OPEN ACCESS
Water Economics and Policy, Vol. 9, No. 3 (2023) 2371005 (23 pages)

DOI: 10.1142/S2382624X23710054

Policy Nook

Received 25 September 2023
Accepted 27 September 2023
Published 21 November 2023

Policy Note: Benefit Cost Analysis of Water Investments in the Anthropocene

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Introduction

Water management is becoming increasingly challenging. The core problem in many locations is an old one: water scarcity will increase as demand rises due to population and economic growth. Conditions in the modern Anthropocene — higher temperatures, continental drying, higher evaporation, and non-stationary hydrology — will add complexity.

The Anthropocene is usually taken to mean the period when humans are the main driving force for the development of planet Earth. The planet is 4.5 billion

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years old, and modern humans have been around for just a few hundred thousand years. They have already fundamentally altered the physical, chemical and biological systems of the planet. Since the end of World War II, human impacts have increased dramatically. This is sometimes known as the Great Acceleration, when global income, widescale natural resource extraction, carbon dioxide (CO_2) emissions, habitat destruction, and species extinction have all risen rapidly.[1] It is hard to point to any single characteristic, but the Anthropocene has brought us closer to various physical limits — sometimes referred to as "planetary boundaries" (Rockström *et al.* 2009). We are now confronted with a number of new large-scale environmental and resource issues, including the possibility of tipping points or regime shifts. Interactions between various environmental problems may increase the risk of moving past those tipping points.

In the Anthropocene, existing water supplies will need to be used more wisely and, where possible, new supplies developed. Water professionals will need to grapple with the possibility of catastrophic and irreversible environmental change (Sterner *et al.* 2019). The benefits and costs of both price and non-price policy instruments will have to be carefully assessed to balance supply and demand over time in an environment where the climate is starting to evolve at an increasing rate.

The use of benefit cost analysis (BCA) in the water sector will likely become more important than ever in the Anthropocene. This policy note describes six key issues that benefit cost (BC) analysts will need to rethink as they estimate the benefits and costs of policies, investments, and regulations designed to address water problems in the Anthropocene: (1) optimizing net benefits within quantity constraints; (2) forecasting the business-as-usual dynamic baseline rather than assuming a static status quo; (3) treatment of multiple sources of risk; (4) evaluating system-wide consequences; (5) the question of standing, that is whose benefits and whose costs count; and (6) how to incorporate equity and distributional issues. None of these are new issues to the field of BCA. However, BCA practitioners will need to sharpen their skills in order to adapt the method to conditions likely to be faced in the Anthropocene (World Bank, forthcoming).

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[1] The start date of the Anthropocene is the subject of considerable debate among different disciplines. Some place the date over a thousand years ago when human agriculture started to have effects on large areas of the planet. Most place the date in the post-World War II nuclear age with many focusing on the testing of the hydrogen bomb. A date we like is 1957 when Roger Revelle tested different radioactive isotopes of carbon in the Pacific Ocean. Revelle, often referred to as the father of modern climate science, discovered that the ocean was not going to absorb much of the CO_2 being produced from burning fossil fuels. This conclusion contradicted prevailing scientific wisdom. Presciently, Revelle and Suess (1957) wrote: "Thus human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future." They then proceeded to make the first modern calculation of how much CO_2 was and would be put up into the atmosphere over the remainder of the 20th century.

1. Optimizing Net Benefits within Quantity Constraints

There has long been a school of thought within the practice of benefit cost analysis that net benefits should be optimized subject to sets of constraints (Cohon 1978; Banzhaf 2009). These constraints might involve either physical quantities such as the quantity of water withdrawals and/or other objectives such as preserving tribal rights to fish for salmon. In the Anthropocene we expect the incorporation of such constraints into formal BCAs in the water sector to become routine practice. Effectively, this would mean that benefit cost analysts would estimate the economic efficiency consequences of water investments and policy interventions in specific locations subject to ensuring that a set of quantity constraints on environmental indicators were met. In the language of constrained optimization, planetary boundaries can be thought of as constraints or thresholds which should not be exceeded.[2]

The difficulty of applying this conceptual framework with planetary boundaries as constraints is that the consequences of an individual water project are largely local or regional even if the project is quite large and connected to large spatial areas. No planetary boundary at the global level is likely to be directly relevant in an operational sense. For a specific water investment or project, local “micro-boundaries” consistent with planetary boundaries will need to be developed. This will be hard from two quite distinct perspectives. First, the underlying physical/biological science modeling is not yet up to this task, particularly in developing countries. Second, pushing up against boundaries involves the notion of cumulative impacts and the implicit assignment of property rights for doing so.

BCA is the best option we have for understanding the consequences for human well-being that will result from the implementation of different policy instruments subject to environmental restrictions. There are two main reasons why we expect this approach of maximizing net benefits subject to physical constraints to become increasingly important in the Anthropocene. First, the human economy will confront more and more of the restrictions imposed by Nature (the “planetary boundaries”). This will imply encountering tipping points and non-linearities where a water resources decision in one arena has complex effects that spill over into other arenas. This makes it more difficult to use simple rules of thumb that have guided much of water resource management. That leads to our second reason.

