

# The Economics of Biodiversity

We are part of Nature, not separate from it. We rely on Nature to provide us with food, water and shelter; regulate our climate and disease; maintain nutrient cycles and oxygen production; and provide us with spiritual fulfilment and opportunities for recreation and recuperation, which can enhance our health and well-being. Nature's constituents such as ecosystems and the biodiversity that are embodied in them are therefore assets. Yet Nature is more than an economic good: many recognise its intrinsic worth and argue that it has moral worth too. This landmark report explains the current state of play in relation to biodiversity loss and outlines a sustainable path to deal with this problem, one that will require us to change how we think, act and measure success. The report was originally commissioned and published by HM Treasury. This title is also available as Open Access on Cambridge Core.

Partha Dasgupta is the Frank Ramsey Professor Emeritus of Economics at the University of Cambridge and Fellow of St John's College, Cambridge. He is a Fellow of the Royal Society and of the British Academy, a Foreign Associate of the US National Academy of Sciences, a Foreign Member of the American Academy of Arts and Sciences and of the American Philosophical Society, and has received the Volvo Environment Prize, the Blue Planet Prize, the Tyler Prize for Environmental Achievement, the Kew International Medal of the Royal Botanical Gardens, Kew, and the BBVA Foundation Frontiers of Knowledge Award. In 2022 Dasgupta was named by the United Nations a Champion of the Earth, the first economist to be so honored, and in 2023 was made Knight Grand Cross of the British Empire by King Charles III for "services to economics and the natural environment".

# The Economics of Biodiversity The Dasgupta Review

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Partha Dasgupta  
*University of Cambridge*



Shaftesbury Road, Cambridge CB2 8EA, United Kingdom  
One Liberty Plaza, 20th Floor, New York, NY 10006, USA  
477 Williamstown Road, Port Melbourne, VIC 3207, Australia  
314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,  
New Delhi – 110025, India  
103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

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# Foreword

We are facing a global crisis. We are totally dependent upon the natural world. It supplies us with every oxygen-laden breath we take and every mouthful of food we eat. But we are currently damaging it so profoundly that many of its natural systems are now on the verge of breakdown.

Every other animal living on this planet, of course, is similarly dependent. But in one crucial way, we are different. We can change not just the numbers, but the very anatomy of the animals and plants that live around us. We acquired that ability, doubtless almost unconsciously, some ten thousand years ago, when we had ceased wandering and built settlements for ourselves. It was then that we started to modify other animals and plants.

At first, doubtless, we did so unintentionally. We collected the kinds of seeds that we wanted to eat and took them back to our houses. Some doubtless fell to the ground and sprouted the following season. So over generations, we became farmers. We domesticated animals in a similar way. We brought back the young of those we had hunted, reared them in our settlements and ultimately bred them there. Over many generations, this changed both the bodies and ultimately the characters of the animals on which we depend.

We are now so mechanically ingenious that we are able to destroy a rainforest, the most species-rich ecosystem that has ever existed, and replace it with plantations of a single species in order to feed burgeoning human populations on the other side of the world. No single species in the whole history of life has ever been so successful or so dominant.

Now we are plundering every corner of the world, apparently neither knowing or caring what the consequences might be. Each nation is doing so within its own territories. Those with lands bordering the sea fish not only in their offshore waters but in parts of the ocean so far from land that no single nation can claim them. So now we are stripping every part of both the land and the sea in order to feed our ever-increasing numbers.

How has the natural world managed to survive this unrelenting ever-increasing onslaught by a single species? The answer of course, is that many animals have not been able to do so. When Europeans first arrived in southern Africa they found immense herds of antelope and zebra. These are now gone and vast cities stand in their stead. In North America, the passenger pigeon once flourished in such vast flocks that when they migrated, they darkened the skies from horizon to horizon and took days to pass. So they were hunted without restraint. Today, that species is extinct. Many others that lived in less dramatic and visible ways simply disappeared without the knowledge of most people worldwide and were mourned only by a few naturalists.

