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Equity and Cost-Effectiveness in Valuation and Action Planning to Preserve Biodiversity

Amy W. Ando[1]

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Abstract
Economic research and frameworks, comprehensively synthesized in "The Economics of Biodiversity: The Dasgupta Review" (Dasgupta 2021), can do much to help stem global biodiversity loss. However, ingrained features of economics as a discipline often produce explanations and solutions for environmental problems that advantage wealthy and powerful entities in our global society rather than those who are poor or otherwise marginalized. This paper highlights two dimensions of economic research related to biodiversity where disciplinary bias can lead to ineffective and inequitable work: biodiversity valuation, and targeting causes of biodiversity loss to be changed. First, it shows how valuation approaches can best be used to inform actions that capture both use and non-use values and include the perspectives and needs of people who are typically marginalized in governance processes. Second, it discusses how global action to preserve biodiversity will be cost-ineffective and inequitable unless we take at least some steps to identify and correct actions taken by wealthy countries and large-scale producers that contribute much to the biodiversity crisis, rather than focusing policy primarily on the behavior of low-income individuals and households.

Keywords Biodiversity · Climate change · Equity · Population · Valuation · Land use

1 Introduction

"*The Economics of Biodiversity: The Dasgupta Review*" (Dasgupta 2021; the *Review*) provides a sweeping synthesis of insights from economics into the causes of and possible solutions to our current biodiversity loss crisis. That synthesis has potential to mobilize important global action to slow or reverse biodiversity loss by formalizing the central role nature and biodiversity play in human prosperity. The *Review* may also improve a wide range of private sector and government decision making by centering natural capital into working definitions of inclusive wealth and sustainable development. Dasgupta's work sounds a

✉ Amy W. Ando
amyando@illinois.edu

1 University of Illinois Urbana-Champaign, 326 Mumford Hall, 1301 W. Gregory Dr., Urbana, IL 61801, US

clarion call to action by making clear that our stocks of biodiversity have great value and many of our actions are heedlessly and irreversibly destroying those stocks.

However, that synthesis naturally embodies many of the tendencies of the discipline as a whole that can lead economics to pose explanations and solutions that advantage wealthy and powerful entities in our global society rather than those who are poor or otherwise marginalized. For example, economic frameworks tend to seek efficient outcomes without interrogating the sources or consequences of the initial endowments of resources and power, and economic models and analyses often achieve tractability by abstracting from important institutional and cultural details like discriminatory barriers to wealth accumulation and property ownership (Ando et al. 2021).

This paper explores two dimensions of the *Review* itself in which re-focusing could improve both the effectiveness and the equity of its suggested global response to the biodiversity loss crisis. First, effective and equitable global efforts to stem biodiversity loss will need to be motivated and directed by complete and unbiased estimates of the values that biodiversity bring to humanity (Atkinson et al. 2012). However, the methods promoted in Chapter 12 of the *Review* are limited in their capacity to meet that need. Section II of this paper identifies several features of those recommendations that will tend to underestimate our estimates of the total values of biodiversity and give particularly short shrift to the important roles that biodiversity plays in the lives of marginalized and indigenous peoples. The section makes a suite of suggestions for how valuation approaches can best be used to inform actions that capture both use and non-use values and include the perspectives and needs of people who are typically neglected in governance processes.

Second, economists must be careful to focus on action recommendations that will actually effect equitable change. Pareto efficiency has dominated the attention of mainstream economics since the middle of the twentieth century (Sandmo 2015). However, one can correct Pareto inefficiencies in many domains of human activity with actions that burden already-vulnerable people without having much impact on the biodiversity problem as a whole (e.g. Bruno et al. 2019). The early core section of the *Review* (specifically Chapters 4, 7, 8 and 9) places the locus of responsibility for biodiversity loss heavily on decisions about consumption and reproduction made by individuals, particularly individuals who happen to be very poor. Section III of this paper analyzes the implications of that focus for both cost-effectiveness and equity. Policies and management decisions to reduce the rate of species extinctions can only be effective if they target actions to promote or modify that are large drivers of habitat and biodiversity loss. Furthermore, global action to preserve biodiversity will be inequitable unless we take at least some steps to identify and correct actions taken by wealthy countries and large-scale producers that contribute much to the biodiversity crisis, rather than just targeting actions taken primarily by low-income individuals and households.

