The economics of biodiversity: accounting for human impact in the biosphere

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Abstract

This article provides an analysis of The Economics of Biodiversity: The Dasgupta Review. The review places the study of biodiversity at the core of economics, by providing a conception that takes into account human impact in the biosphere, and planetary boundaries. This leads to a theoretical model where the human economy is bounded. Within this conception, Nature is valued as an asset, in a context where a social evaluator, or citizen investor, takes into account intergenerational wellbeing. This article discusses the methodology through which human impact in the biosphere is accounted for in the theoretical framework proposed in the review, while scrutinising the method for valuing biodiversity proposed in the review.

Keywords: Biodiversity, economics, value, capital, well-being, biosphere.

1. Introduction

The relationship between humanity and Nature depends crucially on the way in which human beings organise their economic activity. And the way in which economic activity is organised depends on the conceptions shared by human beings on how the economy works, and what impact it has on Nature. The discipline of economics figures centrally in this process, given its role in conceptualising the way in which human beings interact with each other, with other species, and with Nature in general. This idea is reiterated in David Attenborough's foreword to the recent review commissioned to Partha Dasgupta (2021) on the economics of biodiversity – the full title is The Economics of Biodiversity: The Dasgupta Review. Attenborough's foreword finishes by stating that economics shapes decisions with deep consequences, and praises the Dasgupta Review for finally putting biodiversity at the core of economics.

The Dasgupta Review conceptualises biodiversity within a generalised economic model, that takes into account human impact in the biosphere, and planetary boundaries. Thus, the human economy is seen as bounded, rather than unbounded. This is achieved, as Dasgupta notes, through slight adaptations of an analytical framework that builds upon previous contributions in economics. But those slight adaptations have profound implications, to the extent that they enable the development of an economics of the entire biosphere, in which Nature is valued as asset, through a social evaluator, or citizen investor, that takes intergenerational wellbeing into account. The review is quite extensive and summarises many important ideas within a generalised economic model. Here the focus is on the methodology and theory employed when developing an economics of the entire biosphere, taking into account the notion of citizen investor, and the generalised economic model achieved in the review.

The next section, section 2, explains the way in which the Dasgupta Review conceptualises human activity within the biosphere. Section 3 assesses the methodology and theory used when valuing Nature in the Dasgupta Review. Section 4 explains the framework adopted in the review for conceptualising material processes of production, while noting the need of providing an analytical framework that addresses some inconsistencies that arise in the review. Section 5 outlines how the valuation of human impact in the biosphere can be conducted after addressing those inconsistencies. Some concluding remarks follow.

2. Modelling the human economy in the planetary safe zone

After a foreword by David Attenborough, the Dasgupta Review starts by expressing the author's understanding of what economics is or should be. A central aspect of economics, according to Dasgupta (2021, p. 3), is that "economists work with models of those features of the world we want to study in detail." The Dasgupta Review intends to place biodiversity at the core of economic models, by extending the scope of economic modelling so as to reach an "economics of biodiversity" understood as "the economics of the entire biosphere." (Dasgupta 2021, p. 4). The advance over previous efforts in economic modelling thus obtained is the inclusion of the entire biosphere in economic models, while noting that the biosphere, like the global economy embedded in it, is bounded. It is the latter aspect that, according to Dasgupta, has been neglected in economics.

Dasgupta (2021, p. 107, original emphasis) notes the need of taking into account "planetary boundaries", while also highlighting how "Rockström et al. (2009) identified *nine* biophysical processes that are critical for Earth System functioning." Dasgupta (2021, p. 108) notes that the "idea of planetary boundaries has powerful heuristic appeal",

and “may have proved to be a problematic concept, but it is a useful classification of the Earth System’s biogeochemical processes.” When formulating his economic model, Dasgupta (2021, p. 138, original emphasis) notes that he is “interested in studying economic possibilities in the biosphere’s *safe zone*”, noting again how “Rockström et al. (2009) call the edges of that zone *planetary boundaries*”.

This leads Dasgupta (2021, p. 142) to a generalisation of macroeconomic models of growth and development, where the latter can be seen as special or extreme cases of his model: “Contemporary models of macroeconomic growth and development are extreme special cases of our model, the extremities being that they imagine that boundedness of the biosphere does not mean the human economy is bounded.” Dasgupta (2021) then shows how several macroeconomic models of growth and development can be accommodated as particular cases of the more general model he provides.

Dasgupta (2021) interprets his model as a departure from economic orthodoxy to the extent that, unlike other models, it takes the human economy to be bounded. But Dasgupta (2021, p. 4) sees this is an aspect that can be accommodated through a slight analytical generalisation of the typical approach to economic modelling, so as to reach a form of analysis where “although the difference in conception is analytically slight, it has profound implications for what we can legitimately expect of the human enterprise.”

