1 INTRODUCTION

Humankind must accept stewardship of Planet Earth and urgently act on it.

It used to be that only climate activists, environmentalists and street protestors talked about "saving the Earth." Today, this sentiment is expressed by nearly everyone – from citizens to academics to government officials and boardroom executives.

At the 2020 World Economic Forum in Davos, Peter Brabeck-Letmathe, former chairman and CEO of Nestlé, announced:

> Planet Earth is sick . . . so we have to heal it.[1]

And, as Partha Dasgupta explained in his landmark review of *The Economics of Biodiversity*:

> The solution starts with understanding and accepting a simple truth: our economies are embedded within Nature, not external to it.[2]

This shift in sentiment, although welcome, has been a long time coming.

In the 1960s, the economist Kenneth Boulding argued that humankind's future depends on transforming the current "cowboy economy," which treats Earth's resources and sinks as essentially limitless, to a "spaceman economy" that respects the finite biosphere of "Spaceship Earth." Boulding contrasted these two economies in this way:

> I am tempted to call the open economy the "cowboy economy," the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent

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> behavior, which is characteristic of open societies. The closed economy of the future might similarly be called the "spaceman" economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy.[3]

In the 1970s, the historian Arnold Toynbee noted that humankind has always exploited nature with little regard of the environmental impact. Whereas previously we only "devastated patches of the biosphere," this changed with the Industrial Revolution. It gave us the "power to damage and despoil the biosphere irremediably":

> Before the Industrial Revolution, Man had devastated patches of the biosphere ... But, before he had harnessed the physical energy of inanimate nature in machines on the grand scale, Man had not had it in his power to damage and despoil the biosphere irremediably. Till then, the air and the ocean had been virtually infinite, and the supply of timber and metals had far exceeded Man's capacity to use them up. When he had exhausted one mine and had felled one forest, there had always been other virgin mines and virgin forests till waiting to be exploited. By making the Industrial Revolution, Man exposed the biosphere, including Man himself, to a threat that had no precedent.[4]

Ten years later, the scientist James Lovelock elaborated on the possible dire – and irreversible – consequences if we fail to curtail global environmental degradation:

> Anything that makes the world uncomfortable to live in tends to induce the evolution of those species that can achieve a new and more comfortable environment. It follows that, if the world is made unfit by what we do, there is the probability of a change in regime to one that will be better for life but not necessarily better for us ... The things we do to the planet are not offensive nor do they pose a geophysiological threat, unless we do them on a large enough scale ... When all this is taken into account we are indeed in danger of changing the Earth away from the comfortable state it was once in.[5]

Several decades on, the world may be beginning to heed the warnings of Boulding, Toynbee and Lovelock, but we have yet to halt the "danger of changing the Earth away from the comfortable state it was once in."

According to the Intergovernmental Panel on Climate Change (IPCC), by failing to reduce global greenhouse gas emissions, we are destined to live in "a world of worsening food shortages and wildfires, and a mass die-off of coral reefs as soon as 2040 — a period well within the lifetime of much of the global population."[6] Mammals and other species may also be on the verge of "biological annihilation" as forests and other natural habitat continue to be converted and degraded.[7] Currently, at least one-third of fish stocks are overfished; one-third to half of vulnerable marine habitats have been lost; and a substantial fraction of the coastal ocean suffers from pollution, eutrophication, oxygen depletion and is stressed by ocean warming.[8] Rising freshwater scarcity is a present-day danger for the 1.6–2.4 billion people currently living within watersheds with inadequate supplies and exposed to climate change.[9]

Unless we control these alarming trends, they could endanger the health and livelihoods of millions and the sustainability of our economies. Even in a world recovering from the worst health pandemic in more than 100 years and the deepest economic recession since the Great Depression of the 1930s, humankind's devastating impacts on the biosphere remain our biggest global challenge.

So, it is not surprising that, in its first global survey since the COVID-19 outbreak, the World Economic Forum found that four environmental risks – plus the threat of infectious disease outbreaks – are the top five global threats to humankind.[10] These four risks are: extreme weather, climate action failure, human environmental damage and biodiversity loss.

All of these trends and concerns suggest that humankind's relationship with the biosphere is at a critical juncture. Planet Earth could be on the cusp of destabilization, and we may not have many years left to change this path.

The Anthropocene

Human impacts on Earth are now so significant that we have created an entirely new geological epoch – the *Anthropocene*.[11] This era began with the late twentieth-century "Great Acceleration" of

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population growth, industrialization and mineral and energy use, and has continued unabated since.[12] Human activity has become the dominant influence on the global environment. We are altering basic Earth system processes at an increasing rate through climate and land use change, pollution, freshwater use and many other impacts. As a result, the Earth system could be approaching a "tipping point" that could change it irrevocably, with potentially disastrous impacts for humanity.[13]

We do not really know what will happen once this Earth system threshold is crossed (see Figure 1.1). The system may well be out of human control or influence, and will be driven by its own internal dynamics. But if the Great Acceleration continues, one possible outcome is a "catastrophic" Anthropocene, with global warming of 2–4°C or