2 Valuing Biodiversity to Inform Action

Many scholars in conservation biology, ecology, and even economics have long opposed valuation of biodiversity; common objections have been that economic valuation approaches could not capture the intrinsic value of biodiversity and might have objectionable ethical foundations (Matulis 2014; Meinard et al. 2016). Nonetheless, much research has estimated the economics values of individual endangered species (Richardson and Loomis 2009) and of biodiversity (Hanley and Perrings 2019), and economic valuation research does play important roles in conservation decision making by government and private agents. Monetized estimates of the values of biodiversity help make the case that biodiversity conservation has positive net benefits and should be undertaken. For example, estimates of ecosystem-service values are included in the cost–benefit analyses required for approval of any major government regulations in the United States (Smith 2018). Findings from valuation research also help conservation planners choose exactly where and how conservation and restoration programs should be deployed, since benefits can vary with things like proximity to people and the mixture of flora, fauna, and landscape features of areas that are preserved.

The *Review* does discuss biodiversity valuation. Chapter 12 begins helpfully by outlininga wide range of values biodiversity holds for humans. The chapter next describes four common approaches to non-market valuation: stated preference (SP) and revealed preference (RP) methods to estimate people's willingness to pay (WTP) for public goods and amenities; ecosystem service production function analyses that quantify the value of direct services like flood control; and research that monetizes the loss of human life and health that is estimated to result from environmental degradation. The chapter ends with an engaging philosophical discussion of existence value, intrinsic worth, and whether nature itself should have moral standing in human affairs. This exposition of valuation methods does provide some useful background on this field in the discipline. Furthermore, the discussion of spiritual values is a refreshing non-quantitative contribution to discussion of valuation by economists.

However, several features of the *Review*'s discussion of biodiversity valuation would lead practitioners of biodiversity valuation to produce underestimates of the values of biodiversity and inadvertently center value estimates on benefits to dominant groups in society. Specifically, Chapter 12 discourages use of well-established stated preference methods, implicitly favors approaches that estimate WTP over willingness to accept (WTA), and does not provide actionable guidance for valuation and decision making approaches that would be inclusive of people typically marginalized in governance processes.

2.1 Include Stated Preference (SP) Methods in the Biodiversity Valuation Toolkit

Some of the benefits of biodiversity described in Chapter 12 of the *Review* (promoting human health and life, providing enjoyment, producing helpful services) are characterized in environmental economics as use values; other benefits (existence and intrinsic values) are characterized as non-use values. Both RP and SP methods are used widely and included in the toolkit of non-market valuation approaches accepted by entities such as the National Oceanic and Atmospheric Administration and U.S. Environmental Protection Agency. Nonetheless, SP methods are often billed as "controversial," and a drumbeat of criticism has led some work (such as Chapter 12 of the *Review*) to discourage the use of these methods. In fact, blanket rejection of SP methods rests on weak foundations, and economic theory shows that society will greatly underestimate the full values of biodiversity if stated preference methods are disallowed.

To understand the importance of SP methods in estimating the value of biodiversity, one must begin with a clear understanding of the alternative methods; Champ et al. (2017) provides an excellent introduction to both SP and RP methodologies for the reader unfamiliar with the broad area of nonmarket valuation. RP valuation methods use data on actual decisions and outcomes related to an environmental good to quantify some dimension of the value that good provides to people. The category of RP approaches actually includes a diverse set of methodologies. For example, recreational demand studies can use data on where and how often people choose to go bird watching to quantify the value that bird biodiversity has in increasing the enjoyment people gain from bird watching (Kolstoe and Cameron 2017). A hedonic housing price study can use data on the prices of lakefront houses to quantify homeowners' WTP for healthy aquatic biodiversity (Zhang and Boyle 2010).A range of "production function" approaches can quantify the values that plant diversity provide by increasing carbon sequestration (Hungate et al. 2017), the values that mangroves provide to people by buffering coasts against storms and nurturing shrimp populations (Barbier 2000), or the value that diversity of natural economies to crop pests provides by bolstering the yields of marketed crops (Letourneau et al. 2015).

RP methodology has the advantage of being grounded in actual human decisions and market transactions, though each RP approach has its particular limitations. For example, it can be difficult to statistically identify the marginal value of one specific environmental attribute in recreational demand or hedonic housing price models if that attribute tends to co-vary across space and time with other features of the landscape. Production function approaches require the analyst to have an accurate model of the socio-economic-biophysical system that relates changes in the environmental good of interest (such as mangroves) into changes in environmental outcomes that people care about (such as flood damage).

Most importantly for the current discussion, all RP methodologies have one critical limitation in common: none of them can estimate non-use values. In order to use market data like expenditures on recreational trips or the prices of houses to quantify a value of an environmental good, that value must be linked in some way to a market or to human behavior (Flores 2017). That condition does not hold for non-use values such as existence value—the value a person places on something like having the polar bear continue to exist even if they never interact with it or gain tangible value from it.