[2] Rockström *et al.* define ten planetary boundaries (climate change, rate of biodiversity loss, nitrogen cycle, phosphorous cycle, stratospheric ozone depletion, ocean acidification, global freshwater use, change in land use, atmospheric aerosol loading, and chemical pollution). Multiple indicators are proposed for each planetary boundary.

Water management in the Anthropocene will be sufficiently complex that it is both desirable and inevitable that economists will be only one voice on large, interdisciplinary teams responsible for analyzing policy interventions. Increasingly, policymakers will not ask economists for a BCA focused solely on economic efficiency, unconstrained by the effects of investments on planetary boundaries (Dasgupta 2021). Ecologists, sociologists, political scientists, engineers will all want to weigh in on the physical and social constraints within which economic efficiency is maximized.

Reducing CO_2 emissions is a good example of the difficulty of downscaling planetary boundaries. There is no workable agreement on an upper limit on concentration levels. The political economy questions are how proportionate shares for each country and how an overall cap on CO_2 emissions can be enforced. The now long running series of international climate negotiations has shown that the world has yet to solve these problems, despite the fact that the optimal solution from an economic perspective is clear, i.e., price CO_2 emissions using marketable carbon permits or carbon taxes so that the agreed upon CO_2 emission cap is not exceeded. This has not happened and that is due to the inability to reach consensus on the parallel problems of how to divide the revenue from selling the right to emit CO_2 between and within countries, and how to enforce the overall emissions cap. The former often turns on equity issues, such as fear of job loss and regulatory capture. The latter involves an unwillingness to impose meaningful sanctions, such as stiff tariffs on exports, on countries not complying with the agreement.

Managing water is much harder in some ways than limiting CO_2 emissions because it does not have the same uniform global mixing property as CO_2. The problem of limiting CO_2 emissions has the elegant economic solution of separating the issue of how to price carbon from the issue of how to distribute the revenue from allowing a specified quantity of it. Further, the stochastic factors influencing water's availability at any specific location and point in time are much more important. On the other hand, the fact that many water resources problems can be solved at the local level may sometimes be an advantage as smaller resource-using groups can often collaborate more readily that global ones.

Defining these boundary constraints in an operational sense will likely be the hardest task the Anthropocene imposes on water resource management. Their form in many instances will already be familiar. For instance, a requirement that the water flowing past a particular point along a river meet some minimum quantity and quality requirement. This example emphasizes the spatial nature of defining boundary constraints. There are many choices, e.g., between countries, between first-order political subdivisions (e.g., provinces or states), or between river basins. There is no scientific justification for the first two since these natural processes of interest do not change just because a political boundary is crossed. The river basin is potentially the most relevant geophysical unit but lacks the enforcement powers associated with a political entity. Further, there is a tension between choosing the same or different geographic boundaries for different physical and biological boundaries. Whatever spatial definition(s) are chosen, inputs into the area and outputs into other areas will need to be specified.

These are complex processes that need to be adequately modeled in order to make them suitable for inclusion as constraints in a BCA. Efforts to develop broad scale tools for quantifying ecosystem services (such as Stanford's Natural Capital Project) that provide initial estimates for projects can serve an important role here.[3] Such estimates can be improved over time with high quality local area data. It is also possible that advances in machine learning will make the analytic tasks involved in implementing this approach increasingly tractable (Guariso and Sangiorgio 2023). Machine learning can assist with both the design of local micro-boundaries and the search for efficiency gains within these constraints. The difficulty is that machine learning is not a substitute for lack of data. High quality, spatially dense monitoring is needed globally. Indeed, machine learning with sparse, low-quality data may well be worse than expert judgement. More generally, the entire notion of taking downscaled planetary boundaries into account in making policy decisions is predicated on a large-scale increase in monitoring data and the ability to effectively model these processes.

At first glance, respecting planetary boundaries at the level of undertaking a BCA of a large water project might seem likely to make the project look less attractive. However, this is not necessarily the case. From an economic perspective, misguided allocation of water resources is rampant. Currently new water projects are often undertaken without policymakers fixing prior misallocations. With effective constraints, a new water project still could be highly desirable from a social welfare perspective, but the only way it can now be implemented is to free up water resources that are being used for low-valued purposes.

Economics is good at developing trading mechanisms that respect limits. Cap and trade with marketable permits works with a whole range of air pollutants such as sulfur dioxide on a regional and national level (Stavins 1998). The basic problem with such mechanisms is that parties who have used the resource for free fight efforts to make them pay for its scarcity value. In the water policy arena, an example of a potentially workable solution is a micro-boundary that there be no net loss of wetlands within a specified region, coupled with an active wetland bank that records efforts to preserve, rehabilitate and create wetlands.

[3] https://naturalcapitalproject.stanford.edu/.

Non-economists working in the water sector usually think in terms of non-monetary performance indicators to conceptualize the "benefits" of policy interventions. They then compare changes in these indicators to the financial costs of the intervention (a cost effectiveness approach). On the other hand, economists are concerned with the "economic value of water" (Young and Loomis 2014; Hanemann and Whittington 2023). Efficient policy interventions require that water be reallocated from low to high value uses, which often will be socially disruptive and can impose substantial costs on some households, farmers, and firms.