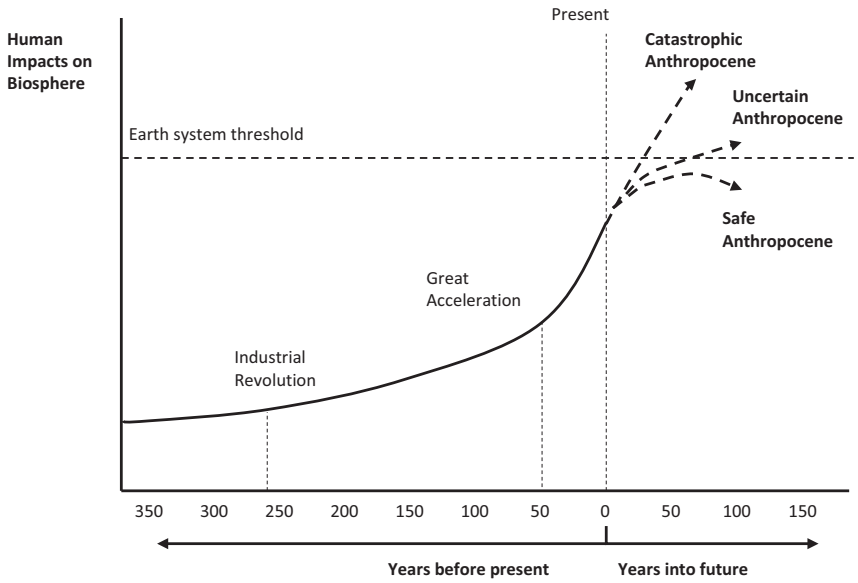

Figure 1.1 Human impacts on Planet Earth
Notes: Since 1970, rapid industrialization, population growth, resource use and pollution have caused a "Great Acceleration" in human impacts on the biosphere. If these impacts continue, in a few decades we could produce a "catastrophic" Anthropocene that would threaten humanity. Even if human impacts are moderated somewhat, crossing the Earth system's threshold would lead to an "uncertain" Anthropocene with unpredictable consequences for the planet. Only by reducing human impacts significantly over the next few decades are we likely to avoid exceeding the Earth system threshold, or "tipping point," and create a relatively "safe" Anthropocene.

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more, massive biodiversity losses and species extinction, chronic freshwater scarcity and other unknown environmental disruptions.[14] If we exceed the Earth system threshold, we could end up in an "uncertain" Anthropocene, where the environmental consequences are difficult to predict and would likely cause serious, and possibly irreversible, damages to ecosystems, society and economies. Only if we act now, and with sufficient efforts to "decouple" human impacts on the planet from economic activity and continued population growth, are we likely to be able to maintain a "safe" Anthropocene that evades Earth's "tipping point."

Some scientists advocate that, to prevent an uncertain or catastrophic Anthropocene, human impacts on the global environment must be kept within the "planetary boundaries" that protect key Earth system processes. They suggest that there are "nine such processes for which we believe it is necessary to define planetary boundaries: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading."[15]

Although there are disagreements over this "planetary boundary" perspective, there is growing scientific consensus that Planet Earth is increasingly fragile, and it is no longer a problem that we can leave future generations to fix. Global environmental change is occurring now, already affecting the lives and livelihoods of billions today, and only getting worse as we delay actions to deal with it. The longer we wait, the more the costs of inaction rise and the risk of potentially catastrophic change occurs. As the scientists Timothy Lenton and Hywell Williams conclude, "regardless of whether it is approaching a global tipping point, we can all agree that the biosphere is in trouble."[16]

We cannot afford to wait any longer. It is now time for humankind to accept stewardship of Planet Earth and to act on it.

This is the contribution of the following book. It begins with acknowledging the "simple truth" – as the quote by Partha Dasgupta so eloquently states – that "our economies are embedded within Nature, not external to it." This modest yet powerful change in our economic view of the world can help guide how we rethink our markets, institutions and governance. And, from these changes, flow a plethora of new incentives, innovations and investments that can transform our economies to become more sustainable and inclusive.

The purpose of this book is to start this process of more innovative thinking on economics and policies for an increasingly "fragile" planet. It requires addressing three crucial questions:

- How do we reduce human impacts on the biosphere to ensure a safe Anthropocene, and if so, what are the implications for our markets, institutions and governance?
- As environmental risks continue to mount, how do we design and run our economies to avoid and mitigate these risks in an inclusive and sustainable manner?
- What policies are required to "decouple" wealth creation and economic prosperity from environmental degradation, to sustain per capita welfare and simultaneously limit environmental risks?

These questions need to be addressed urgently. They represent the major sustainability challenge facing the world today. Yet current economic and policy thinking has largely ignored them.

Throughout this book, we will explore why this has to change and how to do it. The first step is to approach the relationship between nature and economy differently than we have in the past. Tackling the sustainability crisis requires new ways of viewing the world around us, and that in turn, requires some principles to guide economic and policy thinking.