Dasgupta (2021, p. 115) also takes into account in his approach such notions as “ecological footprint” or “human impact”, which are terms that Dasgupta uses “interchangeably” so as to capture “[h]umanity’s demand on the biosphere per unit of time”. When assessing human impact on the biosphere, Dasgupta (2021, p. 130, original emphasis) also notes the source of the problem: “The stresses humanity has inflicted on the biosphere to the point where our mode of conduct is not sustainable are due to *institutional failure* writ large.”

Institutional failure is also due to market failure. Dasgupta (2021, p. 253, original emphasis) notes that an important problem with letting the market set prices "is that even if every household is able to internalise the well-being of its own descendants, no household would be expected to take into account the positive externalities it confers, nor the negative externalities it inflicts on *other* households and *their* descendants." The solution, Dasgupta (2021, p. 253, original emphasis) argues, is to imagine a "social evaluator" or "citizen investor" that takes those externalities into account when modelling the entire biosphere.

Once the entire biosphere is conceptualised using the form of economic modelling advanced by Dasgupta (2021, p. 4), the whole of Nature is seen as an asset, to be managed by a "social evaluator", or "citizen investor". Dasgupta (2021, p. 253, original emphasis) writes: "As biodiversity loss is a global phenomenon, we imagine the social evaluator adopts a global view; she is engaged in global *asset management*." Dasgupta (2021, p. 346) argues that "the starting point in policy analysis is the construction of a macroeconomic model" such as the model he outlines, which means that this modelling exercise is central to how we approach Nature, managing it as a portfolio of assets.

Needless to say, this constitutes a form of analysis where whatever Nature provides us must be translated into measurable values so that it can be quantified and modelled. But Dasgupta (2021, p. 47, original emphasis) stresses that "the absolute value of a portfolio carries no information", for what matters is "*comparisons* of portfolios". When noting the irrelevance of focusing on absolute values, Dasgupta (2021, p. 47, original emphasis) refers to the estimation of the value of ecosystem services at US$33 trillion by Costanza et al (1997) – a "widely cited publication in *Science*" – in the following terms:

"The estimate is a case of misplaced quantification. If the biosphere was to be destroyed, life would cease to exist. Who would then be here to receive US$33 trillion of annual benefits if humanity were to exchange its very existence for them? Economics, when used with care, is meant to serve our ethical values. The language it provides helps us to choose in accordance with those values. But the authors of the paper sought to persuade us that the biosphere is valuable *because* it can be imputed a large monetary value. That is to get things backward."

As an alternative, Dasgupta (2021) proposes a valuation exercise that engages in comparisons taking into account ethical values. Those ethical values are embodied in a utilitarian framework, echoing Dasgupta's (2005, 2007a) previous analyses of the role of values in economics, expressed also in his debates with economists and philosophers (Dasgupta 2002, 2005, 2007b; Putnam & Walsh 2007a, 2007b). Dasgupta (2021, p. 498) writes, in the last paragraph of the review: "Correct economic reasoning is entangled with our values." This echoes the thesis of the entanglement of facts, values and conventions advanced by Hilary Putnam and Vivian Walsh in their debate with Dasgupta (Dasgupta 2005, 2007b; Putnam & Walsh 2007a, 2007b). Dasgupta's (2021) reliance on a broad and philosophically informed understanding on utilitarianism is central to his proposal of managing Nature as an asset, and this core aspect is now addressed in the following section.

3. A utilitarian theory of value

Dasgupta (2021) notes that the citizen investor who manages Nature as an asset maximises *expected utility*, a notion that can be traced back to John Von Neumann and Oskar Morgenstern (1944). When describing the citizen investor who is maximising

expected utility, Dasgupta (2021, p. 145, original emphasis) notes that "we assume that the decision-maker (DM) is a concerned citizen: her viewpoint is *societal*".

Dasgupta (2021, p. 146, original emphasis) further proceeds by "assuming that DM follows statistical decision theory and ranks choices on the basis of the expected values of societal, or *social*, well-being", and adds that in this exercise we "imagine that DM is able to associate with each possible portfolio of her society's assets … a (subjective) probability distribution of yields." This characterisation shows that the basic framework within which biodiversity is to be understood is characterised not only by a subjective theory of value, but also by a subjective theory of probability. Dasgupta (2021, p. 145, original emphasis) stresses the role of subjectivity, noting that "probability weights are *subjective*, as is the corresponding utility function".

When adopting this approach, Dasgupta (2021, p. 256) draws on L. J. Savage's (1954) contribution, namely on "Savage's axioms of rational choice under uncertainty". At a more philosophical level, Dasgupta (2021) draws also upon Henry Sidgwick's (1874) writings on utilitarianism to develop his own utilitarian framework. Dasgupta (2021, p. 260) refers to John Rawls's (1971) framework too (whose contribution is taken as a central influence in the review), but concludes: "So we avoid the route he took and adopt an extension of a line of argument put forward by Harsanyi (1955), who also regarded choice under uncertainty to be at the core of the social evaluator's mode of reasoning."