How economists and non-economists perceive the benefits of "water conservation" provides an illustration of the difference between thinking in terms of quantities and value. Non-economists tend to conceptualize water conservation as unambiguously good (even when water is abundant). Policy interventions that reduce people's water use (e.g., flow-restricting faucets, social nudges) are seen as always desirable.[4] In contrast, for an economist, optimal water use occurs when the social costs of supplying the marginal unit of water to a customer equals the marginal social benefits. It is thus possible that someone's water use is too low (the marginal costs of supply are less than the marginal benefits). Water conservation *per se* is not necessarily desirable. It is in the DNA of economists to always ask the question — "what are economic agents willing to pay for more water versus the cost of supplying more water?"

Supplying more water can be accomplished in multiple ways, such as storing more water in reservoirs during extreme precipitation events, desalination, recharging groundwater aquifers, and recycled water use. The high cost of transporting water long distances often limits the usefulness of some of these actions. Thus, there is not one single global water problem, but rather a series of local problems which may share commonalities but still differ so significantly as to constitute quite separate problems. For example, one location may have droughts and floods in different seasons, and another location may have the opposite seasonal pattern of droughts and floods.

These different perspectives on quantities and values are not easy to reconcile. However, a framework in which net benefits are optimized subject to quantity constraints is a natural extension of a cost effectiveness approach and provides a way for professionals from different disciplines to collaborate to solve water problems.

[4] The problems associated with reduced return flow are already important in many urban sewage systems and reduced downstream return flow from improved irrigation practices are creating large-scale problems in many agricultural areas. The most important difference among experts may not be between economists and others. Instead, it may be between professionals who have formal system-level modeling skills (e.g., civil engineers, hydrologists, and economists) and those who do not.

2. Construction of the Dynamic Baseline (Counterfactual)

BCA involves a comparison of two states of the world: (1) a dynamic baseline (i.e., counterfactual) in which the policy intervention is not implemented, and (2) a state of the world in which the policy being analyzed is implemented. Benefits and costs are measured as the difference in these two states of the world. In the Anthropocene, when we are closer to (or have passed) the boundaries, there may be threshold effects, tipping points, or areas of sharp non-linear responsiveness that make the counterfactual more uncertain and hence more likely be more contested than BC analysts working in the water resources sector have typically assumed (Whittington 2022).

The construction of this dynamic baseline is a challenging task in all sectors and especially in the water resources sector. Many water resources investments last for decades, often much longer than the 20- to 30-year period that characterizes the high end of the timeframe used in most BCAs. Estimation of benefits and costs requires a comparison of these two states of the world far into the future. The dynamic baseline (the world without the intervention) must thus be forecast taking into account such factors as climate change, technological innovation, rural-to-urban migration, population and economic growth, and changing household preferences. Moreover, hydrology itself can no longer be assumed to be stationary (Milly *et al.* 2008). In previous decades BCAs typically assumed that the statistical characteristics of a hydrological times series would be repeated in the future.[5] Water resources infrastructure then could be designed to maximize net benefits given this underlying stationary hydrology.

Such an approach is no longer tenable. How global warming will change a region's hydrology is difficult to know with great precision, but in most locations, higher average temperatures are expected, and extreme weather events, including droughts and flooding, are likely to become more common. Many locations around the world are now experiencing continental drying and a reduction in groundwater storage, due to both unsustainable groundwater extraction and climate change (Rodell *et al.* 2018; Rodell and Li 2023). In the Anthropocene, the construction of the dynamic baseline needs to incorporate the increased uncertainty introduced by

[5] This can be visualized by considering how sensitivity analyses are now often conducted for proposed water projects in the United States. An approach called the "Index-Sequential Method" is often used (Ouarda *et al.* 1997; Kendall and Dracup 1991). The historical hydrology is treated as a continuous loop. Different starting dates in the historical sequence are randomly chosen and the analysis is repeated for each hydrological trace created at the randomly chosen date. In the Anthropocene, the constructed loop of flow traces based on the historical hydrology will no longer reflect what the future is likely to look like in a non-stationary time series world.

non-stationary hydrology, higher temperatures, more extreme precipitation events, continental drying, and other effects of climate change.[6]

This increased attention to the dynamic baseline is not only required for the estimation of the benefits and costs of large water infrastructure such as dams. Population growth and climate change will strain local water resources near urban areas. BC analysts should plan investments in urban water infrastructure that will deliver services in a world different from the status quo. Indeed, perhaps the largest issue raised by a dynamic baseline for water resources in the face of a changing climate is that the entire notion of a steady-state allocation of the flow of a river may no longer be tenable. The general tendency in many places will be that average flows are falling over time and that longer and more extreme periods of drought are likely. This will put pressure on existing property rights regimes for water resources.