This book proposes five such principles:

- Ending the underpricing of nature
- Fostering collective action
- Accepting absolute limits
- Attaining sustainability
- Promoting inclusivity

These principles underlie the approach to economics and policy taken in this book.

Underpricing Nature

Ending the *underpricing of nature* is listed as the first principle, as it lies at the heart of the sustainability crisis.

The failure to take the true value of the environment into account is pervasive in all economies. Poor institutions and governance further exacerbate this disincentive, thus fostering even more environmental mismanagement.

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This book explores how improving markets, institutions and governance can correct the underpricing of nature, and ultimately, enhance the ability of economies to meet the environmental challenges of the Anthropocene.

Economists have always maintained that the key measure of an economy's progress is its ability to create wealth. Today, it is widely recognized that the "real wealth" of a nation comprises three distinct capital assets: manufactured *physical capital*, such as roads, buildings, machinery and factories; *human capital*, such as skills, education and health embodied in the workforce; and *natural capital*, including land, forests, fossil fuels and minerals. In addition, natural capital also comprises those ecosystems that through their natural functioning and habitats provide important goods and services to the economy, or *ecological capital*. But the world economy today is squandering, rather than accumulating, key sources of wealth.

Despite rising natural resource scarcity and increasing environmental and ecological damage, the growth and structure of production in modern economies continues to use more resources and energy. We are not facing up to the rising economic and social costs of increasing natural resource use, pollution and ecological scarcity. We hide these costs by underpricing natural capital in our market, policy and investment decisions.[17] As a consequence, we are using up natural resources as fast as ever, increasingly polluting the environment and rapidly running down our endowment of ecological capital.

This raises two important questions:

- If natural and ecological capital are valuable sources of economic wealth, why are we squandering these assets?
- If ecological scarcity and natural capital loss are on the rise, why are we are we doing so little to address these problems?

The key to this paradox is the underpricing of nature in our economies: The increasing costs associated with many environmental problems – climate change, freshwater scarcity, declining ecosystem services and increasing energy insecurity – are not routinely reflected in markets. Nor have we developed adequate policies and institutions to provide other ways for the true costs of environmental degradation to be taken into account. This means that decision makers do not receive the correct price signals or incentives to adjust production and consumption activities. All too often, policy distortions and failures compound ecological

scarcity, pollution and resource overexploitation by further encouraging wasteful use of natural resources and environmental degradation.

As David Pearce and I argued some years ago, this process has become a *vicious cycle* in today's economies:

> Important environmental values are generally not reflected in markets, and despite much rhetoric to the contrary, are routinely ignored in policy decisions. Institutional failures, such as the lack of property rights, inefficient and corrupt governance, political instability and the absence of public authority or institutions, also compound this problem. The result is economic development that produces excessive environmental degradation and increasing ecological scarcity. As we have demonstrated, the economic and social costs associated with these impacts can be significant.[18]

This vicious cycle can also be depicted visually, as shown in Figure 1.2. Markets and policy decisions currently do not reflect the rising economic costs associated with exploiting the environment. The result is that economic development today produces much more environmental damage and ecosystem harm than it needs to. Such development leads to even more resource depletion, pollution, degradation of ecosystems and, ultimately, rising ecological scarcity. But the rising economic and social costs associated with these impacts and scarcity continue to be "underpriced" by markets and ignored by policies. The vicious cycle is perpetuated, and the current pattern of economic development persists.

Inadequate institutions and governance exacerbate this vicious cycle. Corruption, poor laws, lack of enforcement, inept public administration, insufficient regulation and political instability plague environmental management in many areas of the world; so does lobbying by powerful interest groups that gain considerably from the status quo. But perhaps the biggest challenge facing the world today is the lack of effective collective governance and agreements among nations as to how best to address the growing number of challenges and environmental risks that are occurring on a global scale – climate change, biodiversity loss, freshwater scarcity and the decline of oceans and seas.[19]

Rising environmental risks are one dimension of the problem. Another dimension is the increased societal risks. The vicious cycle also creates a structural imbalance in the economy, where the lack of green innovation and investments prevent the transition from a fossil