Only SP valuation methodologies are capable of estimating non-use values. The two SP methods are the contingent valuation method that was most firmly established by Mitchell and Carson (1989), and the choice experiment method that has gradually eclipsed contingent valuation since its introduction to environmental economics in the 1990's (Adamowicz et al. 1994; Hanley et al. 1998). Both SP methods use surveys of samples of the population of people whose preferences are to be estimated and have sophisticated design features refined by large communities of researchers to optimize the validity of the valuation estimates they produce (Johnston et al. 2017). Contingent valuation surveys describe one particular hypothetical scenario with an environmental good and ask respondents carefully designed questions to elicit the value people place on that good. Choice experiments describe an environmental good that could have varying levels of multiple attributes (including cost to the respondent), and pose an experimentally designed set of choice questions between attribute scenarios that can be analyzed with random-utility model econometrics to estimate the marginal values people have for changes in those attributes. Christie et al. (2006) show how both approaches used to estimate the values of biodiversity.

SP approaches can provide value estimates when it is not possible to observe human behavior related to the good to be valued or when environmental goods are highly correlated with each other or other things in real-world settings (Alberini 2019). SP valuation methods are likely to be especially important for estimating the full values of an element of nature like biodiversity because the existence of species and general diversity of life on earth are likely to have particularly large non-use values among the set of environmental goods one might value. For example, non-use values have been shown to dwarf recreational use values in the careful studies of the damages associated with the Deepwater Horizon oil spill. While English et al. (2018) found that damages to coastal recreational use from this spill totaled only $662 million and Alvarez et al. (2014) found lost recreational angling valued at only $585 million, Bishop et al. (2017) found with a state-of-the-art contingent valuation survey that the U.S. public would be willing to pay up to $17.2 billion to avoid the comprehensive set of damages to use and non-use values of the scale caused by Deepwater Horizon. The Blue-Ribbon panel (Arrow et al. 1983) endorsed the use of SP methodology in valuation for natural resource damage assessments precisely because these tools are the only way to capture non-use values that are likely to be important elements of the damages associated with oil and toxic chemical contamination.

Because SP methods gather and analyze data on what people say they would do, rather than what they actually do, concern has persisted in the discipline that value estimates from SP approaches may suffer from hypothetical bias and other validity concerns (Banzhaf 2017). However, stated preference methods have been carefully refined and validated over the decades since they were first introduced (Kling et al. 2012) and some of the recent continued critiques of contingent valuation are not well founded (Haab et al. 2013). It may not be a coincidence that some of the most prominent criticism of SP valuation has been documented as coming from research financed by the oil industry (Maas and Svorenčík2017), given how much the inclusion of non-use values in a damage assessment increase the damages from oil spills that they can be held liable for under the Oil Pollution Act of 1990.

No methodology is without flaw, including SP valuation methods. However, complete estimates of the benefits of biodiversity require use of stated preference methods because species and diversity are likely to have large non-use values due to cultural and spiritual values or and the lack of substitutes for unique forms of life. By dismissing SP valuation methods, the *Review* would encourage work that chronically underestimates of the total benefits of biodiversity conservation efforts and undermines the case for policy actions to be taken to stem the loss of our natural biological capital.

2.2 Estimate WTA Instead of WTP When Appropriate

Chapter 12 of the *Review* speaks of valuation studies as estimating our "willingness to pay" for nature. That phrase is a natural way to describe the economic concept of value to non-economists. However, WTP is also a technical term and only one of two possible measures of value in environmental economics. Favoring estimates of WTP over the alternative, WTA, is a consequential choice that would yield inappropriately low estimates in some contexts.

Basic microeconomic theory of consumer behavior with respect to ordinary market goods with prices defines two equally valid measures of changes in consumer welfare related to a price change. Compensating variation (CV) is the amount of money we would have to give an optimizing consumer after a price change to make them as well off as they were before. Equivalent variation (EV) sets the consumer's utility after a price change as the baseline, and finds the amount of money we could have taken away from them at the original prices for their utility to meet the baseline. The conceptual difference between the two measures in, say, the case of a disadvantageous price increase, is that CV implicitly grants the consumer the right to the higher level of utility they had before the change, while EV sets the new lower level of utility as the baseline. Willig (1976) showed that for price changes of marketed goods, CV and EV will be very similar unless very large income effects are at play.

Environmental economics expands the traditional neoclassical welfare-economic framework to develop two measures of the change in consumer welfare that would result from a change in the quantity of a non-market good (Cropper and Oates 1992). WTP is essentially the largest amount of money a consumer would be willing to pay to gain a new environmental good, and WTA is the smallest amount of money we would have to pay a consumer to be willing to give up such an environmental good they already enjoy (Flores 2017). SP and RP valuation methodologies alike can be used to measure both measures of value for non-market goods.