In the contribution cited by Dasgupta, John Harsanyi (1955, p. 321) discusses the notion of cardinal utility and probability, and notes that "a rational man (whose choices satisfy certain simple postulates of rationality) must act as if he ascribed numerical subjective probabilities to all alternative hypotheses, even if his factual information is insufficient to do this on an objective basis – so in welfare economics we have also found

that a rational man (whose choices satisfy certain simple postulates of rationality and impartiality) must likewise act as if he made quantitative interpersonal comparisons of utility, even if his factual information is insufficient to do this on an objective basis." This is then an approach that ultimately presupposes we must act as if we ascribe numerical subjective probabilities to all alternative hypotheses, and as if we are engaging in interpersonal (and, in the context of the review, intergenerational) comparisons of utility.

Valuation is then undertaken assuming that subjective preferences are the ultimate source of value. But Dasgupta (2021) takes into account the influence of society in shaping human preferences. In addition to the idea of a citizen investor who takes into account environmental problems and ethical concerns, Dasgupta (2021, p. 232, original emphasis) also presents the notion of "*socially embedded preferences*, or *social preferences* for short", which is used to "identify a person's motivations when their behaviour and practices are influenced by the behaviour and practices of others". Dasgupta (2021, p. 232, original emphasis) then notes that "[t]wo broad classes of social preferences have been found to be empirically significant: *competitive* and *conformist*". Dasgupta (2021, p. 232) attributes the notion of competitive preferences to Thorstein Veblen's (1899) study of consumption aimed at achieving "high social status relative to that of others", while the notion of conformist preferences "embodies a desire to be like others, to not stand out."

While Dasgupta is certainly right in noting the role of competing ethical and social motivations, this also raises the problem of whether a unique and complete preference ordering, which is necessary for the mathematical representation of a utility function, can successfully systematise those competing motivations. Amartya Sen (1997), Hilary Putnam (2002) and Vivian Walsh (2003) argue that this is not necessarily the case, and were criticised by Dasgupta (2005) on this matter, within a debate that is relevant for

understanding this aspect of the review, and how it builds on Dasgupta's earlier contributions.

Dasgupta (2021, p. 6) refers to several of his previous works in the review (Dasgupta & Heal 1979; Dasgupta 1982, 1993, 2004, 2007a, 2019), noting how "[t]he Review builds on six previous publications of mine, each directed at a particular class of problems that belong to the economics of biodiversity." This previous work is thus relevant for understanding the review, and is also in line with other contributions where Dasgupta's (2005, 2007b) notes that the notion of utility function can be conceived in quite broad terms, taking into account ethical and social aspects.

A problem that arises when accommodating ethical and social motivations in a utility function is that it need not be the case (and it is indeed unlikely) that a unique and complete preference ordering is consistent with the various ethical and social motivations human beings have (Sen 1997; Putnam 2002; Walsh 2003). Sen (1997) identifies direct welfare, social commitments, moral imperatives and conventional rule-following as examples of different types of motivations that may not be all congruent with the same preference ordering, much less be aggregated into a complete preference ordering.

Von Neumann and Morgenstern (1944), who advanced the notion of expected utility (as pointed out above), were aware of this problem. Von Neumann and Morgenstern (1944, p. 19) note that their "procedure for a numerical measurement of the utilities of the individual depends, of course, upon the hypothesis of completeness in the system of individual preferences." And they suggest that they accept this assumption simply because it a widespread hypothesis in economics, while conceding that it is an unrealistic hypothesis. Thus Von Neumann and Morgenstern (1944, p. 19) write: "It is conceivable – and may even in a way be more realistic – to allow for cases where the individual is neither able to state which of two alternatives he prefers nor that they are

equally desirable." For this reason, Sen (1982) focuses on partial comparisons of utility, and partial orderings in general, in a context where a unique and complete preference ordering (as opposed to a partial one) is a particular case.

Both Sen and Putnam are criticised by Dasgupta (2005) for taking this stance, leading to a debate (Dasgupta 2005, 2007b; Putnam & Walsh 2007a, 2007b) that echoes Frank Hahn's (1991) earlier critique of Sen's (1982, 1991) position. Dasgupta (2005) argues that empirical evidence indicates that choices are sufficiently consistent to suggest an underlying (unique, complete, reflexive and transitive) preference ordering that can be represented as usually, through a utility function. Dasgupta's (2005) views on this are reflected again in the review.

But in the review, Dasgupta (2021) goes significantly further when proposing a social evaluator or citizen investor that takes into account the whole biosphere when valuing assets and assessing the well-being of the entire human population, including their descendants. For even if we accept that the motivations of a single individual can be represented through a unique and complete preference ordering, we still have the further problem – assuming we do not want the social evaluator to be a dictator – of whether it is possible to aggregate the subjective preferences of multiple individuals into a unique and complete preference ordering (of a social evaluator), at least in a democratic setting involving social choice (Arrow 1951; Sen 1982).

