction of wild foods, fibers, water, minerals, or inputs for medical and medicinal uses for sustenance and sale) • Social, religious, and spiritual events • Education and research • Renewable energy generation (e.g., biofuels, geothermal, hydro)
Indirect use values	• Pollination services • Hydrological services (e.g., flood moderation, groundwater recharge) • Erosion prevention (e.g., soil retention) • Climate moderation • Biodiversity maintenance • Nutrient cycling • Habitat provision
Non-use values or Passive Use Values	
Existence value	• Benefits humans receive from just knowing environmental quality is maintained and related native species exist
Stewardship value	• Appreciation of the fact that the scenic beauty and the natural systems are maintained
Bequest value	• Benefits humans receive from knowing that protection today provides environmental quality to future generations

Source: Kroeger and Manalo, 2006

B.4 Non-Market Valuation Methods

Economists have several means by which to measure benefits that arise from a change in the provision of goods or services not traded in markets. In other words, these methods are not meant to estimate the good or service itself but rather to estimate the *change* in value that will result if the quality or amount of the good is affected. Though this approach may seem limiting, valuing a *change* in environmental quality is the most policy relevant and commonly asked question in policy settings (Bockstael et al., 2000). For example, EPA might propose a new emissions standard for automobiles. The benefits from this proposed policy include improvements to air quality. Employing a non-market valuation method, an economist seeks to find the economic value individuals assign to the improvement in air quality. Put simply, non-market valuation of a given change in air quality is measured by observing the trade-offs individuals are willing to make based on their preferences over alternative outcomes. An example of a tradeoff in the air quality example might be to ask individuals whether they are willing to pay more at the fuel pump in the form of a higher gasoline tax or if they would be willing to pay more for cars and trucks that have improved pollution control devices.

B.4.1 Actual Behavior: Revealed Preference

One approach to monetize non-market goods and services is to model actual consumer behavior. For instance, *travel cost models* use variations, in visitor travel costs and trips to a site, of a given quality to statistically estimate a demand curve for environmental quality at recreation sites (Freeman, 2003). From the demand curve, economists can calculate the additional amount of money, beyond their current travel cost, that those visitors would pay to visit the site, and how that additional amount of money increases with improvements in environmental quality. *Averting behavior models* quantify what people would spend to avoid a negative outcome (Freeman, 2003). Examples include installing a filter or buying bottled water if water quality is poor. By analyzing what people spend on these averting behaviors or goods, economists can estimate the value individuals place on small changes in risk. *Hedonic models* (also known as Hedonic Pricing or Hedonic Property Method) estimate how much people would pay for something like water quality at residential lakes by using real estate transactions of waterfront property to estimate the portion of the sale price that is due to the water quality of the lake (Freeman, 2003). These methods are collectively known as *revealed preference methods* because they are based on the preferences individuals reveal through their related market decisions.

Because revealed preference models use data on people's actual spending behavior, the method has been relatively free of controversy compared to contingent valuation methods (Bishop and Boyle, 2017). The perceived acceptability of estimates arising from revealed preference models is reflected in the following statement from OMB's *Circular A-4* (2003): "Other things equal, you should prefer revealed preference data overstated preference data because revealed preference data are based on actual decisions, where market participants enjoy or suffer the consequences of their decisions." However, revealed preference methods cannot be used in all cases where non-market values are needed. Revealed preference methods can only be used where the value people assign to a particular outcome can be deduced from their behavior. As such, this method cannot be used to quantify non-use values.

B.4.2 Intended Behavior: Stated Preference

Stated preference methods, on the other hand, use surveys to elicit an individual's willingness to pay (WTP) and willingness to accept (WTA) values. Economists derive monetized values of non-market goods and services by measuring an individual's WTP, which is the maximum amount of money that an individual would voluntarily pay to obtain the improvement. A similar construct to monetize a negative change is to measure an individual's WTA, which is the least amount of money the individual would accept to experience some harm or to forego some improvement.