WTP has tended to be favored over WTA at least since Arrow et al. (1983). However, the choice of valuing WTP instead of WTA is likely to be inappropriate for many situations in which estimates of biodiversity values are important for decision making. In contrast to CV and EV for ordinary goods, the values of WTP for an environmental improvement and WTA for the converse loss can be very different (Horowitz and McConnell 2002). In particular, WTA is well documented as being higher than WTP (Hammitt 2015). That gap is often painted as a problem to be solved (e.g. Basu and Srinivasan 2021), though research shows some publication bias may be inflating estimates of the difference (Koń and Jakubczyk 2019). However, there are good theoretical reasons to expect WTA often to be higher than the equivalent WTP.

First, Hanemann (1991) uses neoclassical economic theory to show that WTA can reasonably be orders of magnitude higherthan WTP when a good has no substitutes.The existence of a unique species is clearly a prime example of such a case. A person's WTP to have a new amenity is, by definition, budget constrained. In contrast, WTA (what you would have to pay someone to be indifferent to the loss of something) is not. As Hanemann points out, WTA compensation for loss of a unique good like the existence of polar bears or (in the extreme case) your own life could be extremely large or even infinite.

Second, behavioral economists have established loss aversion (Tversky and Kahneman 1991) as a feature of human behavior: people must be compensated more to give up something they already have than they would pay to obtain it de novo. Loss aversion can be one reason that WTA an environmental loss can be greater than WTP to gain an equivalent environmental improvement (Brown 2005). If scholars truly want to quantify the harm humanity would endure as a result of losing important individual species in our environments or living on an Earth stripped of the diversity that currently enriches our lives, it may be appropriate to account for this well-documented feature of human preferences.

Thus, scholars and decision makers should think carefully about whether to estimate biodiversity values in terms of WTA or WTP because that decision is likely to have a large impact on the size of the estimated values and their conceptual relevance for the decision making setting to be informed; a meta-analysis of papers estimating WTP and WTA for the same goods (Tuncel and Hammitt 2014) shows that the ratio of WTA–WTP is 4.36 for goods with no close substitutes. WTP is conceptually appropriate when the problem at hand is to find the largest payment that would leave people indifferent between giving up that money and gaining an environmental improvement, such as restoring a previously degraded habitat like the Tallgrass Prairie (Dissanayake and Ando 2014). In contrast, WTA is appropriate when we are deciding how much we would have to pay to compensate people for losing a feature of the environment they currently have access to and cherish, like species at risk of extinction (Brown and Gregory 1999). Economists should be willing to use WTA estimation approaches as part of our toolkit to inform the global conversation about preventing biodiversity loss.

2.3 Equity and Representation Concerns in Valuation

Research economists often define the domain of our professional concerns quite narrowly. In the case of biodiversity valuation, this could manifest as focusing attention on generating careful estimates of the monetized values of a change in biodiversity and leaving the interpretation and use of those estimates to others. However, economists are sometimes involved in full cost–benefit analyses that determine the actions that governments take. Some economists contribute to the kind of aggregate measures of natural capital discussed in the *Review* (page 309). And all of us bear responsibility for communicating our work in a manner that forestalls problematic applications. A few examples demonstrate efforts we could make in our valuation work that would advance global equity in efforts to stem biodiversity loss.

First, we could work more to quantify heterogeneity in people's preferences, and have transparent policies and conversations around how much weight society is placing on the preferences of different groups. Most valuation research focuses on producing accurate estimates of the average individual value for an environmental good and uses that value to scale up a calculation of the total value of that good to society (for example, Johnson et al. (2019) find the total value of an expansion of Denali National Park). However, values may vary widely among groups of people. For example, road access to wilderness may have high average value in the population but be anathema in the eyes of indigenous groups such as the Athabaskan people in Denali (Twitchell 2005). In general, the people who live closest to a species are likely to have the highest WTP for its preservation (Yamaguchi and Shah 2020; Johnston et al. 2019; Hanley et al. 2003), although animals like elephants that are treasured by many people around the world can be a mixed blessing for the people who live near them as they pose threats to life and livelihood (Brouwer et al. 2010). The utilitarian model of social welfare produces total values that are just sums of the individual values. However, that approach will necessarily tend to place little weight on the particular preferences of groups of people that are small and/or powerless—like indigenous tribes, racial and ethnic minority groups, or residents of sparsely populated rural areas—yet may have particularly compelling claims in the policy debate. Economists can help inform transparent conversations about whose values are being counted by creating estimates of value heterogeneity that capture culturally and institutionally important sources of such variation.