Because future conditions in the Anthropocene are highly uncertain, BC analysts will often need to evaluate new investments using multiple counterfactuals. Robustness of a project's outcomes to different plausible dynamic baselines is likely to become an important factor in project selection (Lempert *et al.* 2003; Groves and Lempert 2007; Herman *et al.* 2014, 2015). Further, a single estimate of the net present value of an investment based on one dynamic baseline will be an increasingly unsatisfactory approach to BCA. Although Monte Carlo analysis that systematically varies parameter estimates in BC calculations (e.g., discount rate, cost overruns, value of time saved, value of a statistical life) will remain useful, it will not be sufficient to address the deep uncertainty about the underlying physical and biological world in the specification of the counterfactual.[7]

3. Treatment of Risk and Uncertainty

In their seminal contributions on the treatment of risk in the analysis of government investments, Arrow and Lind (1970) and Arrow and Kurz (1970) argued that a government should be risk neutral because the number of policies, regulations, and investments to be analyzed was large and the consequences of each individual government action were small relative to the size of the economy. Governments could thus maximize the expected value of investment returns without worrying about the variance of returns, effectively self-insuring against the risk of poor returns in any one investment. Although Arrow and Fisher (1974) soon qualified

[6] Continental drying is cause by both climate change and excessive groundwater extraction.

[7] Economists have long recognized that uncertainty over benefits and cost could influence the optimal choice of policy instrument (Weitzman 1974). Less well-known is the fact that uncertainty over the parameters in the underlying biological and physical science models can have much different and quite profound implications in evaluating policy options (Carson and LaRiviere 2018).

the argument for risk-neutrality in government investment appraisal, noting the problems posed by irreversible environmental losses and uncertainty, many BC analysts have continued to follow Arrow and Lind's advice on risk neutrality.

In addition to the Arrow–Fisher argument, there may be other situations in which risks should be taken explicitly into account. An example is when risks are correlated — for instance between a project whose costs and benefits are being analyzed and climate change itself. Assume climate change implies a risk to the economy that can be (at least partly) captured by its effect on the growth rate. If climate change turns out not to be as bad as expected, economic growth might be high — say 5% and if the climate change is really bad and causes havoc, then growth might be reduced to 1%. Now suppose we are evaluating airports and hospitals. The former might have a higher rate of return in the state of the world in which economic growth is high while the latter are more useful in the scenario where the economy grows slowly. One approach for dealing with such correlated risks is to adjust the discount rate (i.e., climate beta) so that it depends on the characteristics of the project studied (Dietz *et al.* 2018).

Numerous scholars have noted the limitations of being risk neutral in the analysis of climate change mitigation and adaptation measures (Weitzman 2009). In the Anthropocene, *homo sapiens* face an existential uncertainty of the collapse of food and water systems that were not built for future climate conditions. Confronted with the possibility of disastrous right-tail consequences, BC analysts need to recognize that risk neutrality for many policies is an untenable assumption. Wagner and Weitzman (2015) explain this in simple terms, arguing that even a small probability of a globally disastrous climate change outcome would justify aggressive mitigation measures. They argue that such measures should be conceptualized as insurance against the worst case.

The rationality of safety-first policies in many circumstances has long been recognized (Farmer and Randall 1998, Randall 2011). "Safety first" is an economic variant of the precautionary principle, which is a useful way to conceptualize localized micro-boundary planetary constraints.[8] In an early paper, Kunreuther and

[8] A core difficulty with the notion of localized micro-boundary constraints is that even if there is a binding constraint at the planetary level, this could not be remotely true at a localized level and human societies have a long history of abandoning for long periods of time areas they have made uninhabitable. The Anthropocene Age recognizes that humans have and are now exercising the capability of doing that on a global scale. The economic variant of the precautionary principle recognizes substantial but not infinite costs of violating safety standards. It also provides one means of thinking about a constraint such as no net loss of wetlands that allows both localized destruction and creation of wetlands as long as the overall constraint is not violated at some spatial level such as a U.S. state.

Wright (1979) make a similar point in the context of a subsistence farmer's analysis of investment returns from different cropping decisions: safety comes first. Similarly for *homo sapiens* facing catastrophic global climate change risk, safety comes first.

The argument against risk neutrality in the Anthropocene applies not only to climate mitigation and adaptation measures, but to a wide array of policies, regulations, and investments that will deliver streams of benefits and costs far into the future. These flows of benefits and costs may be subject to deep uncertainty and should be evaluated in terms of their potential to minimize equally uncertain downside consequences of climate change.

The careful analysis of risk and deep uncertainty in the Anthropocene is important because individuals and states both face a devilishly complex choice between allocating scarce resources between investments to mitigate greenhouse gas emissions and investments to adapt to a changing climate. The essential character of this budget allocation problem has been characterized in many ways. Hirschman (1970) wrote about how people respond to decline in firms, organizations, and states. He described the option of continuing to work for an institution and trying to foster change from within (voice, loyalty) versus leaving to promote change from the outside the institution (exit). The analogy here is how individuals and governments will respond to a decline in global environment services and their local manifestations.