Nonetheless, in spite of these assaults, the biodiversity of the world is still immense. And therein lies the strength that has enabled much of its wildlife to survive until now. Economists understand the wisdom of spreading their investments across a wide range of activities. It enables them to withstand disasters that may strike any one particular asset. The same is true in the natural world. If conditions change, either climatically or as a consequence of a new development in the never-ending competition between species, the ecosystem as a whole is able to maintain its vigour.

But consider the following facts. Today, we ourselves, together with the livestock we rear for food, constitute 96% of the mass of all mammals on the planet. Only 4% is everything else – from elephants to badgers, from moose to monkeys. And 70% of all birds alive at this moment are poultry – mostly

## Foreword

chickens for us to eat. We are destroying biodiversity, the very characteristic that until recently enabled the natural world to flourish so abundantly. If we continue this damage, whole ecosystems will collapse. That is now a real risk.

Putting things right will take collaborative action by every nation on earth. It will require international agreements to change our ways. Each ecosystem has its own vulnerabilities and requires its own solutions. There has to be a universally shared understanding of how these systems work, and how those that have been damaged can be brought back to health.

This comprehensive, detailed and immensely important report is grounded in that understanding. It explains how we have come to create these problems and the actions we must take to solve them. It then provides a map for navigating a path towards the restoration of our planet's biodiversity.

Economics is a discipline that shapes decisions of the utmost consequence, and so matters to us all. The Dasgupta Review at last puts biodiversity at its core and provides the compass that we urgently need. In doing so, it shows us how, by bringing economics and ecology together, we can help save the natural world at what may be the last minute – and in doing so, save ourselves.

**David Attenborough**

# Preface to the CUP Edition

That economic policies should be evidence-based is, or should be, an incontrovertible requirement; but it is of no use if the evidence is obtained from a misleading conception of the human condition; for faulty models produce spurious evidence. Systems of thought that do not acknowledge humanity's embeddedness in Nature when used to project present and future possibilities open to us mislead. They mislead so hugely that policies based on them damage future generations, and in many instances, they damage some of the world's poorest communities.

The global standard of living has improved enormously since the end of World War II. Per capita income has increased nearly 5-fold to some 16,000 dollars PPP annually (at 2011 prices), life expectancy at birth has increased from 46 years to 72 years, and the proportion of people in extreme poverty has declined from approximately 60% to 10%. This enormous success has been achieved by an accumulation of *produced capital* (roads, buildings, ports, machines) and *human capital* (health, education, skills, character), but it has also been accompanied by the decumulation of *natural capital* (wetlands, grasslands, mangroves, coral reefs, woodlands, forests, lakes, and such biomes as the atmosphere, the oceans, the soils, and sub-soil resources). And these statistics reflect a rare contact between economics and the Earth sciences, for Earth scientists have dubbed 1950 as being the year we entered the Anthropocene, a human dominated Earth. In 1950 the global economy was small in comparison to the Earth system, today it is huge.

In the Anthropocene, expansion in our demands for Nature's 'provisioning goods' (food, water, timber, fibres, pharmaceuticals, non-living materials – i.e., the ingredients that, with human effort, go to shape the final products reflected in GDP) has eaten into Nature's ability to supply 'regulating and maintenance services,' such as climate regulation, decomposition of organic waste, nutrient recycling, nitrogen fixation, air and water purification, soil regeneration, pollination, and maintenance of the biosphere's gaseous composition.

Technological advancements have repeatedly shown ways to substitute provisioning goods among one another (fossil fuels replacing timber, solar panels and wind farms substituting for fossil fuels, and so on). Resource economists in their studies of production possibilities have thus emphasised substitution possibilities between natural resources and produced and human capital. In contrast, Nature's regulating and maintenance services have been found by Earth scientists and ecologists to be complementary to one another: disrupting one sufficiently disrupts the others. The mutual influence of climate change and the processes underlying the oceans is an example. Those complementarities tell us that we are embedded in Nature, we are not external to her. The biosphere is not exactly a house of cards, but we humans are now so ingenuous that we would be able to reduce it to one if we put our mind to it.