Contingent valuation and *choice experiments* are two methods used by economists. These methods construct simulated or hypothetical markets to identify values similar to actual markets, if they existed (Boyle, 2017). Economists' use carefully designed surveys to ask individuals questions about decisions they would make in a hypothetical setting. For example, a survey question might compare existing river water quality and the associated allowable recreation uses (e.g., boating) with improved water quality and additional recreational uses (e.g., swimming). In this scenario, the respondent might be asked to tradeoff improved water quality with a corresponding increase in available recreation activities versus a higher entrance fee to the site. If managers desire to know the non-use value of improving water quality to recover a native species of concern, households might be asked how much of an increase in their water bill they would pay for a program that would increase water quality and increase populations of the native species by X amount. By repeating variations of these WTP questions and surveying a large sample of the population, economists gather enough data to estimate the value of a change in water quality to visitors and/or households.

The contingent valuation method has been beset by criticism for over 30 years (Bishop and Boyle, 2017). The most common criticism is that the method suffers from hypothetical bias because the contingent valuation question does not require people to make a monetary payment (Hausman, 2012). The concern is that this leads to WTP estimates that tend to be upward-biased and thus overstates benefits. However, stated preferences methods are the only approach to estimating non-use values, which can make up the majority of total economic value. In response to the criticism of hypothetical bias, among other criticisms, economists have responded to the debate with a plethora of research on the subject (Kling, Phaneuf and Zhoa, 2012). For instance, researchers have delved into the design features of surveys and how that can affect choices as well as having developed tools to measure the accuracy of state preference estimates (Kling, Phaneuf and Zhoa, 2012). In short, many studies have found evidence that a well-conducted contingent valuation study can produce "reasonably reliable estimates of value" (Bishop and Boyle, 2017).

B.4.3 Benefit Transfer

When insufficient time and funds have been budgeted for an original valuation study, benefit transfer is often relied upon. Benefit transfer applies a benefit per unit estimate (e.g., per visitor day, per household, per acre) *from an existing study site to an unstudied policy site* where such a benefit per unit value is needed (Rosenberger and Loomis, 2017). The typical application of benefit transfer involves selecting a per unit benefit measure from existing studies or a table of average values and applying it to the site/activity for which values are needed, after adjusting for inflation. In some cases, statistical models, such as meta regressions, exist that can be used to tailor the benefit estimates to the specifics of the geographic region of the study site, recreation activity, etc. (Rosenberger and Loomis, 2017). For example, a per unit value (e.g., per visitor day, per household, or per acre) would be multiplied by the change in human use (e.g., number of visitors or households) or number of acres associated with a policy or management action.

There are three conditions that have been proposed for an ideal benefit transfer (Boyle and Bergstrom, 1992):

a) The non-market commodity valued at the study site must be identical to the non-market commodity to be valued at the policy site.
b) The human populations affected by the non-market commodity at the study site and the policy site have identical characteristics.
c) The assignment of property rights at both sites must lead to the same theoretically appropriate benefit measure (e.g., original study uses WTP and a measure of WTP is desired for the policy site).

As a practical matter most adherents to benefit transfer recognize that it is unlikely that all three of these can be met exactly. This is particularly true of condition (a) and (b), although use of meta-analysis models for benefit transfer allow for tailoring the WTP estimate closer to condition (a) and (b) than do most average value estimates.

As might be expected from Boyle and Bergstrom's list of conditions for an ideal benefit transfer, the accuracy of benefit transfer is less than conducting an original study. The percent error of benefit transfer relative to original studies can be as small as 4% and occasionally as large as 500% (Rosenberger and Loomis, 2017). However, typical range of errors is 4% to 40%. A comparison of meta-analysis estimates of threatened and endangered species values and the original study values indicates a range of average error of 34% to 45% (Richardson and Loomis, 2008). Thus, benefit transfer is also useful to provide a rough estimate of the benefits in order to decide if an original study is warranted.

Allen and Loomis (2008) estimate the economic returns from conducting original research versus benefit transfer in terms of improvements to accuracy in value estimates leading to better decision making by policy makers. The authors argue that there is an opportunity cost to poor policy decisions – "… falsely adopting an uneconomical policy versus failing to adopt an economical policy." For the most part, only very small projects (i.e., benefits are less than $500,000) would not yield positive economic returns from doing original valuation research. A second calculation enables policymakers to compare the returns to original research with all other possible uses of funds (Allen and Loomis, 2008).

B.4.4 Valuation Examples from the EPA

Environmental regulation enacted by EPA may have quantifiable reductions in the risk of adverse health outcomes, such as reduced mortality rates; decreased incidence of non-fatal cancers, chronic conditions, and other illnesses; and reduced adverse reproductive or developmental effects (EPA, 2014). Descriptions of how EPA monetizes mortality and morbidity are described in the following sections.