Second, economists could be careful in our writing not to rhetorically confound the ability someone has to pay for high environmental quality with preferences they have for having environmental goods. WTP for an environmental goodis fundamentally budget constrained; one cannot be willing to pay more money to protect biodiversity than one has. Thus, WTP for a given set of preferences is increasing in income (Barbier et al. 2017). However, it is easy for our writing inadvertently to elide the role poverty plays in shaping WTP when we write about preference variation. One paper, for example, estimated race-specific preferences for environmental quality in a sorting model and find in the abstract that "Hispanics may dislike cancer risk but be less willing to trade other forms of consumption to avoid it" (Depro et al. 2015). The paper explains much later in the paragraphs just before the conclusion that racial disparitiesin WTP to avoid pollution probably stem from the income disparity between White and Hispanic people in the study area. However, many readers never read past the abstract. In a world with massive income and wealth gaps in general (Piketty 2018) and between people of different races and ethnicities (Darity and Hamilton 2012), we must work actively to avoid confusing the positive finding that poor people are willing to pay less to preserve their natural heritage with a normative policy or management conclusion that it's fine not to protect those resources because they don't care as much as wealthier people.

Third, economists could be more inclusive in our work on environmental valuation by choosing sometimes not to estimate neo-classical economic values at all. Many indigenous cultures have value structures that do not recognize some elements of nature ascommodities that are fungible with other goods (Temper and Martinez-Alier 2013). Dasgupta (2021), p. 309 itself discusses in Sect. 12.6 that nature may have powerful existence value and intrinsic worth: "One may doubt, however, that hard-nosed cost–benefit analysis could be the right language in which to express all our values. … Many people, perhaps in all societies, locate the sacred in Nature. And the sacred is not negotiable, unless we rationalise by imagining it to be incorruptible … we do not put a price on the sacred. Our urge is simply to protect it." In important cases where standard economic tools like cost–benefit analyses are inappropriate, economists might more usefully find other uses for their skills like finding effective strategies for promoting conservation objectives in sites people access and hold sacred (Rutte 2011).

3 Focusing Biodiversity Policy for Cost-Effectiveness and Equity

Even our current estimates of the values of endangered species and biodiversity indicate there is great value to humanity in preserving these features of the planet (Richardson and Loomis 2009; Hanley and Perrings 2019). In order to slow the pace of global ecological degradation and concomitant biodiversity loss, scholars and policy makers must first identify what factors are the most significant drivers of that degradation, and then set about identifying policies or management actions that can make change. The vast majority of human actions have deleterious effects on the environment, and those effects are not fully considered in the deliberations that lead to actions because of externalities (Dasgupta 2021, pp 189–190). Effective and equitable actions will focus on drivers of degradation that (a) have large enough effects on biodiversity for change to make a difference, and (b) can be changed through policy or management without creating costs that outweigh the benefits, violating moral standards, or generating gross inequities. This section of the paper summarizes which drivers are the focus of the *Review*, lays out a conceptual framework for thinking about what bundles of policies are most likely to be mostcost-effective and equitable, and suggests policy foci that are likely to be critical supplements to those emphasized by the *Review*.

3.1 Drivers Emphasized by the Core of the Review

As the *Review* explains in Chapter 4, the total impact of humanity on the environment depends on three general factors. In the notation of the *Review*, the impact $I$of humanity on the biosphere can be represented as:

$$I = Ny/\alpha \tag{1}$$

where N is population size, y is per capita consumption, and α is a parameter that captures the efficiency with which technology and production practices create products to consume. Humanity has more impact on the environment if there are more people, the impact of each individual person will be higher if they consume more things, and the environmental impact of a unit of goods depends on how that unit is produced. The principal part of the *Review* (the first several hundred pages prior to discussions relegated to “Extensions”) focuses its analysis and concern heavily on the roles that the first two factors—Human population levels and individual consumption—play in driving biodiversity loss.

Concern about population increases driven by unfettered human fertility appear in Chapter 7 on externalities. Section 7.2 points out the international declarations and agreements that have established individual rights over their own reproductive decisions, but then spends a page fretting that this international norm means that scholars and policy makers do little to study or control “reproductive externalities.” Chapter 9 (“Consumption Practices and Reproductive Behavior”) speaks of social preferences in wealthy countries that drive high levels of consumption, and shows evidence that “the world’s poorest countries cannot even remotely be held responsible for the size of the Impact Inequality today.” But immediately after a call for social nudges to reduce consumption by the wealthy, the chapter lays out concerns about rates of childbearing by the poor: “The [Sustainable Development Goals] are reticent about family planning, and yet it is hard to imagine that they can be met without addressing the subject.” There is more discussion of reproductive externalities and what the *Review* refers to as socially conformist preferences for childbearing among people in poor countries. The chapter concludes with a lengthy discussion of how family planning programs in low-income countries could counter socially embedded preferences and reduce childbearing by the global poor.