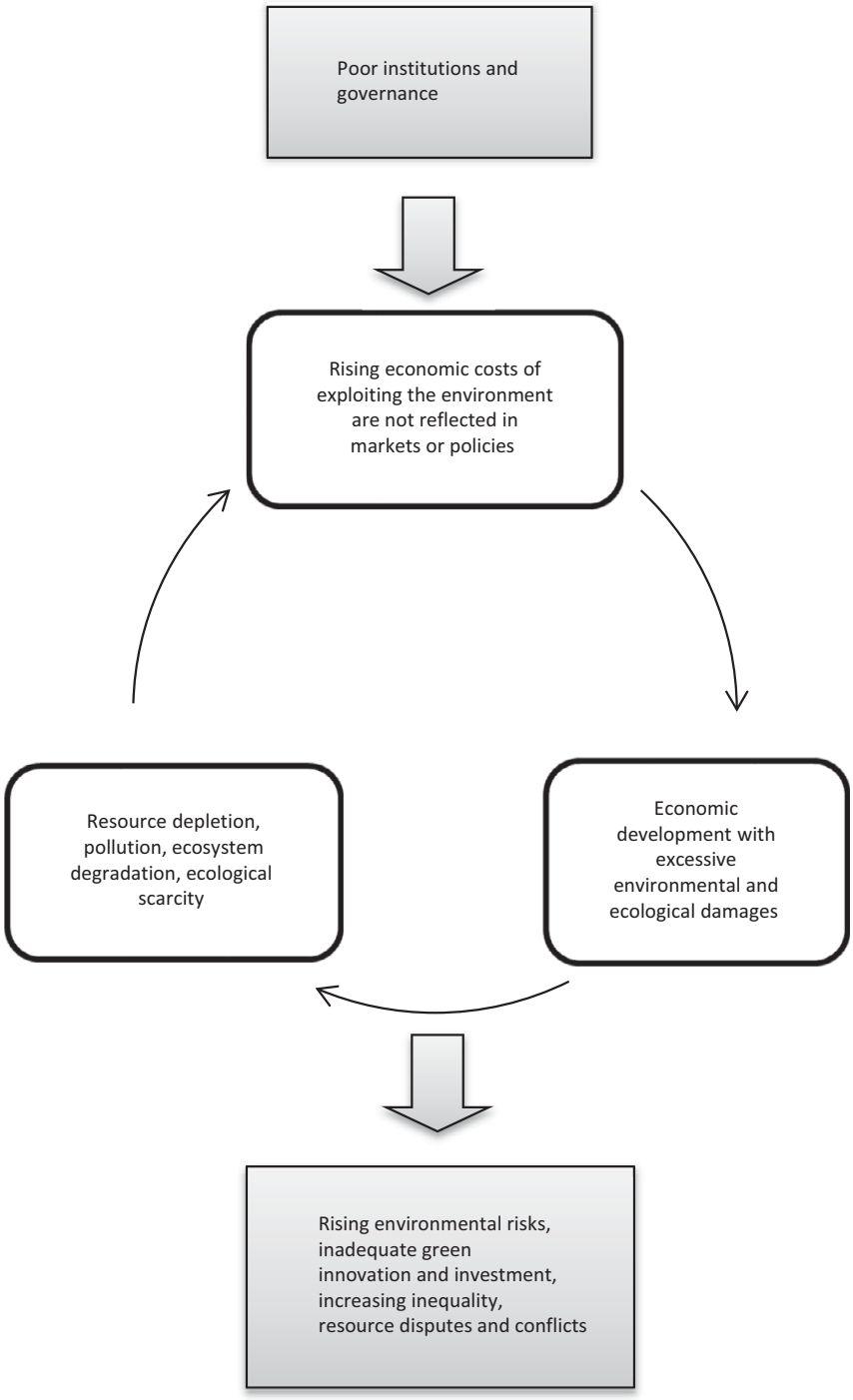

Figure 1.2 The vicious cycle of underpricing nature

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fuel–based economy dependent on high rates of material and nonrenewable use to one that fosters cleaner energy sources and uses less resources. Degradation of the environment and ecosystems also impacts inequality, as it is the poorer and more vulnerable members of society that depend the most on nature and are affected the worst by pollution, climate change, natural disasters and other environmental risks. Ultimately, the rising environmental and societal risks could lead to greater conflicts over scarce environmental and natural resources. Already, there is concern about how climate change, disasters, water scarcity and other environmental threats are displacing large numbers of people, leading to enforced migration and exacerbating tensions and disputes among nations.

Collective Action

As we shall see throughout this book, one of the key mechanisms for reducing environmental degradation and threats is *collective action*, which is joint action in the pursuit of a common goal.

The reason why collective action is required for reducing many environmental risks is that the resulting benefits are what economists call *public goods*.[20] The reduction in the environmental "bad" may benefit many individuals at once, and no individual's gain comes at the expense of another.

For example, improvement in water quality through limiting pollution, removing sediment or controlling temperature extremes can have the characteristics of a public good. If I live by a lake that has had a reduction in pollution, any benefits I receive from the cleaner lake water do not lessen the benefits of others also living by the lake. All of us gain from a cleaner lake, and we enjoy these benefits simultaneously.

Realizing such an environmental improvement usually requires collective action. The members of a group who benefit need to act together to secure the outcome that has the most potential to benefit the group as a whole. The reason why this is necessary is because individual action will fall short of this outcome. Any single member who benefits has little incentive to deliver on the action that yields the most gain to all.

Take the example of cleaning up lake pollution. If I pay for the removal of pollution from the lake, then I will benefit from the resulting improvement in water quality. But so will others living by the lake. The difference is that they have no incentive to pay for the pollution

removal, because I have already done so. I may decide that it might be worthwhile making such an investment anyway. But more often than not, because removing pollution from water is likely to be expensive, and I know that I cannot charge others for this benefit, I would probably not act on my own to curb lake pollution. As other individuals using the lake would reach the same conclusion, the pollution cleanup will not occur.[21]

As we shall see in this book, collective action is increasingly required to deal with a variety of environmental threats – from pollution to resource depletion to ecosystem and biodiversity loss to global environmental risks. Moreover, such action is required by groups of individuals, communities, businesses, regional and local governments and nations. It will certainly be necessary for addressing the top five global threats to humankind identified by the World Economic Forum: extreme weather, climate action failure, human environmental damage, infectious diseases and biodiversity loss.