B.4.4.1 Mortality

In estimating the benefits from a reduction in the risk of mortality, EPA uses the value per statistical life (VSL). VSL is calculated by dividing estimates of individual WTP, for a small change in one's own mortality risk, by the size of the risk reduction. To be clear, environmental policies do not affect the probability of death for a particular individual with certainty. Instead, they lead to small changes in the probability of death for many people (EPA, 2014). EPA has used VSL in a number of environmental regulations including the Clean Air Interstate Rule, the Non-Road Diesel Rule, and the Stage 2 Disinfection By-Products rule (EPA, 2014).

In their *Guidelines*, EPA (2014) summarizes three primary methods for valuing changes in mortality risk—hedonic wage, averting behavior, and stated preference. The hedonic wage method is the most common and infers value from the income-risk tradeoffs made by workers for on-the-job risks. Averting behavior studies infer value by examining the goods that individuals purchase that can affect mortality risk like bicycle helmets. Finally, stated preference studies ask people their WTP for a small reduction in mortality risk.

In an RIA, the VSL is typically a population average estimate, which obscures the distributional effects. Thus, these estimates may not reflect the values held by the affected groups for reductions in their own risks (Robinson et al., 2014). EPA (2014) recognizes that individuals assign value to changes in health risk depending on the characteristics of those affected (e.g., age, income, race, education) and the risk itself (e.g., voluntarily assumed risk, timing of risk, source of risk, and causative events like cancer versus an accident). EPA (2014) guidance in this matter is that the analyst should consider heterogeneity in risk and population characteristics when estimating mortality benefits by including these variables in their models.

B.4.4.2 Morbidity

Morbidity benefits cover reductions in the risk across a wide range of illness from non-fatal health effects like headaches or nausea to very serious illnesses, like cancer. Conditions like birth defects and low birth weight are also included in this group.

WTP to reduce the risk of experiencing an illness is the preferred measure of value in estimating morbidity benefits (EPA, 2014). The methods most often used to estimate WTP for a small change in morbidity risk are stated preference and averting behavior. Few empirical studies, however, have estimated WTP for nonfatal illnesses and injuries (Robinson et al., 2014). Therefore, EPA relies on proxy measures, such as cost-of-illness (COI) studies. Unlike WTP studies, COI studies estimate total costs of treatment and time lost due to illness while omitting lost utility from pain and suffering and averting expenditures. As such, COI estimates often underestimate WTP to reduce risk or avoid a specific health effect.

Appendix C. Intergenerational Discounting

Discounting is the process by which each year's future values are reduced to enable comparison with current benefits and costs to society. The discount rate determines the extent of this reduction. Benefits and costs that are expected many years in the future are also sensitive to the chosen discount rate. Hence, small differences in the discount rate can compound over time leading to large differences in the net present value of benefits/costs. When benefits and costs have similar time profiles, the BCA will be insensitive to the use of alternative discount rates because the application of discount rates will be mathematically redundant.

The main reasons for discounting future impacts are:

1. Invested resources are expected to have a positive return, so current consumption is more expensive than future consumption because you are giving up that expected return on investment in the future when you consume today.
2. People generally prefer to consume something now versus in the future: hence, postponed benefits have a cost.
3. Diminishing marginal utility implies that as total consumption increases, the value of the next marginal unit of consumption is less than the previous unit of consumption. If consumption continues to increase over time, as it has for most of human history, then a unit of consumption in the future will be worth less than it would be today.

There are two predominant approaches from the economics literature for determining the discount rate. The first, the *social opportunity cost of capital* method, which relies on market-based estimates and is often referred to as the "descriptive" or positive approach. The second, the *social rate of time preference* method, takes the perspective of society's willingness to trade off present consumption for future consumption and is often referred to as the "prescriptive" or normative approach (Boardman et al., 2018). In general, the literature on discounting examines the relationship between consumption rates of interest and the rate of return on private capital.

The *social opportunity cost of capital*, the descriptive approach, recognizes that funding government projects or spending to meet government regulations has an opportunity cost of foregone investments and thus future consumption. The descriptive approach infers a discount rate from actual choices made by consumers such as the pre-tax marginal rate of return on private investments.