Even though the literature on environmental and resource economics has repeatedly exposed the harm done by the practice in contemporary economics of ignoring Nature, it hasn't done so from top to bottom. If contemporary economics is to be reconstructed, we would have to study our embeddedness in Nature at all levels: from the individual person, through households, communities, nations, regions, to the global economy. This book studies salient problems in each of those levels (Ch. 4 onward). The global economy is the scene where growth and development economics of the long run is fashioned, so the needed reconstruction would also refashion macroeconomic models of the long run. It would read contemporary economic growth as being countered by depreciation of the biosphere, which is a self-organizing regenerative entity. Chapters 4\* and 13\* contain a prototype of the kind of macroeconomic



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model of the long run that is now needed. But it is only a prototype. Much work remains to be done, extending its coverage, and estimating the parameters of such a model.

The *Review of the Economics of Biodiversity* was launched at the Royal Society, London, on 2<sup>nd</sup> February 2021. The UK Treasury displayed exquisite courtesy in retaining part of my team for the remainder of the calendar year to help its dissemination. Since its launch I have engaged in more than 200, mostly virtual events, involving lectures, Q&As, panel discussions, and interviews. They have included not only professionals from environmental charities, government departments, international organisations, scientific associations, think tanks, academic journals, literary magazines, research institutes, NGOs, business schools, corporate bodies, and groups representing indigenous people, but numerically even more, financiers, bankers, insurers, farmers, ecologists, legal scholars, agronomists, journalists, statisticians, clerics, politicians, Earth scientists, and national and international civil servants.<sup>1</sup> There has no doubt been self-selection at work, but the level of interest in the economics of the biosphere among people at large feels unbelievable to me when I place it in comparison to the interest among editorial boards of leading economics journals.<sup>2</sup>

Which is why in preparing this edition of the Review, I have had graduate students in economics especially in mind. Although the version I prepared for the Treasury was both technical and detailed, there were several missing items of interest to students. I have prepared a few of the most important such items in new sections, boxes, and annexes. In such material, where necessary, I have used more contemporary estimates of such indices as global GDP and the human ecological footprint. The new material appears as Annex 4.2, Box 4\*.1, Box 5.8, Sect. 10.11-10.12, Box 10.8, and Annex 10.3.

I am most grateful to Phil Good, economics editor of Cambridge University Press, for his encouragement, advice, and help in preparing this published edition.

To authors it is the final stages of publication that count most. So, I am particularly grateful to Claire Sissen, who has edited the typescript with enormous skill, encouragement, and patience. She has not balked once when I have asked to be allowed to make changes, even at the very last minute. This is editorial leadership at its finest.

### Partha Dasgupta

*St John's College, Cambridge*

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<sup>1</sup> Based on what I took away from those events, I prepared a paper – “The Economics of Biodiversity: Afterword” (Dasgupta, 2022) – listing those among the Review’s recommendations that are very likely to be adopted by countries, those that are appreciated to be important but are felt to be unworkable under current circumstances, and those that are not for discussion because of alleged political sensitivities. The paper was published in *Environmental and Resource Economics*, in a symposium on the Review, edited by Ingmar Schumacher, for whose encouragement I am very grateful.

<sup>2</sup> An article-length presentation of the ecological economics underlying the Review (Dasgupta and Levin, 2023) has been published in a symposium on “detecting and attributing the causes of biodiversity change: needs, gaps, and solutions,” in *Philosophical Transactions of the Royal Society B* (Vol. 378, Issue, 1881, 17 July 2023).

# Preface

Economics, like I imagine other scientific disciplines, normally moves in incremental steps, and always without a central guide. Much like practitioners of other disciplines, we economists work with models of those features of the world we want to study in detail. That involves keeping all else in the far background. Models are thus parables, some say they are caricatures, which is of course their point.

Economics is also a quantitative subject. Finance ministers need estimates of tax revenues if they are to meet intended government expenditure; environment ministers today cannot but ask how much farmers should be paid to set aside land for ‘greening’ the landscape, and whether fossil-fuel subsidies should be eliminated; health ministers look to convince cabinet colleagues that investment in health is good for economic growth; and so on. Which is why economic models are almost invariably cast in mathematical terms.