A somewhat similar choice is posed in the prisoner's dilemma: to defect or cooperate. Some adverse consequences from climate change are now inevitable regardless of mitigation efforts, so some expenditures on adaptation are not difficult to justify. But at the margin the tradeoff remains: is mitigation or adaptation the best use of the government's marginal expenditure? Deeply embedded in this question is the fact that it cannot be answered without making assumptions about what other political jurisdictions are going to do. Different assumptions can lead to radically different outcomes. An optimistic country might make large-scale investments in technological research and development (R&D) that it plans to make publicly available to all in order to reduce the costs of global mitigation efforts. A pessimistic country might start building massive seawalls believing that a global mitigation strategy is doomed to fail. From our perspective, BCA offers the best framework for analyzing such choices between mitigation and adaptation, but only if the simplistic risk neutrality assumption that has long characterized BCA is abandoned.

4. System-wide Consequences: From Partial to General Equilibrium Analyses

In his 2014 Stockholm Water Prize acceptance speech, the late Dr. John Briscoe, Global Water Advisor at the World Bank, stated that "water problems are local, and solutions are contingent". Briscoe argued that most (but not all) water problems result from a nexus of local conditions that require water professionals to find local solutions that fit their specific circumstances in time and place. However, in the Anthropocene global forces such as rising temperatures, an increase in the frequency of extreme events, and continental drying will require not only local but global policy responses (Ringler *et al.* 2016). Because some policy responses will be implemented at the regional and global scales, it will become increasingly important in the Anthropocene to move from the partial equilibrium framework of most BCAs to a general equilibrium framework that can incorporate system-wide consequences of policy interventions.

General equilibrium analysis in the water resources field is not new (Dinar 2014; Whittington and Smith 2020). Scholars have been working to integrate water resources into economy-wide models for decades (e.g., Berck *et al.* 1991; Roe *et al.* 2005; Strzepek *et al.* 2008; Diao *et al.* 2008). More recent efforts have followed the lead of integrated assessment models in climate change in bringing forth an increasing complex picture of how natural and economic forces operate together (Kling *et al.* 2017). There have, however, been several stumbling blocks to the widespread use of such models for the assessment of the benefits and costs of water policies, projects, and regulations. First, the time-step for economy-wide models is typically one year, much too long a period for many of the practical problems facing water resource managers. Local water managers are often dealing with problems that require forecasts on a much finer time scale.

Second, most economy-wide models do not incorporate the infrastructure needed to move water in time and space; they simply assume that water can be delivered where it is needed most on time and at no cost. Third, most economy-wide modelers have not had the data to incorporate the non-market values associated with changes in water uses. This often requires primary data collection that is typically beyond the resources of such modeling teams.

Fourth, we need to rethink the way we discount costs and benefits of both large, long-lived public investments in water resources infrastructure and policy interventions to reduce and mitigate the effects of climate change in general equilibrium analysis. For investments and policies with consequences far into the future, the use of discount rates commonly mandated in countries for short- and medium-term private investments is inappropriate. Discount rates for such investments need to be adjusted for several related but different reasons. Uncertainty in growth rates is one (Arrow *et al.* 2013). The risk and climate beta argument mentioned above is another. Also, both a warmer climate and rapid economic growth will increase the economic value of ecosystem services like water due to increasing scarcity. One fundamental reason for discounting the value of some dollars of consumption goods is that we will have more in the future (assuming economic growth continues). In such a scenario with growth we may however still have less of some ecosystem resources (such as coral reefs or clean and accessible water resources). This can be dealt with in a BCA either by using a lower ecological discount rate for such sectors or by using a standard discount rate and complementing it with an increasing relative price for the services of (the scarcer) ecological sectors, (Hoel and Sterner 2007; Sterner and Persson 2008).

However, these limitations are being overcome. Understanding the general equilibrium consequences of water policies is increasingly tractable analytically (Kahsay *et al.* 2015, 2019; Basheer *et al.* 2021, 2023). For example, Basheer *et al.* (2021) link a state-of-the-art river basin simulation model of the Nile with monthly time steps and an annual, economy-wide computable general equilibrium (CGE) model of the Egyptian economy to better understand how different operating policies for the Grand Ethiopian Renaissance Dam would affect macroeconomic indicators of the Egyptian economy.

BC analysts working in the Anthropocene will need to estimate the general equilibrium consequences of large policy interventions in the water resources sector. This will require more resources. Partial and general equilibrium analyses are not mutually exclusive. Each does some things well. We recommend that the *ex-ante* evaluation of most large water investments and policy interventions (especially on large transboundary rivers) include both a traditional, partial equilibrium BCA that includes the estimates of effects not valued in markets and a general equilibrium analysis using a CGE model to better understand the system-wide macroeconomic effects of policy interventions.

5. Standing (Who Counts?)

The question of “who counts” in a BCA will need to be rethought in the Anthropocene. It will be increasingly common for a nation-state’s regulations and investments to have consequences that spillover beyond national borders. Projects that decrease or increase greenhouse gas emissions will affect everyone on the planet. Issues of social justice and moral imperatives likely will leave most nation states struggling with the issue of climate change refugees, driven from their home countries by extreme droughts, floods, and loss of traditional agricultural livelihoods (Alemanno 2013). Countries that are currently well endowed in terms of available water per capita may experience scarcity in the future due to the in-migration of people or expansion of their agricultural sector.