Absolute Limits

As noted previously, some scientists advocate that, to prevent an uncertain or catastrophic Anthropocene, human impacts on the global environment must be kept within the "planetary boundaries" that protect key Earth system processes. Such boundaries impose *absolute limits* on human exploitation of critical global biophysical sinks or resources. For example, advocates of this approach have proposed boundaries to restrict depletion of terrestrial net primary production, freshwater, species richness, assimilative capacity for various pollutants, forest land area and the global carbon budget for 1.5°C or 2.0°C warming.[22]

Whether one agrees or not with the need for such absolute limits to safeguard the health of Earth's life-support systems, this viewpoint has been shaping approaches to sustainability for some time.[23] As pointed out by Robert Kates and colleagues, "Meeting fundamental human needs while preserving the life-support systems of planet Earth is the essence of sustainable development."[24]

In the next two chapters we will explore the scientific arguments for and against this perspective, as well as its implications for an "economics for a fragile planet." Regardless of the differing views on the planetary boundary debate, an important consensus is emerging that

global environmental risks are mounting, and some control of the human sources of these threats is necessary to ensure a safe, as opposed to an uncertain or catastrophic, Anthropocene.

Accepting absolute limits on our cumulative environmental impacts on the biosphere has implications for both economics and policy.

Such a perspective challenges economists to reconsider whether there is an absolute limit on human exploitation of critical global biophysical sinks or resources. Over the years, some economists have advanced this view on sustainability. As we saw with the quote earlier in this chapter, it began with the economist Kenneth Boulding in the 1960s, who argued that the Earth is ultimately finite, and thus transition to a "spaceship economy" that respects such limits is unavoidable. However, this perspective was largely rejected by Boulding's fellow economists.[25]

But with the mounting scientific evidence on rising global environmental risks, and the possible need to safeguard essential Earth system life-support processes, economic views on absolute limits are beginning to change. Economic approaches to sustainability are increasingly recognizing the need to curb human activities threatening critical Earth system processes, resources and sinks.[26]

As we shall see in this book, the recognition that our planet is not a limitless source of exploitation for humankind is a simple – but ultimately profound – insight. Acknowledging that certain Earth system processes and vital resources cannot be endlessly polluted, depleted and degraded is an important starting point for thinking how best to ensure a safe Anthropocene in an efficient and sustainable manner.

It also has important policy implications. Accepting that the economy is embedded within nature and that the economy, in turn, must safeguard the health of Earth's life-support systems is essential for developing the correct policies to manage such an economy. And, we need the right policies to foster the institutions, incentives and innovations necessary to limit the rising global environmental risks posed by climate change, biodiversity loss, water scarcity and other major human impacts on the biosphere.

However, recognizing limits on humankind's endless exploitation of the Earth is not enough. As leading scholars in natural and social sciences have concluded: "Keeping within planetary boundaries requires that we make better and more cost-effective use of the finite

resources and sinks available to us."[27] Such efficient use is essential, but it must also be sustainable as well as inclusive.

Sustainable and Inclusive Development

By ending the underpricing of nature and invoking collective action, we can go a long way toward realizing outcomes that have the greatest potential benefits at the least possible costs. This is an important efficiency goal of choosing the right policies among the options available to us.

However, in a world of rising global environmental risks, efficiency does not necessarily guarantee sustainability. As we have seen, one important rationale for minimizing these risks is to ensure a safe Anthropocene with healthy Earth life-support systems, well-functioning ecosystems and sufficient resources and sinks not just for ourselves but for our children and their offspring as well. In other words, we should ensure that future generations have at least the same level of economic opportunities and well-being that we presently enjoy. This concern about *intergenerational equity* is at the heart of the concept of sustainability.

For example, most interpretations of sustainability today are based on the consensus reached by the mid-1980s World Commission on Environment and Development (WCED), which defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[28] But as we have noted previously, meeting this objective may require accepting absolute limits on the global economy's accelerating pollution, depletion and degradation of key ecosystems, resources and sinks.

In other words, as David Griggs and coauthors point out, attaining sustainability requires "safeguarding Earth's life-support system, on which the welfare of current and future generations depends." Consequently, they suggest modifying the WCED definition of sustainability to "development that meets the needs of the present while safeguarding Earth's life-support system, on which the welfare of current and future generations depends."[29]

As we shall explore in this book, such a sustainable path for our economies will require additional policies and collective action to counter rising global environmental risks and safeguard key Earth system processes. The protection of essential environments that may be subject

to irreversible conversion could require the implementation of a whole suite of bold and innovative policy approaches to invest in global public environmental goods.[30]

However, ensuring that development is sustainable does not necessarily guarantee that it is also inclusive. For one, imposing any limits on human exploitation of critical global sinks and resources raises important issues of *intragenerational equity*.[31] If current access to these sinks and resources is unequally distributed and dominated by wealthy nations, regions and individuals, then additional policies may be necessary either to improve access by the poor or to ensure that they are adequately reimbursed for any additional burdens imposed by reduced access.