That is also why the models that appear in economics journals can appear esoteric, unreal, and even self-indulgent. Many would argue as well that to model human behaviour formally, let alone mathematically, is to tarnish the human experience, with all its richness. And yet, economists in governments, international organisations, and private corporations find those models and their adaptations essential for collecting and analysing data, forecasting economic trajectories, evaluating options and designing policy. Perhaps, then, it should be no surprise that those same models go on to shape the conception we build of our economic possibilities. In turn, our acceptance of the economic possibilities those models say are open to us encourages academic economists to refine and develop them further along their tested contours. And that in turn further contributes to our beliefs about what is achievable in our economic future. The mutual influence is synergistic.<sup>3</sup>

That has had at least one unintended and costly consequence. Not so long ago, when the world was very different from what it is now, the economic questions that needed urgent response could be studied most productively by excluding Nature from economic models. At the end of the Second World War, absolute poverty was endemic in much of Africa, Asia, and Latin America; and Europe needed reconstruction. It was natural to focus on the accumulation of produced capital (roads, machines, buildings, factories, and ports) and what we today call human capital (health and education). To introduce Nature, or natural capital, into economic models would have been to add unnecessary luggage to the exercise.<sup>4</sup>

Nature entered macroeconomic models of growth and development in the 1970s, but in an inessential form.<sup>5</sup> The thought was that human ingenuity could overcome Nature’s scarcity over time, and ultimately (formally, in the limit) allow humanity to be free of Nature’s constraints (Chapter 4\*). But the

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<sup>3</sup> It will be asked who is represented in the collective ‘we’ and ‘our’ that I am using here. It is not everyone in the world, and certainly not restricted to those who agree with the claims I am making about the mutual influence of academic economic models and a general reading of economic possibilities. The group I have in mind is not fixed by designation but through invitation – for example, people who read this Review – to consider why and how we need to break the cycle and revise the conception we hold of humanity’s place in the biosphere.

<sup>4</sup> The significance of the years immediately following the Second World War for the economics of biodiversity is shown repeatedly in the Review (see especially Chapter 4). I am referring to the evolution of economic thinking in the West. However, to the best of my knowledge the economic models that shaped state policy in the Soviet Union, and the ones developed by prominent academics in Latin America, also did not include Nature. In the Review, the terms Nature, natural capital, the natural environment, the biosphere, and the natural world are used interchangeably.

<sup>5</sup> See, for example, the special issue in the *Review of Economic Studies* (1974) on the economics of exhaustible resources.

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practice of building economic models on the backs of those that had most recently been designed meant that the macroeconomics of growth and development continued to be built without Nature's appearance as an essential entity in our economic lives. Historians of science and technology call that feature of the process of selection 'path dependence'.<sup>6</sup> That may be why economic and finance ministries and international organisations today graft particular features of Nature, such as the global climate, onto their models as and when the need arises, but otherwise continue to assume the biosphere to be external to the human economy. In turn, the practice continues to influence our conception of economic possibilities for the future. We may have increasingly queried the absence of Nature from official conceptions of economic possibilities, but the worry has been left for Sundays. On week-days, our thinking has remained as usual.<sup>7</sup>

Biodiversity is the diversity of life. We will find that the economics of biodiversity is the economics of the entire biosphere. So, when developing the subject, we will keep in mind that we are embedded in Nature. The Review shows (Chapter 4\*) that although the difference in conception is analytically slight, it has profound implications for what we can legitimately expect of the human enterprise. The former viewpoint encourages the thought that human ingenuity, when it is directed at advancing the common good, can raise global output indefinitely without affecting the biosphere so adversely that it is tipped into a state far-removed from where it has been since long before human societies began to form; the latter is an expression of the thought that because the biosphere is bounded, the global economy is bounded.