Dasgupta (2005, 2021) notes that choices must be made at some point, and this requires the ability to engage in comparisons (Hahn 1991), which must eventually lead to the formation of a complete preference ordering. But all that is required for a choice to be made is the existence of a non-empty set of elements such that no other element outside that set is strictly preferred to the elements of that set (Sen 1997). This is a weaker condition than the existence of a complete and transitive ordering, in the sense that it

allows for a choice to be made even with incomplete preferences. And such a weaker condition can accommodate more easily (and realistically) the existence of multiple ethical and social considerations (Sen 1997) across multiple individuals in a society (Sen 1982).

The use of subjective preferences as a basis for social evaluation raises yet another problem when addressing sustainability. Sustainability is often interpreted in terms of the ability to deliver to future generations the same level of well-being enjoyed by present generations. While the Brundtland Report measures well-being in terms of needs, the conception adopted in the Dasgupta Review would measure well-being in terms of subjective utility. But as noted by Sidgwick (1874), future generations may have different preferences than we do, and thus value outcomes in a different way than we do (Martins 2011). And there is no basis for the citizen investor to know what those preferences may be.

That is, uncertainty applies not only to outcomes, but also to the very preferences in terms of which those outcomes are valued, if we follow a subjective method of valuation. The uncertainty surrounding biophysical processes already provides difficult challenges (Baumgärtner & Quaas 2010; Martins 2011). If we add the uncertainty connected to subjective preferences, our conceptualisation of sustainability becomes even more difficult, if not altogether intractable.

The notion of probability advanced by Dasgupta (2021) when describing a concerned citizen investor presupposes – drawing on Savage (1954) and Harsanyi (1955) – that individuals assign numerical values to each subjective probability weight. John Maynard Keynes (1973), however, noted that in many cases, we really have no basis for ascribing numerical values to subjective probability. This led to Keynes' famous exchange with Frank Ramsey (1978), who advanced a notion of probability that is behind

the subjective approach to probability and expected utility subsequently developed by Savage (1954), and adopted by Dasgupta, as noted above.

Dasgupta (2021) adopts a conception where (we act as if) the whole biosphere is valued according to numerical values assigned to subjective utility, and the subjective probabilities of the various scenarios that may occur. The emphasis on subjective valuation using subjective probabilities raises important questions regarding the adequacy of such a method for reaching a theory of human impact on the biosphere that can conceptualise adequately the intrinsic logic of biophysical processes. Biophysical processes function in a way which has little to do with our subjective valuation of Nature.

To act as if our subjective probabilities capture adequately what may happen in each scenario seems quite imprudent given the contemporary ecological problems. More than that, such an attitude can arguably be seen as a main reason, if not the main reason, of why we got to where we are – to use Dasgupta's (2021, p. 130) words, to a situation where we witness "stresses humanity has inflicted on the biosphere to the point where our mode of conduct is not sustainable".

4. The production function and aggregate capital

An economic theory that successfully accounts for human impact in the biosphere must be able to conceptualise the material processes of production, and their objective impact on planetary boundaries. Despite its emphasis on subjective valuation, the Dasgupta Review still presents a model for conceptualising the material processes of production, and their objective impact on the biosphere. In order to conceptualise the material processes of production, Dasgupta (2021, p. 139) presents a production function where the product, designated by the scalar Y, contains several "categories of capital goods", also conceptualised as scalar variables, which "are required for producing *Y*: produced

capital (*K*), human capital (*H*), natural capital (*S*) – each of which is taken to be measurable as a scalar – and publicly available knowledge (*A*, also a scalar)." Dasgupta's formulation of the production function builds upon Robert Solow's (1956, p. 67) influential model of economic growth, where a production function was advanced while "assuming that there is no scarce nonaugmentable resource like land." Dasgupta (2021) expands this approach by including human capital and natural capital in the production function.

The notion of human capital is itself a problematic one, since it tends to make us see human beings as instruments of production, neglecting their intrinsic value (Sen 1999). Dasgupta is aware of the difficulties in considering instrumental value only. But he finds the distinction between intrinsic and instrumental value difficult to sustain. Thus, when discussing yet another form of capital, social capital, Dasgupta (2021, p. 185) writes that "[t]he line separating an instrumental value from an intrinsic value is, in any case, wafer-thin when the instrument advances a value we hold deeply."

A similar discussion can be undertaken regarding the notion of natural capital. Again, seeing Nature as capital seems to point towards an idea of Nature as merely an instrument of production, while neglecting its intrinsic value. This is connected to the anthropocentric approach that Dasgupta explicitly adopts. Dasgupta (2021, p. 49) warns us: "In the chapters that follow, we mostly adopt an anthropocentric viewpoint – the value of biodiversity is studied in terms of its contributions to humanity, that is human well-being." Since well-being and the probability of each scenario both depend on subjective utility, as noted above, the approach is anthropocentric not only regarding its goals – namely, human well-being – but also regarding the methods of valuation employed for reaching those goals.