Related to this concern is the growing income and wealth inequality over the past several decades. Since 1980, there has been rising inequality in most of the world's regions, as the top 10 percent increased their share of income. A major factor has been the unequal distribution of the growth in global income over past decades between the rich and poor. While the poorest half of the global population has seen its income grow significantly, especially in China, India and other Asian countries, since 1980 the top 1 percent richest individuals in the world captured twice as much growth as the bottom 50 percent.[32]

In addition, wealth inequality has worsened during the COVID-19 pandemic. The world's richest have become wealthier and poverty reduction has suffered a major setback. Worldwide, the wealth of billionaires increased by $3.9 trillion during the pandemic in 2020, whereas the total number of people living in extreme poverty may have increased from 70 million to 200–500 million, the first rise in over two decades.[33]

These worsening inequality trends pose a challenge to any sustainable development strategy. Ensuring that such a strategy is inclusive is even more of a priority in the coming decades, given the skyrocketing unemployment and likely disproportionate impacts on low-income households and countries caused by the pandemic. As we will discuss in later chapters, there a number of policies that economies could adopt that could both "green" a post-pandemic recovery and ensure more equitable and just distributions of benefits. Tackling the trend of growing wealth inequality may also require additional collective actions to make economic development and the world economy more inclusive in the coming decades.

Economics for a Fragile Planet

To summarize, ensuring a "safe" Anthropocene is the major sustainability challenge facing humankind today. Meeting this challenge places a significant responsibility on economics to lead the way in designing new policies and strategies. The aim of this book is to explain what this "economics for a fragile planet" might look like. The five principles outlined in this introductory chapter are the building blocks for this new economic thinking and can help guide our policy approaches.

Chapter 2 reviews the mounting scientific evidence of the growing "fragility" of the Earth system and its implications for the planet. It traces the long history of how humans have exploited nature to create wealth, starting with the Agricultural Transition 10,000 years ago up to the Fossil Fuel Age and its global consequences. The chapter then focuses on the four threats created by current human impacts on the biosphere: climate change, land use and biodiversity loss, freshwater scarcity and deteriorating marine and coastal habitats. Each of these global challenges will be examined in more detail in later chapters (see Chapters 4–7).

The need to curb human activities threatening critical Earth system processes, resources and sinks is an important starting point for thinking how best to manage our planet in an efficient, sustainable and inclusive manner. Chapter 3 explains how this can form the basis for an "economics for a fragile planet." This perspective began with Kenneth Boulding in the 1960s, who argued that the Earth is ultimately finite, and thus, transition to a "spaceship economy" that respects such limits is unavoidable. The implications are that the exploitation of Earth's sources of natural resources and sinks for pollution is not limitless, and that it is essential to end the *underpricing of nature* that currently ignores the rising costs associated with ecological scarcity and environmental degradation. This requires in turn rethinking the markets, institutions and governance needed for a green and inclusive economic transformation. The overall objective should be to manage an economy's overall stock of physical, human and natural capital to sustain per capita human welfare while limiting global environmental risks.

Chapter 4 focuses on how this new thinking is critical to addressing climate change. International action is failing to deliver on slowing greenhouse gas emissions to keep the planet from warming dangerously, yet considerable progress is occurring by some countries,

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companies, states or provinces, and even cities. Chapter 4 argues that ending the underpricing of fossil fuels is essential to a low-carbon transition. Major economies must lead by removing fossil fuel subsidies and employing carbon taxes and other policies to further reduce the social cost of fossil fuel use, and allocate any resulting revenue to public support for green innovation and key infrastructure investments. Ending the underpricing of fossil fuels in low- and middle-income countries must occur through policies that are compatible with achieving immediate development objectives, such as ending poverty and especially the widespread "energy poverty" in rural areas. Climate policies need also to expand beyond actions by national governments and instead focus on a "bottom-up" strategy that supports and expands initiatives by corporations, local governments and other "sub-national" entities that are pushing and innovating low-carbon strategies.

Land use change by humans has transformed ecosystem patterns and processes across most of the terrestrial biosphere, a global change that could be potentially catastrophic for both humankind and the environment. Chapter 5 explores how this threat is related to the underpricing of natural landscape in all economies, and how addressing this critical problem is essential to creating the incentives, institutions and innovations needed to change humankind's relationship with nature. The underpricing of natural landscape also perpetuates rural poverty, and the impacts of land use change are borne increasingly by the poor. Decoupling development from excessive land use change leading to ecosystem decline is necessary to make our economies both more sustainable and inclusive. Global biodiversity conservation is also plagued by underfunding, as the international community struggles to compensate developing countries for protecting valuable terrestrial habitats. Collective action will require commitments not only by rich countries to assist poorer ones in protection and restoration efforts, but also by the private sector to invest in nature to reduce the risks from biodiversity and ecosystem loss.