In stark contrast, the potential need for policies that transform large scale industrial production to decouple consumption from biodiversity destruction is featured very little in the early core of the *Review*. Section 6 of Chapter 4 does mention that nature saving technologies and incentives could help to increase the size of the α parameter and reduce the environmental footprint of a given level of consumption, but does not follow through with a specific discussion of what production-side policies would be particular helpful for slowing biodiversity loss. Chapter 7 on the regulation of unidirectional externalities does mention commercial fishing in one side box; however, any other mention of industrial sources of damage in that chapter is confined to abstract models of how externalities from a hypothetical factory’s pollution could best be regulated. Instead, the chapter has extensive discussion of the payment for ecosystem services (PES) programs that have been implemented in poor areas of the world to try to encourage individual land users to adopt more environmentally friendly behaviors. Chapter 8 discusses reciprocal externalities in overuse of common property resources (CPRs) and mentions in passing that climate change would be a good example of a such a problem that society might want to correct. However, most of Chapter 8 (pages 210–217) discusses threats to biodiversity posed by small scale resource extraction carried out by largely low-income individuals who happen to live in biodiverse parts of the globe and rely on CPRs with “fragile” governance.

3.2 Conceptual Framework for Focusing Policy Investments

National and global policy makers cannot simply choose values for the quantities in Eq. 1 above of population, per capita consumption, and the efficiency with which natural capital is harnessed for production. Rather, policy makers choose how much to invest in each of a set of policies and initiatives that could help protect biodiversity, each of which has costs. A simple conceptual framework can help us think about the cost-effectiveness and equity of different strategies for allocating our global investments in policies to protect biodiversity.

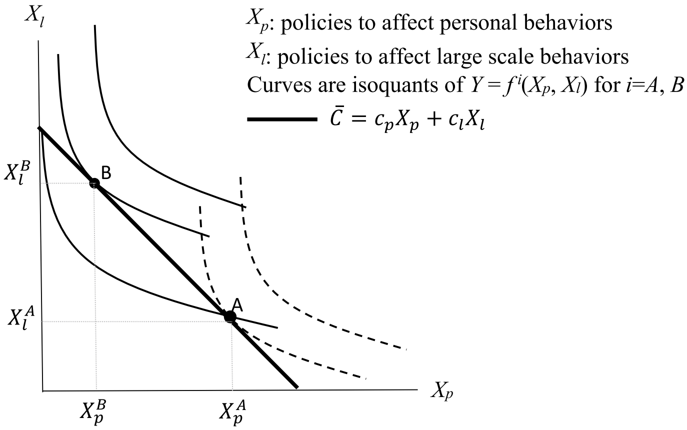

Fig. 1 Cost-effective allocation of biodiversity investments

In this framework, biodiversity protection, Y, can be produced by two sets of policies and actions. Actions to alter personal behaviors like individual consumption and childbearing in developing countries are denoted X_p and have constant marginal costs c_p that are borne disproportionately by low-income people of the world. The other actions, denoted X_l, change large-scale behaviors like industrial fishing and logging and fossil-fuel-based energy production; these constant marginal costs, c_l, are borne disproportionately by the relatively wealthy people in the world who own and control these sources of environmental degradation. Cost-effective global biodiversity policy will choose policy investments to maximize biodiversity protection, Y, for a given total cost, C:

$$\max Y = f\left(X_p, X_l\right) \quad s.t. \quad C = c_pX_p + c_lX_l \tag{2}$$

Figure 1 shows an iso-cost line of investments in X_p and X_l; points lower on the iso-cost line allocate more of the total cost of conservation to low-income people. The figure also shows two sets of hypothetical isoquants of production of biodiversity protection, $\overline{Y} = f^i\left(X_p, X_l\right)$ where $i$is denoted as A or B. If society is sure that the relationships between the marginal products of X_p and X_l yield dotted isoquants of biodiversity protection that are steep relative to the isocost line, thenthe cost-effective global action would be at bundle A (reflecting the emphasis of the *Review*). That bundle would devote most of our biodiversity investments to policies that control personal drivers and impose costs disproportionately on low-income people. Under this kind of conservation-protection production function, there would be a tradeoff between burdening vulnerable people and achieving cost effectiveness.

If, however, the true isoquants were captured by the solid lines, then policy bundle A yields much less biodiversity conservation than would be possible for the same total social cost by shifting investment away from personal drivers and towards controlling large-scale industrial activities as captured in bundle B. Some effort would still be indicated for programs to encourage less consumption and lower birth rates. However, the change from the emphasis on personal drivers reflected in A would yield a progressive shift in the distribution of the burden of total policy costs.