I imagine the person reading the Review is doing so because she wants to understand our place in Nature as a citizen. She is curious to know what sustainable development should mean; what criteria governments and private companies should use when choosing investment projects; what rules private investors such as herself should use to compare alternative asset portfolios; what she should insist be the practices of companies producing the goods and services she purchases and consumes; whether the social returns on investment in family planning and reproductive health to meet the unmet needs of millions of the world's poorest women are so low that the European Union assigns less than 1% of their international aid budget to them; and so on. Depending on the context, I call her the 'social evaluator', or the 'citizen investor'. The social evaluator recognises that her perspective as a citizen is different from the one she assumes as she goes about her daily life. And she wants to understand why that is so.

In the chapters that follow, the natural world is studied in relation to the many other assets we hold in our portfolios, such as the vehicles we use for transport, the homes in which we live, and the machines and equipment that furnish our offices and factories. But like education and health, Nature is more than a mere economic good. Nature nurtures and nourishes us, so we will think of assets as durable entities that not only have use value, but may also have intrinsic worth. Once we make that extension, the economics of biodiversity becomes a study in portfolio management.

That should be no surprise, for we are all asset managers pretty much all of the time. Whether as farmers or fishers, foresters or miners, households or companies, governments or communities, we manage the assets to which we have access, in line with our motivations as best as we can. But the best each of us is able to achieve with our portfolios may nevertheless result in a massive collective failure to manage the global portfolio of all our assets. The analogy of each of a crowd of people trying to keep balance on a hanging bridge and bringing it crashing down speaks to that possibility.

<sup>6</sup> A clear statement is in P. A. David (1985), "Clio and the Economics of QWERTY," *American Economic Review*, 75(2), 332–337.

<sup>7</sup> Over the years the absence of Nature's essentiality from macroeconomic models of growth and development has been remarked upon by scholars outside the mainstream of economic thinking and practice. But while it is all too easy to criticise existing practices, it is a lot harder to develop alternative models of comparable analytical depth and empirical reach to ones that have been honed by years of patient work. That may be why the criticisms have not been taken seriously by mainstream economists.

The Review has been prompted by a growing body of evidence that in recent decades humanity has been degrading our most precious asset, Nature, at rates far greater than ever before. Simultaneously, the material standard of living of the average person in the world has become far higher today than it has ever been; indeed, we have never had it so good. In the process of getting to where we are, though, we have degraded the biosphere to the point where the demands we make of its goods and services far exceed its ability to meet them on a sustainable basis. That is ominous for our descendants and suggests we have been living at both the best and worst of times.

The Review demonstrates that in order to judge whether the path of economic development we choose to follow is sustainable, nations need to adopt a system of economic accounts that records an inclusive measure of their wealth. The qualifier 'inclusive' says that wealth includes Nature as an asset. The contemporary practice of using Gross Domestic Product (GDP) to judge economic performance is based on a faulty application of economics. GDP is a flow (so many market dollars of output per year), in contrast to inclusive wealth, which is a stock (it is the social worth of the economy's entire portfolio of assets). Relatedly, GDP does not include the depreciation of assets, for example the degradation of the natural environment (we should remember that 'G' in GDP stands for gross output of final goods and services, not output net of depreciation of assets). As a measure of economic activity, GDP is indispensable in short-run macroeconomic analysis and management, but it is wholly unsuitable for appraising investment projects and identifying sustainable development. Nor was GDP intended by economists who fashioned it to be used for those two purposes. An economy could record a high rate of growth of GDP by depreciating its assets, but one would not know that from national statistics. The chapters that follow show that in recent decades eroding natural capital has been precisely the means the world economy has deployed for enjoying what is routinely celebrated as 'economic growth'. The founding father of economics asked after The Wealth of Nations, not the GDP of nations. The idea of wealth that is developed in the Review is, not surprisingly, a lot richer than the one Adam Smith was able to fashion, but his identification of assets as the objects of interest was exactly right.

Acknowledgement that by economic progress we should mean growth in inclusive wealth brings the Review back full circle to where it begins, which is that just as the private investor manages his portfolio with an eye on its market value, the citizen investor appraises the portfolio of global assets with an eye on their social worth. Wealth maximisation in its various guises unites microeconomic reasoning with its macroeconomic counterpart.