It is important to note, however, that Dasgupta's anthropocentrism seems to be essentially strategic. Thus Dasgupta (2021, p. 49) writes:

"If we are able to show, as we intend to in the Review, that biodiversity is of the utmost value to humanity, and that because we are embedded in Nature, gradual biological extinction will hasten our own extinction, then for purely anthropocentric reasons we would wish to preserve and promote it. But if biodiversity is worth preserving and promoting for purely anthropocentric reasons, it would be even more deserving of protection and promotion if it had sacred status. Therein lies the advantage of a limited point of view."

At the end of the review, it becomes even clearer that Dasgupta's own moral views are not inherently anthropocentric, when Dasgupta (2021, p. 498) writes: "Biodiversity does not only have instrumental value, it also has existence and intrinsic value, perhaps even moral worth." The emphasis on instrumental value, as the anthropocentric viewpoint adopted in the review, is thus essentially strategic.

But anthropocentrism, strategic or not, combined with a belief that human beings have a greater control over Nature than they really have, has also led in the past to the belief that the ecosystem's inputs can be substituted by produced capital, at least in earlier formulations of the production function (Solow 1956). It also led to a neglect of nature's resources which, unlike produced capital, are characterised by irreversibility (Costanza & Daly, 1992; Pelenc & Ballet, 2015). There are, of course, other problems with the notions of human capital and natural capital, for example, whether whatever those names mean can be quantified in terms of a single scalar. Dasgupta (2021, p. 141) notes this

problem, stressing how "we assume heroically that the biosphere's goods and services can be so aggregated as to be measurable as a scalar quantity."

In order to understand the implications of this assumption, it is important to note that problems in obtaining a scalar measure of capital have been extensively discussed in a series of debates known as the Cambridge controversies in the theory of capital (Cohen & Harcourt 2003; Garegnani 2012; Harcourt 1972). While this is not the occasion to revisit the intricacies of those debates, some aspects of it are quite relevant for the approach to valuation adopted by Dasgupta in the review.

In the Cambridge controversies in the theory of capital, several inconsistencies were found in the construction of a measure of aggregate capital, and its use in the production function. The problem at stake, brought to the public attention by Joan Robinson (1953-4), is that heterogenous capital units must be valued at a given price before being aggregated. This price also depends on the moment in time in which capital units were produced. If capital units are produced in different moments in time, it is necessary to know the interest rate (used as a rate of discount, and seen also as the rate of return on capital) at which their value can be capitalised or discounted, so that all capital units can be aggregated. So we need to know the interest rate *before* we know the quantity of aggregate capital. However, the interest rate is typically obtained by differentiating the production function (constructed assuming a given quantity of aggregate capital) with respect to the quantity of aggregate capital. So we would also need to know the quantity of aggregate capital *before* knowing the interest rate, and thus a paradox, or problem of circular reasoning, arises (Cohen & Harcourt 2003; Harcourt 1972; Robinson 1953-4; Sraffa 1960).

Solow's (1956) model of economic growth contains an implicit solution to this problem, since it assumes not only homogeneous capital, but also that the good produced

is the same good used as capital. Hence, the physical quantities of capital and product can be aggregated, unlike what would happen with heterogeneous goods, in which relative prices have still to be found. Dasgupta's (2021) version of the production function, however, introduces different types of capital, and the problem of capital aggregation appears again. More than that, the problem becomes particularly severe in Dasgupta's (2021) own conceptualisation of the production function, given the need of a rate of discount not only for reaching a measure of produced capital, but also a measure of natural capital – assumed "heroically" to be "measurable as a scalar quantity" (Dasgupta 2021, p. 141) – taking into account intergenerational wellbeing.

This becomes clear when explaining the optimisation problem facing the citizen investor, which requires knowing the prices of produced and natural assets, and the rate of return. Dasgupta (2021, p. 40) writes: "The yield on investment in produced capital is its marginal product." This is, as noted above, a usual procedure for obtaining a yield, but one which requires that the prices of the capital units used for aggregating capital and constructing a production function have already been found, which is not the case in Dasgupta's (2021) model.

Dasgupta (2021, p. 40, original emphasis) again presupposes that this problem has already been solved, when he defines rates of return in terms of yield and capital gains: "The *rate of return* on an asset (as opposed to the asset's *own* rate of return) is its yield plus the capital gains it enjoys over a unit of time." So to know the rate of return we need to know the yield, which in turn is obtained as the marginal product of produced capital. But the latter can only be calculated *after* knowing its rate of return, so as to aggregate heterogeneous capital units, and the problem of circular reasoning identified by Joan Robinson (1953-4) and Piero Sraffa (1960) during the Cambridge controversies in the theory of capital (Harcourt 1972) appears again.