3.3 Limits on Marginal Values of Policies to Alter Personal Drivers of Biodiversity Loss

Research would be needed to quantify the nature of the production function that translates sets of policy and management actions into biodiversity protection. Changing technological mixes alone is unlikely to be a successful sole strategy; as indicated in Dasgupta et al (2021), the rate of technological change would have to be extraordinary to meet Sustainable Development Goals in the future without changes to population or per-capita consumption. However, it seems likely that investments in policies to alter personal behavior—population growth, consumption, and small-scale production—have limited marginal value as a strategy for averting the crisis of biodiversity loss. Even from a simple cost-effectiveness perspective, individualistic factors are not really the biggest drivers of concern in environmental crises like climate change and biodiversity loss.

First, total population itself is not a primary driver of environmental harm.[1]As the *Review* itself points out repeatedly, most of the impact of humans on the environment stems from a small number of wealthy individuals; this is true by international comparison and by looking at the carbon footprints of neighborhoods within a single country (Goldstein et al. 2020). Furthermore, recent research suggests that total global population may naturally decline after 2064 after reaching a lower peak than was previously forecast (Vollset et al. 2020).

Second, people face serious challenges in understanding the true environmental costs of their purchases. Thus, even successful nudging to change consumer's environmental attitudes toward consumption (as discussed in Chapter 9) is unlikely to be an effective strategy for reducing humanity's aggregate impact on the biosphere. The harm done by consumption itself could instead be reduced with a wide range of changes in supply behaviors that decouple consumption from environmental harm. For example, changing growing practices can reduce the environmental footprint of food (Chai et al. 2021), and changing to renewables can reduce climate change and progress is happening to make what once seemed a pipe dream into a reality (Borenstein and Kellogg 2021; Zerrahn et al. 2018).

Third, while personal extractive behaviors by low-income people certainly do have direct impacts on habitat and species, research shows that the impact of local extraction is small compared to large scale industrial production (Marques et al. 2019).[2] Economists have understood since "The Problem of Social Cost" (Coase 1960) that producers and resource extractors have insufficient private incentives to choose socially efficient levels of environmental protection, and large-scale activity inflicts large-scale damage. Economists have paid less attention to the incentives that resource owners and large industries have to exert political influence to thwart policies and technical change that will strand their resources. Researchers have detailed campaigns of disinformation and intimidation by industrial interests to prevent regulation of harmful materials including lead (Rosner and Markowitz 2007) and fossil fuels (Oreskes and Conway 2010, 2011). The results are

[1] Indeed, continued focus on population control in low income countries as a key driver of environmental woes is actively harmful, especially to women in vulnerable minority groups.Overpopulation narratives functionally vilify childbearing by women in developing countries. Calls for modern population control canreflect the racist history of environmental scholars like Garret Hardin (Oakes 2016), and help fuel modern episodes of forced sterilization of indigenous women in places like Canada and Peru (Ko 2021).

[2] These numbers were also presented much later in the *Review* in Chapter 15 on trade, though trade itself is not the only source of large scale industrial activity that causes environmental damage.

widespread damage to humans and wildlife from (in those examples) toxic exposure to lead and from climate change accelerated by uncontrolled burning of fossil fuels.

3.4 Alternative Emphases on Large-Scale Drivers to Protect Biodiversity

Thus, we are not likely to accomplish cost-effective and equitable solutions to the crisis of biodiversity loss by emphasizing the roles of childbearing, consumer choice, and small-scale resource use in developing countries. While there is no formal aggregate budget constraint on global actions to protect biodiversity, emphases on individual actions can distract biodiversity activists and absorb the finite appetite policy makers have for making change. Thus, global action may be both more effective and equitable iftargeted in good measure at large-scale drivers where policiescan have greater impact.

Furthermore, there are large scale issues of justice if our biodiversity crisis exists because of centuries of extraction and pollution by wealthy nations and sectors of the global economy, but we respond with actions that burden people who are currently very poor and rely on using nature for survival. Instead, conversation about the drivers of and solutions to biodiversity loss can advance equity ty tackling some of the biggest drivers of biodiversity loss that happen to stem from globally powerful interests.

For example, we cannot slow biodiversity loss unless we control climate change. Climate change policy is not mentioned in Chapter 21 of the *Review* as a priority in "Options for Change." However, the *Review* itself repeatedly acknowledges that climate change is a huge driver of biodiversity loss. For example, Annex 4.1 gives a compelling description of the damage climate change is causing to biodiversity in general, and Chapter 14 points out the climate changes is responsible for most of the stress on fish stocks (Halpern et al. 2019). Indeed, research shows alarming evidence that places with greatest marine biodiversity are also most affected by climate change and industrial fishing pressure (Ramírez et al. 2017).