The Review makes use of this unification to develop the idea of sustainable development. It constructs a grammar for understanding our engagements with Nature – what we take from it, how we transform what we take from it and return to it, why and how in recent decades we have disrupted Nature's processes to the detriment of our own and our descendants' lives, and what we can do to change direction.

As this is a global Review, I often speak of the demands humanity makes on Nature. But much of the time the Review is obliged to look closely at smaller scales and local engagement with Nature. Differences in the way communities are able to live tell us that people do not experience increasing resource scarcity in the same way. Food, potable water, clothing, a roof over one's head, clean air, a sense of belonging, participating with others in one's community, and a reason for hope are no doubt universal needs. But the emphasis people place on the goods and services Nature supplies differs widely. To farmers in South Asia and Sub-Saharan Africa, it could be declining sources of water and increasing variability in rainfall in the foreground of global climate change; to indigenous populations in Amazonia, it may be eviction not just from their physical home, but from their spiritual home too; to inhabitants of shanty towns everywhere, the worry may be the infections they are exposed and subjected to from open sewers; to the suburban household in the UK, it may be the absence of bees and butterflies in the garden; to residents of mega-cities, it could be the poisonous air they breathe; to the multi-national company, it may be the worry about supply chains, as disruptions to the biosphere make

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old sources of primary products unreliable and investments generally more risky; to governments in many places, it may be the call by citizens, even children, to stem global climate change; and to people everywhere today, it may be the ways in which those varied experiences combine and give rise to environmental problems that affect us all, not least the COVID-19 pandemic and other emerging infectious diseases, of which land-use change and species exploitation are major drivers. Degradation of Nature is not experienced in the same way by everyone.

Nature has features that differ subtly from produced capital goods. The financier may be moving assets around in his portfolio, but that is only a figure of speech. His portfolio represents factories and ports, plantations and agricultural land, and mines and oil fields. Reasonably, he takes them to be immobile. In contrast, Nature is in large measure mobile. Insects and birds fly, fish swim, the wind blows, rivers flow, and the oceans circulate, and even earthworms travel. Economists have long realised that Nature's mobility is one reason the citizen investor will not take the market prices of natural capital to represent their social worth even when markets for them exist. The Review studies the wedge between the prices we pay for Nature's goods and services and their social worth (the Review calls their social worth 'accounting prices') in terms of what economists call 'externalities'. Over the years a rich and extensive literature has identified the measures that can be deployed (the forces of the law and social norms) for closing that wedge. The presence of the wedge is why the citizen investor will insist that companies disclose activities along their entire supply chain. Disclosure serves to substitute for imperfect markets.

But in addition to mobility, Nature has two properties that make the economics of biodiversity markedly different from the economics that informs our intuitions about the character of produced capital. Many of the processes that shape our natural world are silent and invisible. The soils are a seat of a bewildering number of processes with all three attributes. Taken together the attributes are the reason it is not possible to trace very many of the harms inflicted on Nature (and by extension, on humanity too) to those who are responsible. Just who is responsible for a particular harm is often neither observable nor verifiable. No social mechanism can meet this problem in its entirety, meaning that no institution can be devised to enforce socially responsible conduct.

It would seem then that, ultimately, we each have to serve as judge and jury for our own actions. And that cannot happen unless we develop an affection for Nature and its processes. As that affection can flourish only if we each develop an appreciation of Nature's workings, the Review ends with a plea that our education systems should introduce Nature studies from the earliest stages of our lives, and revisit them in the years we spend in secondary and tertiary education. The conclusion we should draw from this is unmistakable: if we care about our common future and the common future of our descendants, we should all in part be naturalists.

The Review builds on six previous publications of mine, each directed at a particular class of problems that belong to the economics of biodiversity.<sup>8</sup> I may have been trying in those publications to develop a grammar for the subject, but I did not know it then, at least not consciously. For that reason, the exercises there now read like acts of reconnaissance. Each has informed the Review in essential ways, but taken together they did not sum to an economics of biodiversity. Which is why I am particularly grateful to Lord (Philip) Hammond, who as Chancellor of the Exchequer of the UK Government, invited me to lead the Review in Spring 2019.