Rising freshwater scarcity is a present-day danger that is likely to worsen as supplies become increasingly scarce. Chapter 6 takes the view that the current overuse of freshwater supplies worldwide is as much a failure of water management as it is a result of scarcity. Outdated governance structures and institutions, combined with continual underpricing, have perpetuated the overuse and undervaluation of water, requiring reforms to markets and policies to ensure that they

adequately capture the rising economic costs of exploiting water resources to foster more conservation, control of pollution and ecosystem protection. The result will be more efficient allocation of water among its competing agricultural; industrial and urban uses; fostering of water-saving innovations and further mitigation of water scarcity and its costs.

Chapter 7 argues that, if we are to halt humankind's unrelenting exploitation of marine sources and sinks, we need to change our economic approach to oceans and coasts. It begins with addressing the underpricing of marine capital and their services and the underfunding of ocean and coastal conservation. Addressing these challenges must be the focus of global collective action. The savings and revenues generated can also be allocated to support global funds and investments in marine capital and protection. However, more comprehensive cooperation between the international community, national governments and the private sector is required to develop global policies to protect vulnerable coastal populations and disappearing marine habitats, such as coral reefs and mangroves, and the deep sea.

Chapter 8 elaborates further on the public policies needed for "greening" economic activity and promoting better stewardship of the environment. The focus is primarily on strategies that governments might adopt to achieve economy-wide green transformation for more efficient, sustainable and inclusive development. The chapter explores what these short- and long-term policy efforts will look like, providing examples from both major economies and low- and middle-income countries. At the center is ending the underpricing of nature to unleash the economic potential of green developments for generating economy-wide innovation and prosperity, and more equitable income and wealth distribution.

Public polices alone cannot build a green economy for a safe Anthropocene. In any economy, the catalyst for change comes from private investment, financing and innovation. Chapter 9 examines the evidence of growing adoption and initiatives by corporations, businesses and the financial system to incorporate actions to mitigate environmental risks and improve the global environment, and looks in particular at the possibility of private sector action to move toward better environmental stewardship. Firms increasingly find that improved environmental performance reduces their overall cost of capital and their attractiveness to potential investors. However, better

environmental scarcity and risk management by firms requires a range of complementary policies for green financing and investment, ending the underpricing of nature and taxing major biosphere exploiters. Corporations that are willing to become biosphere stewards should also collaborate with governments in collective action to address global environmental risks.

The concluding chapter brings together the main themes and messages of the book. Chapter 10 argues that the economics for a "fragile planet" is about ensuring that our economies can attain a "safe," as opposed to "catastrophic" or "uncertain" Anthropocene (see Figure 1.1). To be successful, such a transition must transform our markets, institutions and governance to reduce human impacts on the biosphere; mitigate environmental risks in an inclusive and sustainable manner; and decouple wealth creation and economic prosperity from environmental degradation. Above all, we must end the underpricing of nature so that our institutions, incentives and innovations reflect the growing ecological and natural resource scarcity that our current economic use of the environment has created. Taking this first step is essential to developing an economics for an increasingly fragile planet.

Notes

1 As quoted by Johnny Wood, "Q and A: This Is How Stakeholder Capitalism Can Help Heal the Planet." World Economic Forum, January 20, 2020. www.weforum.org/agenda/2020/01/stakeholder-capitalism-environment-planet.
2 Quoted from p. 2 of *The Economics of Biodiversity: The Dasgupta Review – Headline Messages*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957629/Dasgupta_Review_-_Headline_Messages.pdf For Professor Sir Partha Dasgupta's full report, see Dasgupta (2021).
3 Boulding (1966), pp. 7–8.
4 Toynbee (1978), pp. 17 and 566. See also Barbier (2011) for an in-depth exploration of how exploitation of natural resource and land frontiers, from the Agricultural Transition 10,000 years ago to the present day, has influenced economic development and progress.
5 Lovelock (1988), pp. 178–179.
6 From www.nytimes.com/2018/10/07/climate/ipcc-climate-report-2040.html.
7 Ceballos et al. (2017) used the term "biological annihilation" to describe the current species extinction crisis. Other global assessments that illustrate how land use change is leading to unprecedented loss of biodiversity and ecosystem services include Bar-On et al. (2018); Elhacham et al. (2020); IPBES (2019); and Newbold et al. (2016).
8 See Duarte et al. (2020) for further details on these trends.
9 Gosling and Arnell (2016). For other global water scarcity trends and issues, see Barbier (2019b).
10 WEF (2021). The World Economic Forum bases its assessment of the likelihood and impact of various risks on a global survey of businesses, governments and individuals.

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11 Scientists believe that the Anthropocene started as a distinct geological epoch in the mid-twentieth century. See Waters et al. (2016). The biologist Eugene Stoermer and the Nobel Prize–winning atmospheric chemist Paul Crutzen are credited with coining the term "Anthropocene." See Crutzen (2002), Crutzen and Stoermer (2000); and Steffen et al. (2011).