The issue of who should count in a BCA has been discussed in the literature for decades. From its basic utilitarian origin of the greatest good for the greatest number of people, it is clear that any assessment of social welfare in a BCA should count all of the gains and all of the losses no matter to whom they accrue or where they accrue. This has never been implemented in practice. Instead as Howe (1971) argued over 50 years ago, it is natural for each level of government to adopt an "accounting stance" that counted benefits and costs within its own jurisdiction, and excluded benefits and costs that fall outside its boundaries. While political support for this position will continue, it will be harder to justify in the Anthropocene because the ability of human activities to affect large-scale physical and biological processes will become increasingly apparent.

The flash point is whether and when "foreigners" should have standing, an issue scholars have long debated (Whittington and MacRae 1986, 1990; Trumbull 1990a,b; Zerbe 1991). The global nature of climate change has been forcing a re-examination of this issue. Abelson (2020) and Boardman *et al.* (2022) recently reviewed the guidance documents from several national and international agencies and concluded that there is still no consensus on how BC practitioners should answer this foundational question of "who counts" in the application of the method. As Boardman *et al.* (2022) noted, even within a single organization, guidance may be contradictory, citing internal World Bank guidance documents that argue both for and against including the effects of a policy or regulation on people living outside a nation's borders.

In the past most BCAs have been conducted from the perspective of the nation-state, i.e., citizens and residents within a country's national borders should count and people outside these boundaries should not. Boardman *et al.* (2022) argue that this national perspective should be the default assumption in BCA and then discuss situations in which it is appropriate to include the benefits and costs to "foreigners". The most clear-cut case in which foreigners should be included is when there is an international agreement between two countries that defines their respective rights and obligations. All one needs to do though is to think about policies that shift pollution or water-intensive production across national borders to see that this issue is hardly resolved. Even within many countries where ecotourism is a major driver of the economy, it is hard to see how ignoring the consumer surplus of potential foreign visitors, who are free to travel elsewhere, can be justified.

This issue of who has standing is deeply contentious and will dominate many future policy discussions in the Anthropocene. The United States Environmental Protection Agency (2022) has recently issued guidance that a global estimate of the social cost of carbon (SOC) should be used in be used in BCAs of US environmental regulations, effectively implying that the benefits to both US residents and foreigners from reduction of greenhouse gas emissions should be counted in the assessment of US regulations. In response, Fraas *et al.* (2016, 2023a, b) argued that the United States Environmental Protection Agency (USEPA) should calculate a domestic SOC, i.e., the damages incurred by people living in the United States from an increase of one ton of carbon, and require that it be used in a second, separate BC assessment of US regulations. The use of a domestic SOC would effectively limit the benefits of a regulation reducing greenhouse gas emissions to citizens and permanent residents of the United States. Such a sensitivity analysis does not resolve the issue of what the national government should actually do if there is a conflict in the results of the two sets of BC calculations. For example, should the United States Office of Management and Budget support (approve) a regulation that passes a BC test from a global perspective but fails from a national perspective or vice versa?

In the Anthropocene an increasing number of water projects and investments undertaken by a nation-state will have transboundary consequences. If these consequences include benefits to people living outside the nation-state, and these benefits are not included in the BCA, each nation-state will engage in a suboptimal investment policy from the global perspective, undertaking too few investments that help neighboring countries and too many investments that harm neighboring countries. Adopting the perspective of the nation-state as the default assumption in BCA is simply an example of the tragedy of the commons writ large. This is the same reason that BCAs adopted a national perspective rather than a local or state perspective in considering who's benefits and costs should count in the analysis.

The Anthropocene will tend to push us more and more into the realm of global public goods. The management of global public goods can only be solved if other "players" (countries) will see and count the benefits we experience. For the sake of reciprocity, we must internalize the benefits they will experience. If we want India, China, and other countries to use a global estimate of the SCC in their national decision-making, we need to use one too.

There is an additional issue regarding "standing" that is likely to grow in prominence in the Anthropocene: whether non-human species should have standing? BCA is an anthropocentric method and based on utilitarian principles (Hanemann and Whittington 2023). It assumes that humans are the ultimate source of value. In contrast, many people believe that other living species have value regardless of what *homo sapiens* think. This is not a new critique of BCA (see Stone 1972). The standard anthropocentric economic response is that other living species have economic value because people are willing to pay to protect them (Mitchell and Carson 1989). This emphasizes the critical importance of including all non-market values in BCA, which otherwise are incomplete and potentially misleading (Bateman *et al.* 2023). However, as the number of species on the planet continues to collapse (Dasgupta 2021), it seems likely that many people will become increasingly alarmed and find the anthropocentrism of BCA problematic and support planetary boundaries for species extinction.