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<sup>8</sup> P.S. Dasgupta and G.M. Heal (1979), *Economic Theory and Exhaustible Resources* (Cambridge: Cambridge University Press), and P. Dasgupta: *The Control of Resources* (Cambridge, MA: Harvard University Press, 1982); *An Inquiry into Well-Being and Destitution* (Oxford: Clarendon Press, 1993); *Human Well-Being and the Natural Environment* (Oxford: Oxford University Press, 2004); *Economics: A Very Short Introduction* (Oxford: Oxford University Press, 2007); and *Time and the Generations: Population Ethics for a Diminishing Planet* (New York, NY: Columbia University Press, 2019).



My education in what is the substance of the Review began in the late 1970s in conversations with Karl-Göran Mäler. He encouraged me to develop my ideas on the links between rural poverty and the state of the local environmental resource-base in the world's poorest countries – a subject that was then notably absent from mainstream development economics, and which remained absent until well into the 1990s. I was further encouraged by Lal Jayawardena, Director of the World Institute of Development Economics Research (WIDER), Helsinki, who invited Mäler and me in 1988 to establish a programme at his institute on the environment and emerging development issues.<sup>9</sup>

But it wasn't until 1991 when, as the newly appointed Director of the Beijer Institute of Ecological Economics, Stockholm, Mäler asked me to serve as Chair of the Institute's Scientific Advisory Board, that we were able to pursue the programme jointly with ecologists. The Institute's mandate made it possible, which was unusual at that time, for ecologists and economists to conduct a regular series of workshops in ecological economics. In this, Mäler and I were aided greatly by the intellectual authority of Kenneth Arrow, Bert Bolin, Paul Ehrlich, and Simon Levin. The Institute's activities have continued with the same exacting standard under Carl Folke, who assumed the Directorship when Mäler retired.

As these developments were confined to Continental Europe, it was natural for us to imagine regional networks of ecological economists in developing countries. That was made possible by a grant from the MacArthur Foundation, Chicago. It enabled Mäler and me in 1999 to establish the South Asian Network for Development and Environmental Economics (SANDEE) and simultaneously the journal *Environment and Development Economics* (Cambridge University Press). Our idea was to offer not only encouragement, but also financial help and a journal based in the West where university teachers of economics in developing countries could publish their research findings. We were able soon after to help colleagues in Eastern and Southern Africa and in Latin America to establish their own networks.<sup>10</sup>

Mäler and I received further help. This time from Miguel Virasoro, Director of the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, who invited us in 2001 to create a programme in ecological economics at ICTP. We used the opportunity to invite economists in our newly formed networks to the Centre, so that they could prepare their findings for publication with help from members of the journal's editorial board. Readers will find that the Review has been much influenced by the rich body of work by colleagues in those networks.

The economics of biodiversity requires attention to local socio-ecological details. I was introduced to the idea of social capital and its relevance for ecological economics at the biannual retreat that Ismail Serageldin convened for an advisory panel he had constituted in the mid-1990s at the Sustainable Development Vice Presidency of the World Bank.<sup>11</sup> My understanding of the subject has deepened at the annual teaching workshop that SANDEE has organised since its inception, from discussions with my fellow lecturers Rabindranath Bhattacharya, Randall Bluffstone, Enamul Haque, Karl-Göran Mäler, Pranab Mukhopadhyay, M.N. Murty, Mani Nepal, Subhrendu Pattanayak, Priya Shyamsundar, E. Somanathan, Jeff Vincent, and participants from Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka, too numerous to mention individually. On the science of complexity, I have learnt enormously from discussions over a period of fifteen years with fellow members of the Scientific Advisory Panel of

<sup>9</sup> The programme's proceedings were published in P. Dasgupta and K.-G. Mäler, eds., *The Environment and Emerging Development Issues*, Vols. I and II (Oxford: Clarendon Press, 1997), and P. Dasgupta, K.-G. Mäler, and A. Vercelli, eds., *The Economics of Transnational Commons* (Oxford: Clarendon Press, 1997).