12 According to Steffen et al. (2015a), p. 2: "The term 'Great Acceleration' was first used in a working group of a 2005 Dahlem Conference on the history of the human–environment relationship (Hibbard et al. 2006)." It was also used by Steffen et al. (2007) to describe the "second phase" of the Anthropocene (from 1945 to ca. 2015). See also McNeill and Egelke (2016) for an "environmental history" of the Great Acceleration. What has been widely known as the "Great Acceleration" graphs of global socioeconomic and Earth system long-run trends were originally designed and constructed as part of the synthesis project of the International Geosphere-Biosphere Programme (IGBP), and which show how human impacts on the planet have accelerated since 1950–2000 compared to the long-run trends from 1750 onward (Steffen et al. 2004 and 2007). These graphs and trends have been updated to 2010 by the IGBP and are available at their website www.igbp.net/globalchange/greatacceleration.4.1b8ae20512db692f2a680001630.html and also presented in Steffen et al. (2015a).

13 Lenton et al. (2008) first postulated the possibility of tipping points or "elements" in the Earth's climate systems. A special issue edited by Schellnhuber (2009) then extended the concept to other Earth system processes. Rockström et al. (2009) used the possibility of such human-induced stresses on the Earth system to develop the "planetary boundaries" concept.

14 One such "catastrophic" Anthropocene outcome is the "Hothouse Earth" state described by Steffen et al. (2018).

15 Rockström et al. (2009), p. 472. See also Steffen et al. (2015b) and Lade et al. (2020).

16 Lenton and Williams (2013), p. 382.

17 For our purposes, *ecological scarcity* can be defined as the loss of the myriad contributions that ecosystems make to human well-being as these natural systems are exploited for human use and economic activity. These contributions include not only loss of recreation opportunities, harvests of wild resources and genetic material but also many vital benefits, such as natural hazard protection, nutrient uptake, erosion control, water purification and carbon sequestration. All these valuable goods and services provided by ecosystems are now called *ecosystem services* for short, or as the Millennium Ecosystem Assessment defines them, "ecosystem services are the benefits people obtain from ecosystems" (MA 2005). For the original definition of *ecological scarcity* see Barbier (1989), pp. 96–97: "The fundamental scarcity problem … is that as the environment is increasingly being exploited for one set of uses (e.g., to provide sources of raw material and energy, and to assimilate additional waste), the quality of the environment may deteriorate. The consequence is an increasing *relative scarcity* of essential natural services and ecological functions … In other words, if 'the environment is regarded as a scarce resource', then the 'deterioration of the environment is also an economic problem.'"

18 Pearce and Barbier (2000), p. 157.

19 This governance challenge for individual nations to agree collectively to "saving the biosphere" was noted by Toynbee (1978), pp. 592–593: "Since the dawn of civilization, Man's master institution has been states – in the plural, not in the singular; for, to date, there has never been one single state embracing the whole living generation of mankind all round the globe … The present-day global set of local sovereign states is not capable of keeping the peace, and it is also not capable of saving the biosphere

from man-made pollution or of conserving the biosphere's non-replaceable natural resources ... In the age in which mankind has acquired the command over nuclear power, political unification can be accomplished only voluntarily, and, since it is evidently going to be accepted only reluctantly, it seems probable that it will be delayed until mankind has brought upon itself further disasters of a magnitude that will induce it to acquiesce at last in global political union."

20 Economists usually distinguish *public* from *private goods* based on two properties: rivalry and excludability in use or consumption. When a good is *rival*, then one person's use of the good reduces the amount available for everybody else. When a good is *exclusive*, then one user can exclude others from consuming the good at the same time.

21 This example of improving water quality of a lake is excerpted from Barbier (2019b, chapter 1).

22 See, for example, Dinerstein et al. (2017); Gerten et al. (2013); Lade et al. (2020); Mace et al. (2014); Newbold et al. (2016); Rockström et al. (2009); Running (2012); and Steffen et al. (2015).

23 For further discussion, see Barbier (2021); Clark and Harley (2020); Griggs et al. (2013); and Kates et al. (2001).

24 Kates et al. (2001), p. 641.

25 See Barbier (2021) for an overview of the evolution of economic views on natural resource scarcity, and how these views have changed in recent years due to the mounting scientific evidence on ecosystem and biodiversity loss, rising global environmental risks and the need to safeguard essential Earth system life-support processes.

26 This changing respective is reflected, most recently, in the review of the economics of biodiversity by Dasgupta (2021).

27 Sterner et al. (2019), p. 19.

28 WCED (1987), p. 43.

29 Griggs et al. (2013), p. 306.

30 See, for example, Barbier et al. (2018); Dasgupta (2021); and Sterner et al. (2019).

31 See, for example, the review of critiques of the planetary boundary framework by Biermann and Kim (2020), who note the many equity and development concerns raised about the "global limits" concept underlying this framework.

32 These trends in inequality since 1980 are from Alvaredo et al. (2017).

33 See Oxfam (2021); UN (2020); and World Bank (2020).