During the Cambridge controversies in the theory of capital (Harcourt 1972), the solutions found to the problem of valuing capital were developed drawing on a disaggregated conception of capital instead, be it Sraffa's (1960) revival of classical economic theory, or Walrasian general equilibrium theory (Cohen & Harcourt 2003). In the process, Sraffa's (1960) revival of the classical standpoint started to be interpreted in terms of Walrasian general equilibrium theory. Thus Hahn (1975, p. 362) asserts that "there is not a single formal proposition in Sraffa's book which is not also true in a General Equilibrium model constructed on his assumptions."

Besides the obvious advantages of addressing the analytical inconsistencies highlighted above, a disaggregated notion of capital also provides a more direct way to conceptualise important processes. A study of production and its supply chains, for example, could be more easily conducted drawing on a disaggregated conception of capital, where the various industries can be represented. This would help addressing central problems noted by Dasgupta (2021, p. 490), for example when he writes: "If we are to avoid exceeding the limits to what Nature can provide on a sustainable basis, consumption, production and supply chains have to be fundamentally restructured."

General equilibrium theory, as elaborated drawing on Kenneth Arrow and Gérard Debreu (1954), draws on the notion of production sets within a disaggregated notion of capital (rather than production functions that presuppose aggregate and homogenous capital), and devotes attention to resource constraints and technology. This would allow for conceptualising energy and natural resources as essential inputs that lack substitutes. It also allows obtaining prices of capital goods so as to solve the problem of aggregating capital. Those prices are obtained through interaction between supply, which depends on biophysical and technological constraints, and demand, which depends on subjective and exogenous preferences.

However, besides the problems surrounding the conceptualisation of subjective preferences alluded above, an important problem when using a general equilibrium framework within the framework set out by Dasgupta (2021) is that it need not deliver a unique rate of return on capital (Garegnani 2012). This raises the question of which rate to use as a rate of discount when addressing intergenerational wellbeing, and conceptualising Nature as an asset as Dasgupta (2021) intends, not least when Dasgupta (2021, p. 41) explains arbitrage conditions (which presuppose a tendency towards a uniform rate of return across the economy) while noting: "If asset markets were functioning well, their prices would adjust so as to equalise the rates of return." Of course, Dasgupta (2021) is well aware that markets do not always function well, and this is expressed several times in the review. But the point is that the basic framework would not deliver a unique rate of return even if markets were functioning well (Garegnani 2012).

Ramsey (1928) assumed that human beings do not discount the value of future assets. In fact, Ramsey found the overall idea ethically indefensible, in line with other authors of the Cambridge tradition, like Sidgwick and Arthur Cecil Pigou, who had an early concern with the ethics of intergenerational wellbeing. But this corresponds to a model with a uniform rate of return, namely zero, and is thus also inconsistent with the possibility of multiple rates of return. As noted above, another solution to the problems raised in the Cambridge controversies (Garegnani 2012; Harcourt 1972) is Sraffa's (1960) revival of classical economic theory, which conceptualises disaggregated capital in a way that is consistent with a unique rate of return used for capitalising and discounting capital assets at different moments in time (Garegnani 2012). This would provide a solution to the problems mentioned above regarding the aggregation of capital units.

Furthermore, since Sraffa's (1960) framework does not require the notion of a utility function – prices depend upon the cost of production instead, as in classical analysis in general – it also provides more degrees of freedom for considering ethical and social questions (Martins 2013; Walsh 2003). So ethical and social motivations need not be aggregated and collapsed into a unique and complete preference ordering. Thus, Putnam (2002) and Walsh (2003) argue – also in their debate with Dasgupta (Dasgupta 2005, 2007b; Putnam & Walsh 2007a, 2007b) – that Sraffa's (1960) revival of classical economic theory can be more easily combined with a study of competing ethical and social motivations, such as Sen's (1997). This is an aspect of the debate between Dasgupta (2005, 2007b) and Putnam and Walsh (2007a, 2007b) that has been relatively neglected. But achieves a renewed relevance in the context of the ecological problems addressed in the Dasgupta Review, and is now discussed in more detail before concluding.

5. Accounting for human impact in the biosphere

One reason Dasgupta does not consider alternative solutions, such as the revival of classical political economy suggested by Putnam and Walsh (2007a, 2007b) is that, as Dasgupta (2005, 2007b) makes it clear in the course of his debate with Putnam and Walsh (2007a, 2007b), he is critical of the overall vision implied in it. Even before, in another debate with Robert Heilbroner, Dasgupta (2002, p. 59) assesses the latter's call for a broader vision for economics, noting how "this strand deplores the abandonment by modern economists of what is in effect an amalgam of the intellectual agenda of classical political economists and that of John Maynard Keynes." Dasgupta (2002, pp. 59-60) then sets himself the task of producing "a methodological essay, one that would weave together in a narrative form not only why "political economy" in the late eighteenth-to-mid-nineteenth-century sense holds no attractions for the modern economist, but also give

the reader an idea of how very much farther economics has progressed in recent years than its critics realize."