<sup>10</sup> Resource Accounting Network for Eastern and Southern Africa (RANESA) and the Centre for Environmental Economics and Policy in Africa (CEEPA), Pretoria; and Latin American and Caribbean Environmental Economics (LACEEP) and the Tropical Agricultural Research and Higher Education Center (CATIE), Costa Rica. SANDEE is based at the International Center for Integrated Mountain Development (ICIMOD), Kathmandu.

<sup>11</sup> The Panel's proceedings were published in P. Dasgupta and I. Serageldin, eds. (2000), *Social Capital: A Multifaceted Perspective* (Washington, DC: World Bank).

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the Programme on Complex Systems at the James S. McDonnell Foundation, St. Louis, and from the Foundation's successive Presidents, John Bruer and Susan Fitzpatrick.

My understanding of the social embeddedness of individual preferences improved greatly by the many discussions I had with Dale Sutherland and Alistair Ulph during my tenure in 2008–2013 as Visiting Professor at the Sustainable Consumption Institute of the University of Manchester.

Before beginning work on the Review, I asked Simon Beard, John Bongaarts, Simon Levin, Tom Lovejoy, and Peter Raven to prepare essays for me on subjects I knew to be essential but on which I was inexpert. The ideas they developed are reflected in the present work.

The Review has been much influenced by Scott Barrett and Aisha Dasgupta, who assumed the lead in collaborative works that form the basis of some of the central ideas here.

During the Review's preparation, I have gained enormously from correspondence and discussions with Inger Andersen, Robert Aumann, Scott Barrett, Ian Bateman, Simon Beard, Simon Blackburn, Caroline Bledsoe, John Bongaarts, Stephen Carpenter, William Clark, Mary Colwell, Diane Coyle, Aisha Dasgupta, Shamik Dasgupta, Zubeida Dasgupta, Paul Ehrlich, Carl Folke, Patrick Gerland, Roger Gifford, Lawrence Goulder, Ben Groom, Andy Haines, Geoffrey Heal, Cameron Hepburn, Girol Karacaoglu, Phoebe Koundouri, Pushpam Kumar, Tim Lenton, Simon Levin, Justin Lin, Tim Littlewood, Georgina Mace, Robert Macfarlane, Shunsuke Managi, Eric Maskin, Henrietta Moore, Tid Morton, Ilan Noy, Gustav Paez, Charles Perrings, Stuart Pimm, Peter Raven, Martin Rees, Fiona Reynolds, Marten Scheffer, Ingmar Schumacher, V. Kerry Smith, Denise Spinney, Will Steffen, Nicholas Stern, Thomas Sterner, William Sutherland, Nicola Tagart, Alistair Ulph, Ruut Veenhoven, Jeff Vincent, Robert Watson, Gavin Wright, Anastasios Xepapadeas, Menahem Yaari, and Aart de Zeeuw.

I am especially grateful to HM Treasury for enabling Sandy Sheard to assemble an exceptionally gifted team who have helped me think through the economics of biodiversity. Drawn from across the public sector and based in HM Treasury, they have provided me with invaluable support over the course of the Review, including Mark Anderson, Heather Britton, Abbas Chaudri, Dana Cybuch, Rebecca Gray, Haroon Mohamoud, Robert Marks, Emily McKenzie, Diana Mortimer, Rebecca Nohl, Felix Nugee, Ant Parham, Victoria Robb, Sandy Sheard, Sehr Syed, Thomas Viegas, Ruth Waters, and Lucy Watkinson. They have gathered evidence from a wide range of experts from around the world, arranged for me to meet many of them, supported my Advisory Panel, prepared a wealth of case studies, edited the Review, and made vital contributions to drafting elements of the Review itself – particularly, the chapters in Part II. Even more, they queried every intellectual move I made; to a professor, there can be no greater reward.

Above all, I am grateful to Carol Dasgupta, on whom I have tested pretty much every idea in the Review. Her suggestions on what to emphasise and what is superficial have been invaluable.

The influence of Amiya Dasgupta, Kenneth Arrow, Paul Ehrlich, Peter Raven, John Rawls, and Robert Solow on the way I frame economics has become increasingly evident to me.

### **Partha Dasgupta**

*St John's College, Cambridge*