A close analogy to the imposition of a planetary boundary for species extinction is the United States Endangered Species Act. It has evoked enormous animosity from landowners, incurred substantial costs, and achieved at best mediocre results (Langpap *et al.* 2018). The policy instrument that does seem to work best within the framework of the U.S. Endangered Species Act is targeted government expenditures designed to help specific species. This experience should give pause to anyone who thinks that establishing a planetary boundary-type requirement to preserve all species as a condition for approving water projects will be an easy solution to preventing species loss. Irrespective of one's philosophical and ethical positions on whether non-human species have intrinsic value in their own right, establishing micro-boundaries for species preservation in the context of water projects will be a complex technical challenge in the Anthropocene.[9] Ensuring that a BCA for a project explicitly includes the public's willingness to pay to offset adverse impacts on particular species and biodiversity more generally, will be increasingly important.[10]

6. Equity and Distributional Issues

In the Anthropocene, BC analysts will need to pay much more attention to the distributional consequences of investments, policies, and regulations than they have in the past. There are three main reasons. First, the costs of climate change are likely to fall disproportionately on the poor and most vulnerable. This will matter to both citizens and policymakers. Second, successful policy implementation depends crucially on marshalling broad public support (Sterner *et al.* 2020). Policy mixes are required that include policies not only to mitigate and adapt to climate change, but also to minimize adverse impacts on the disadvantaged. Third, distributional consequences of policies have feedback effects on the future behavior of the economy. Not taking them into account will result in poor estimates of the consequences of implementing different policy mixes.

[9] Climate change will cause large-scale species extinction, irrespective of individual water projects. As such the appropriate baseline is not the current status quo but rather a world with an increasing loss of existing species over time. From an economic perspective, this is likely to make preservation of particular species more valuable over time.

[10] The general public's willingness to pay (sacrifice) more for the sake of biodiversity may well represent a rational anthropocentric preference to protect species if people think preserving biodiversity/individual species is an important obligation of people or an important aspect of human life on Earth. It may, but need not, imply that people think individual species or biodiversity more generally has intrinsic value that is independent of humans.

For decades economists have debated how best to take account of distributional issues in BCA (Dasgupta *et al.* 1972; Harberger 1978). The simplest approach is to present a tabular display of the types and magnitudes of gains and losses that would accrue to different groups as a result of different policy proposals. Policy-makers can then decide which proposal is preferable. There are also a variety of approaches in the literature to increase the weight given to gains of poor, disadvantaged individuals in aggregating benefits and costs. These distributional weights can be derived based on different assumptions about the marginal utility of income and the appropriate social welfare function (Acland and Greenberg 2023; Ferranna *et al.* 2023).

In practice distributional weighting schemes have not been used in most countries. In the United States, Robinson *et al.* (2016) report that regulatory impact analyses (RIAs) conducted for US government agencies rarely consider distributional issues at all. In the RIAs they reviewed, few included even a simple tabular display of who would benefit and who would lose from the implementation of a specific regulation or policy proposal. Some World Bank economists were originally proponents of the use of distributional weights in BCA of Bank-financed projects (Squire and Tak 1975), but here too such proposals were never implemented, i.e., distributional weights were not used in practice.[11]

There is no consensus globally on how to incorporate equity issues in BCA. Nation-states will decide how they want to weight the gains and losses to their own citizens (and to foreigners). In the Anthropocene the first step for BC analysts must be to pay attention to distributional issues by including a tabular display of the magnitude of the gains and losses that would accrue to different groups as a result of policy proposals under consideration. Such results will be of interest both within countries and globally.

However, the calculation of who wins and who loses is more difficult than is commonly assumed. Because most BC analysts have not been doing even this first step in the analysis of distributional consequences, they are often not fully aware of the challenges involved.[12] In order to analyze the distributional consequences of a proposed investment, policy or regulation, a BC analyst must use a dynamic baseline that describes the condition of each of the affected parties of interest in the

[11] The World Bank now uses “poverty assessments” to examine distributional consequences of projects. These are separate reports, not part of the BCA.

[12] With the use of aggregate level data, it is not even clear how to proceed with such an analysis. However, many contemporary studies use individual-level revealed or stated preference data that result in individual-level estimates of monetized welfare changes. With a representative sample of agents and reasonably rich set of demographic and spatial covariates, performing a distributional analysis is relatively straightforward. Conventions on how to display the results of such an analysis so they are accessible to policymakers and the public are likely to evolve over time.

distributional analysis. For example, if an analyst wants to estimate the welfare effects of a regulation to mitigate flood damages on different income groups, flood risk over time for each dwelling unit in the area of interest needs to be forecasted with and without (the dynamic baseline) the regulation. Then some method of obtaining actual household income for each of these dwelling units or estimating it with reasonable statistical precision is needed. With all three pieces of information in hand, it is possible to show decision makers how the regulation would impact households in different income categories.

The estimation of distributional effects requires that an analyst not only estimate the distribution of the benefits of a policy intervention across affected parties, but also the distribution of the costs (Cecot 2023). The forecast of the dynamic baseline must thus include the wellbeing of the parties who will be bearing the costs in the state of the world without the policy intervention as well as those who will benefit. The data requirements for such careful distributional analysis are large, and primary data collection may be necessary to establish and then forecast the counterfactual.