The debates above (Dasgupta 2002, 2005, 2007b; Putnam & Walsh 2007a, 2007b), in which Dasgupta expresses somewhat more bluntly his philosophical and methodological views, are important for understanding the Dasgupta Review, and why the latter is also a vindication of a certain form of doing economics, defended in previous writings on which the review draws upon (Dasgupta & Heal 1979; Dasgupta 1982, 1993, 2004, 2007b, 2019), while extending it to the analysis of the entire biosphere. Dasgupta (2021, p. 130) summarises his strategy in the following way, while taking his view of economics as a starting point:

"Economics provides a remarkably effective language in which to read the socio-ecological world. The problem is not with economics, it is rather the fundamentally flawed reading of the structure of economic reasoning. The Review will use examples and illustrations to provide a language for identifying institutional arrangements that align the incentives facing various actors in an economy, so as to protect and sustain our place in the biosphere. It is a fundamental misconception of economists that we can continue to rely on models of growth and development in which our impact on the biosphere is of second-order importance (Chapter 4*). This Review is an attempt at constructing a formulation of economic reasoning that has the biosphere always in sight. Much remains to be done in advancing the subject; this is only a start."

An important question is, however, whether the specific conception of economics advanced by Dasgupta (2021) is really the best starting point, or at any rate a starting point which requires only "analytically slight" (Dasgupta 2021, p. 4) changes. This

question is especially relevant given the analytical difficulties that arise when addressing broader concerns such as the ones Dasgupta (2021) rightly identifies, which lead to some inconsistencies in his use of production functions, or when presupposing a social evaluator or citizen investor that maximises expected utility, as noted above.

Chapter 4* of the review, which is noted in the paragraph above, is where Dasgupta presents the production function explained above, with its conceptualisation of human, produced and natural capital drawing on post-war macroeconomic growth theory. Dasgupta's starting point, drawing on post-war growth theory, explains why Dasgupta notes that Nature has entered into economic models quite recently, in the 1970s. If we narrow our view of economics to post-war growth models, that is certainly the time when Nature starts to be considered in economic models. But if we take a broader view of economics, we can see that Nature has been present in economics much earlier, at least since the contributions of the classical political economists.

In the review, Dasgupta (2021, p. 138) notes that the "classical economists" used "models" that "did not entertain the possibility that output could grow indefinitely through technological advances." (Dasgupta 2021, p. 139). The contributions of the classical economists were certainly more cautious regarding the limits of economic growth than those we find in post-war economic models. But Dasgupta's (2021, p. 138) use of the term "models" is somewhat misleading here, since the classical contributions can hardly be described as consisting of models in the same sense as modern economic models. The classical political economists expressed themselves essentially using words, and employed numbers for arithmetical analysis of observable and objective magnitudes, without taking the further step of using those magnitudes to produce a mathematical model (much less a model using subjective concepts such as utility).

To explain what he means by classical economists, Dasgupta (2021, p. 139, fn. 160) writes: “The pantheon of classical economists is usually taken to be Adam Smith, David Ricardo, Thomas Malthus and John Stuart Mill.” He further adds that Amiya Dasgupta (1985) included Karl Marx as one of the classical economists. Marx (1999, p. 493), in fact, coined the term “classical political economy” to designate a form of analysis developed “since the time of W. Petty”, which includes Smith and Ricardo.

The type of arithmetical analysis undertaken by the classical political economists since Petty is concerned with observable magnitudes used to measure the cost of production, such as the quantity of labour time employed in production, and the quantity of land required to maintain the labourer during the period of production. In his unpublished writings, when preparing the ground for a revival of the classical standpoint (Sraffa 1960; Meek 1961), Sraffa praises Petty’s use of the quantity of land necessary to sustain the labourer when measuring the cost of production (Martins 2013, 2016). Sraffa finds Petty’s approach a more objective one, since it uses observable entities that can be measured with more accuracy, within what Sraffa calls a “physical real costs” approach (Martins 2013, p. 17). In fact, Sraffa sees the labour theory of value of the classical economists essentially as an approximation to the more objective procedure of focusing on “physical real costs” (Martins 2013, p. 17), such as the quantity of land necessary for sustaining the labourer.

The idea of focusing on “physical real costs” (Martins 2013, p. 17) is in line with more recent approaches to measure human impact on the biosphere, including many discussed by Dasgupta (2021, p. 115) in the review, when referring to such notions as “ecological footprint” or “human impact”. Dasgupta’s (2021, p. 115) procedure consists of “defining the footprint of smaller economic units and then sum them to define the global footprint.” This allows defining valuing more objectively activities connected to

whether human impact on various dimensions of the biosphere, such as those considered as planetary boundaries (Rockström et al., 2009), which Dasgupta (2021) includes in his model.