The *social rate of time preference*, the prescriptive approach, is often approximated using the market rate of interest from long-term, risk-free assets like government bonds. The rationale is that this market rate reflects how individuals discount future consumption and government should value policy-induced changes in consumption in the same way individuals do. Thus, this approach equates the social discount rate with the consumption rate of interest. A second approach is the so-called Ramsey equation. The Ramsey equation reflects both the value of additional consumption as income changes and a "pure rate of time preference" that weights utility in one period against utility in a later period (EPA, 2014). The pure rate of time preference is unobservable; thus, its estimation involves value judgments implying the approach is subjective (Boardman et al., 2018). If a proposed rule is expected to divert private investment, then the costs and benefits that directly affect investment could be multiplied by the *shadow price of capital* (Boardman et al., 2018). The rational for applying the shadow price of capital is that resources in the private sector generally earn a higher return than that at which individuals discount those returns (Boardman et al., 2018).

OMB guidance documents – Circular A-4 (2003) and Circular A-94 (1992)—provide federal agencies with recommendations for discount rates for use in economic analyses. The current suggestion is to use three percent and seven percent discount rates in BCA. These two values are based on observed market rates of return. The three percent discount rate is a proxy for the real, after-tax riskless interest rate associated with U.S. government bonds and the seven percent rate is intended to reflect the real equity returns in the U.S. economy, like those in the stock market. OMB allows for a possible lower rate if costs and benefits accrue to future generations over long time horizons.

Special ethical considerations arise when comparing benefits and costs across generations. While economics can systematically compare alternative discounting methods to reveal the effect of discounting over long periods, the choice of how to proceed with intergenerational discounting should not be made on economic principles alone. In the estimation of the social cost of carbon (SCC), the National Academy of Sciences (NAS, 2017) framed intergenerational social discounting as "… a social planner who prescribes weights to the welfare of future and current generations." The mention of a "social planner" implies the presence of a moral element to this calculation.

Social Cost of Carbon (SCC)

SCC is an estimate of the economic damages that would result from emitting one additional ton of carbon dioxide. SCC is used in BCA to estimate the economic impact of climate change due to changes in carbon dioxide emissions. For policies that decrease carbon dioxide emissions, the change in emissions is multiplied by the SCC and the result is the expected benefits of the proposed policy.

The following factors are broadly acknowledged as contributing to the complexity of discounting over long time periods. First, future citizens are not present when the choices that will affect them are made. In other words, the current generation may fail to account for the welfare of future generations when evaluating the effects of long-term projects. Second, the period over which discounting decisions are made is much longer than what is reflected in observed interest rates, which are used to guide the choice of discount rates. Third, the uncertainty is considerably greater when the time interval is intergenerational as compared to intragenerational. Greater uncertainty implies lower rates than those observed in the marketplace. Fourth, values will drop to nearly nothing because the discount factor declines geometrically. Thus, using a constant discount rate above two percent implies that it is not efficient for society to spend "even a small amount today in order to avert a very costly environmental disaster…" in the future (Boardman et al., 2018). Fifth, empirical behavioral evidence suggests individuals use a lower discount rate for events that occur further in the future (Boardman et al., 2018).

Intergenerational discounting is one of four modules in computing the Social Cost of Carbon (SCC). Carleton and Greenstone (2021) have provided compelling arguments for a riskless discount rate of no higher than two percent. In their opinion, the seven percent discount rate is inappropriate given that climate damages have been shown to be uncorrelated with market returns. Further, global markets have changed considerably since the publication of *Circular A-4* in 2003, suggesting that three percent is no longer an accurate estimate of the return on riskless investments. Carleton and Greenstone (2021) also argue for using models like capital asset pricing models that better reflect the returns to investments that mitigate climate change to set the discount rate. The NAS (2017) recommended using the Ramsey equation as a potential approach for deriving the discount rate, which would explicitly account for future economic growth. Based on the reasons that contribute to the complexity of intergenerational discounting, Boardman et al. (2018) advocate the use of time-declining social discount rates (i.e., rates that get smaller the farther the benefits and costs are in the future).

That intergenerational discounting is complex, highlights the need to be transparent about the considerations that go into choosing an appropriate discount rate. For instance, the chosen rate should reflect how society chooses to weigh the utility of different generations and their beliefs about the rate at which consumption is expected to change over time. Divulging the process that goes into establishing these values, in addition to using more than one discount rate, should be standard practice in discounting future benefits to present values.

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