At the time this paper was written (September 2023), the issue of how to incorporate distributional effects in BCAs conducted in the United States is being actively debated and discussed. On January 20, 2021, President Biden issued an Executive Memorandum entitled "Modernizing Regulatory Review,"(MRR) which stated:

> "I therefore direct the Director of OMB, in consultation with representatives of executive departments and agencies, as appropriate and as soon as practicable, to begin a process with the goal of producing a set of recommendations for improving and modernizing regulatory review. These recommendations should provide concrete suggestions on how the regulatory review process can promote public health and safety, economic growth, social welfare, racial justice, environmental stewardship, human dignity, equity, and the interests of future generations."

MRR states that the Office of Management and Budget (OMB) should:

(i) "identify ways to modernize and improve the regulatory review process, including through revisions to OMB's Circular A-4"...

(ii) "propose procedures that take into account the distributional consequences of regulations, including as part of any quantitative or qualitative analysis of the costs and benefits of regulations, to ensure that regulatory initiatives appropriately benefit and do not inappropriately burden disadvantaged, vulnerable, or marginalized communities;"...

On the same day, President Biden also issued Executive Order 13985 on "Advancing Racial Equity and Support for Underserved Communities Through the Federal Government." EO 13985 directed OMB to "study methods for assessing whether agency policies and actions create or exacerbate barriers to full and equal participation by all eligible individuals. The study should aim to identify the best methods, consistent with applicable law, to assist agencies in assessing equity with respect to race, ethnicity, religion, income, geography, gender identify, sexual orientation, and disability." In combination, MRR and EO 13985 charge OMB with the task of developing new guidance on how equity and distributional effects should be incorporated into the evaluation of regulatory actions by federal government agencies.

In response, in April 2023, Richard Revesz, the Administrator of the Office of Information and Regulatory Affairs (OIRA) at OMB issued proposed revisions to Circular A4, which provides guidance to US federal agencies on how to conduct a BCA of a proposed regulation. Public comments on the proposed revisions were elicited, and literally thousands of individuals and organizations submitted responses.

For the first time, this new draft guidance invites federal agencies to use equity weights in the summation of costs and benefits to affected parties. However, the draft guidance does not make the use of equity weighting mandatory; their use is at the discretion of the agency proposing the regulation. Public comments on OIRA's proposal to make use of equity weights optional are wide-ranging, both for and against. No doubt the use of equity weights in the US regulatory process will engender future legal challenges.

7. Concluding Remarks

Currently some countries use BCA regularly while others hardly use the method at all. We believe that more widespread use of BCA methods in the water sector globally would be a good way to spread knowledge and understanding while sharing experiences. Issues such as the design of water and sanitation tariff structures have often been the focus of ideological debates. An alternative approach is to see such interventions as policy experiments. We can then learn from these experiments, avoiding failures and refining the policy mixes that work best.

BCA has three main strengths, and these will continue in the Anthropocene. First, the method can be embedded in the administrative state to evaluate government budgetary and regulatory decisions. If deployed effectively by the administrative state, BCA can facilitate cross-sectoral comparisons and discussions across government agencies. BCA poses the question, "Are the benefits of the project greater than the costs?" The conceptual simplicity of the end result of the method is an important strength. Adaptation of the method to meet the demands of the Anthropocene should not dilute this message. Many proposals to solve problems fail this test, and this is often apparent early in the evaluation process. The ability of the method to focus policy attention on proposals that increase overall social welfare should not be lost. The temptation to caveat main findings and to delve into complex linkages will result in producing reports that only an elite group of technocrats can understand.

The second strength of BCA is that it helps to organize the sources of benefits and costs in a consistent way across proposed policies and keeps the opportunity costs of the policies, investments, and regulations front and center for policymakers to consider. Even a simple BCA reminds decision makers that there are winners and losers associated with any policy, investment, or regulation. Too often project proponents devote the majority of their attention to the advantages of a project and downplay its opportunity costs. If BCA is done well, it serves to keep the bigger picture in focus for a decision maker.

The third (potential) strength of BCA is that it provides a framework that can account for distributional consequences of policy interventions. BCA results can be downscaled to examine the consequences of policy interventions on different groups or spatial areas. The use of public funds to finance water projects will almost always create both winners and losers. The assessment of the distributional consequences of such interventions must be done as objectively and rigorously as possible. Non-economists will be especially interested and are likely to get heavily involved in the distributional analysis of policy interventions. Using a unified BCA methodology can help spread good examples of distributional analysis and provide a way for non-economists to become involved in BCA. The interactions between economists and professionals from other disciplines can become more productive.

In summary, the Anthropocene will see large, disruptive changes to the environment. These will likely increase the demand for water and the value of water resources. It is important to use the latest developments in BCA to take account of the (1) increasing scarcity and value of water; (2) increased potential for the analysis of distributional issues and conflicts around water; and (3) distinct risk profile of water investments in the face of generalized uncertainty about the future. As the Anthropocene evolves, more and more water challenges will have characteristics of global public goods. This requires global cooperation and will have repercussions on who has standing in BCA.

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