Climate change is driven by fossil fuel use; we could have the same levels of global consumption with a much lower carbon footprint with serious effort to reduce carbon emissions from fossil fuels. Efforts by the U.N. to navigate global climate change mitigation have sought to emphasize heightened responsibilities for industrialized nations since they produced most of the emissions that created the problem (United Nations 1992). Frumhoff et al. (2015) suggest further that fossil fuel companies themselves have been heavily responsible for the climate change crisis, and that just climate solutions would call on those companies to make change.

Industrialized nations could also simultaneously promote justice and reverse major contributions to biodiversity loss through habitat restoration. Chapter 19 describes a range of restoration activities that could reverse biodiversity loss in degraded areas, though few details are provided in the *Review*'s summary call for change. The global stock of degraded habitat includes large areas of devastation caused by industrial use, such as large-scale deforestation to make way for sugar-cane plantations (Obidzinski et al. 2015). The history of large-scale land conversion and habitat destruction also includes cases in which colonizing peoples wrought land use changes that displaced or extirpated local racial and ethnic groups, and in the process decimated biodiversity. We see this in cases ranging from bison hunting and grassland conversion in the American prairie (Andregg 2008; Isenberg 2020) to the transformation of sheep husbandry and the Highland Clearances in Scotland (Ryder 1968; Walker 2003). Wealthy nations could target areas for restoration investments that would do much to promote biodiversity that was damaged through centuries of their own actions.

Finally, efforts to promote biodiversity conservation can focus on reducing ongoing industrial-scale land conversion, resource extraction, and pollution. Chapter 21 of the *Review* does call for changes to trade, pointing out important ways in which trade has decoupled the location of demand for consumption from the location of production and placed heightened pressure on habitats in low income countries. That focus is, indeed, important, as we see from ongoing industrial conversion of natural forests in Indonesia for palm oil (Cisneros et al. 2021) and deforestation in Brazil for trade in timber and cattle (Rudel et al. 2009). However, not all large scale production and conversion relates to trade, so trade restrictions alone will leave many damaging activities unchanged. Policy makers can aim policy and regulations at large-scale pollution and resource damage regardless of the source of demand.

4 Conclusions

Chapter 14 of the *Review* talks about distribution in reliance on environmental assets and "suggests ecosystem management and poverty alleviation policies should not be independent" (Schaafsma and Fisher 2016). Concern about equity and distribution should be centered in our approach to stopping the crisis of biodiversity loss if we are to accomplish the joint grand challenges of preserving our natural biological heritage, correcting historic injustices, and mitigating the current extreme levels of human inequity (Piketty 2018).

Effective and equitable use of valuation to inform how much and how to act to stop biodiversity loss would have several key features. First, analysts would draw on research using all valuation methods, including stated preference approaches. In this manner, non-use values of biodiversity would be included in assessments of the benefits of biodiversity preservation to avoid chronic underestimates of the values biodiversity provides. Second, researchers and decision makers would estimate the values necessary to compensate people for prospective biodiversity loss (WTA) rather than the amount people would be willing to pay for a resource (WTP) when we are studying cases where ongoing environmental degradation threatens to strip resources from people who currently rely on them. The WTA is conceptually more appropriate and just in such cases. Estimates of WTP for biodiversity restoration will tend to be much lower than the values of WTA and thus understate the case for action, especially in cases where the people who rely on the threatened resource are poor.

As the world sets out priorities for action to halt biodiversity loss, we can choose sets of strategies that are both more cost-effective at increasing total social welfare and more equitable than just controlling the actions of individual people, especially those in low-income countries. Emphasizing population control accomplishes little for biodiversity and can harm vulnerable women. And while programs like payments for environmental services will be useful for limiting externalities from small scale extraction in particularly biodiverse areas that are sensitive to use, more progress can likely be made by targeting policies elsewhere.

Cost-effective and equitable strategies to slow biodiversity loss are likely to focus action on controlling climate change and large-scale industrial land use change and resource extraction. New research in political economy may be needed to identify ways to overcome historical barriers that have diverted policy attention away from actions taken by powerful actors toward the behaviors of individual consumers and small-scale resource users. However, changes to large-scale resource use may be necessary actually to be effective in correcting the largest environmental externalities and preserving biodiversity, and they place responsibility for addressing the crisis on wealthy and powerful industries and countries rather than low-income people and nations.

Finally, this time of renewed global concern for biodiversity is a moment in which industrialized nations can usefully reflect on their historical contributions to large-scale habitat loss through production or colonization. In cases where restoration is possible to bring back the biodiversity and ecosystem services that were damaged by those actions, they can take steps that would both help slow global biodiversity loss and make amends for the harm done to marginalized groups of people by that past.

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