Of course, even a (bio)physical real costs approach along classical lines needs to be significantly expanded. The planetary boundaries considered by Rockström et al. (2009) include not only land used in agriculture, but also human impact on various essential cycles for regenerative processes such as the nitrogen and phosphorous cycle, amount of carbon dioxide, ozone and aerosols in the atmosphere, loss of biodiversity, acidification of oceans, global fresh water consumption and chemical pollution.

Dasgupta's (2021) emphasis of including notions such as human impact, ecological footprint or planetary boundaries (Rockström et al., 2009) in economic analysis contains much merit. But the potential of such an idea is hampered by the specific technical apparatus adopted by Dasgupta (2021). Valuing Nature as an asset through the use of a subjective notion of expected utility makes it difficult to provide an objective measurement of biophysical processes, one that can capture adequately the biophysical real costs involved.

The potential behind the idea of including human impact, ecological footprints or planetary boundaries within economic theory can be more readily explored through a conception where human activity is certainly part of the biosphere, but in the sense that human impact is itself assessed in terms of the intrinsic logic of objective biophysical processes. This requires a broader view of economics than the one we find vindicated in the Dasgupta Review.

6. Concluding remarks

One can certainly agree with David Attenborough's assessment, in the foreword to the Dasgupta Review, that economics shapes decisions with deep consequences. Attenborough's praise to the Dasgupta Review for finally putting biodiversity at the core of economics highlights also what can be seen as the great contribution of the Dasgupta Review. The inclusion of the notion of planetary boundaries (Rockström et al 2009), or notions such as human impact or ecological footprints, is of the utmost importance for addressing contemporary ecological problems. And the inclusion of ethical and social aspects in economic analysis is also an important aspect.

The specific analytical framework through which those important ideas are put together, however, raises considerable problems. The overall impression the reader (or at least this reader) gets is that the Dasgupta Review constitutes a great effort to include various important (one may say, urgently needed) ideas, while insisting that those ideas must be inserted into a theoretical framework that is not ready to accommodate them all. This occurs, of course, because the Dasgupta Review is also a vindication of a certain form of doing economics, and of its relevance. To be sure, those problems exist in much economic research, and are essentially inherited, rather than created, by Dasgupta (2021) when vindicating a certain form of doing economics. But they appear in a starker light when attempting to expand this form of analysis to the study of the entire biosphere.

The consequence of imposing a more restrictive approach to economics as a starting point is the emergence of some anomalies, for example concerning utility functions and production functions. Those anomalies are ultimately aggregation problems. Regarding the utility function to be adopted by the citizen investor, the problem is how to aggregate various ethical and social considerations into a unique and complete preference ordering (Putnam 2002; Sen 1982, 1997). Regarding the production function, the problem is how to aggregate capital units into a scalar measure of capital (Cohen &

Harcourt 2003; Harcourt 1972; Robinson 1953-4; Sraffa 1960). Those problems pose important constraints to what could be a more objective valuation of a variety of biophysical processes necessary for production, and lead to inconsistencies when valuing various assets in terms of a given rate of return as intended by Dasgupta (2021).

Dasgupta's (2021) insistence on collapsing various important aspects into a scalar measure is driven by a concern with explaining human impact in the biosphere drawing on certain analytical tools, where the use of scalar measures facilitates mathematical tractability. But the processes at stake are multidimensional processes, and may not be adequately captured through a unidimensional approach. Rather than expecting that reality will conform to a given method, it seems more reasonable to develop methods that take into account the nature of the reality being analysed (Lawson 2003).

The problems raised above can also be seen as the kind of anomalies that typically appear when science is on the verge of a paradigm shift which is required for accommodating new important findings. It may well be the time to reformulate the theory of value somewhat more radically, so as to achieve a framework that can accommodate successfully the important concerns raised by Dasgupta (2021), such as planetary boundaries, human impact or ecological footprints.

Dasgupta (2021, p. 49) warns us that he adopts an "anthropocentric viewpoint" which, as noted above, is essentially strategic. But Dasgupta's (2021) strategic anthropocentrism has an even deeper sense. It is anthropocentric not only regarding its goals of enhancing human well-being, but also regarding the methods of valuation employed for reaching those goals, systematised in the idea of a citizen investor managing Nature as an asset. In truth, this amounts not so much to conceptualising human activity as part of the biosphere, but rather to subsuming the biosphere within human activity. To

really conceptualise human activity as part of the biosphere, human impact must itself be assessed in terms of the intrinsic logic of objective biophysical processes.

The latter constitutes a vision that can more readily and realistically accommodate the contemporary ecological problems, especially if compared with a vision where (we act as if) Nature is valued and controlled in terms of subjective probabilities and subjective utility, which is the underlying vision behind the Dasgupta Review. One can certainly accept the idea that economic theory has an important contribution to give when facing contemporary ecological problems. But to fully concretise such an idea, we need to expand our understanding of what economics is beyond what we find vindicated in the Dasgupta Review.

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