Chapter 1. The need for green growth strategies

The world faces twin challenges: expanding economic opportunities for a growing global population, and addressing environmental pressures that, if left unaddressed, could undermine our ability to seize these opportunities.

Green growth strategies are needed because:

- *The impacts of economic activity on environmental systems are creating imbalances which are putting economic growth and development at risk. Increased efforts to address climate change and biodiversity loss are needed to address these risks.*
- *Natural capital, encompassing natural resource stocks, land and ecosystems, is often undervalued and mismanaged. This imposes costs to the economy and human well-being.*
- *The absence of coherent strategies to deal with these issues creates uncertainty, inhibits investment and innovation, and can thus slow economic growth and development.*

This underscores a need for better ways of measuring economic progress: measures to be used alongside GDP which more fully account for the role of natural capital in economic growth, human health and well-being.

While different country situations will demand different responses, clear and predictable policy signals to investors and consumers will deliver benefits from greening growth in the form of:

- *Economic gains from eliminating inefficiency in the use and management of natural capital.*
- *New sources of growth and jobs from innovation and the emergence of green markets and activities.*

The gains from growth, while distributed unevenly around the world, have been dramatic. Over the past 150 years life expectancy increased by around thirty years in most regions, including some of the least developed parts of the world. OECD countries experienced a three-fold increase in both the amount of time and money spent on leisure since the late nineteenth century, while health status and education and labour market opportunities also grew.[1]

Many of the economic, technological, social, and institutional changes that helped to drive growth in the twentieth century are yet to be delivered to a vast number of people. There is therefore considerable potential for further growth and improvements in living standards. The question is whether this potential can be realised.

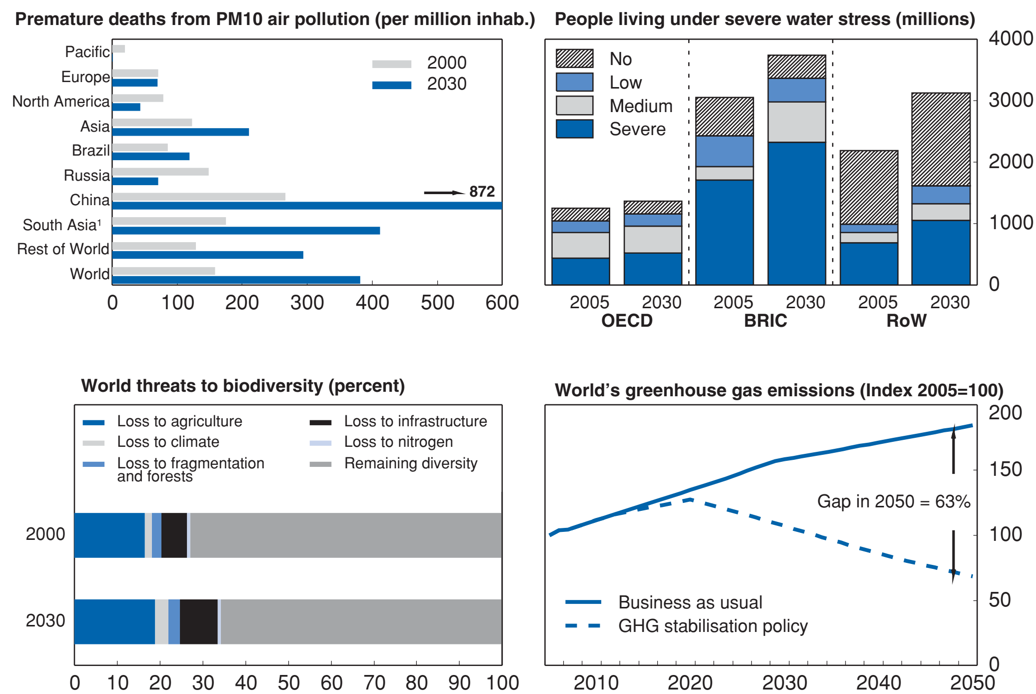
The growth dynamic that has yielded these improvements in living standards has entailed substantial costs to the physical environment on which human well-being ultimately depends. It is increasingly apparent that the way in which we use natural resources could place higher living standards and even conventionally measured growth at risk.

In the 20th century the world population grew 4 times, economic output 22 times and fossil fuel consumption 14 times (UNEP, 2011). The resilience of a wide range of environmental systems is now being tested by the requirements of a rapidly growing global population and increased levels of economic activity. This includes meeting the energy and food needs of 9 billion people in 2050. Water supplies are coming under increasing pressure and, without new policy action a further 1 billion people are expected to live in severe water-stressed areas by 2030 (Figure 1.1).

Thus the world faces twin challenges: expanding economic opportunities for a growing global population; and addressing environmental pressures that, if left unaddressed, could undermine our ability to seize these opportunities. Green growth is where these two challenges meet and about exploiting the opportunities which lie within. It is about fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services[2] on which our well-being relies. It is also about fostering investment and innovation which will underpin sustained growth and give rise to new economic opportunities.

Greening the growth path of an economy depends on policy and institutional settings, level of development, resource endowments and particular environmental pressure points. There is no "one-size-fits-all" prescription for implementing a green growth strategy. Advanced, emerging, and developing countries will face different challenges and opportunities in greening growth, as will countries with differing economic and political circumstances. There are, on the other hand, common considerations that need to be applied in all settings. And in every case, policy action requires looking across a very wide range of policies, not just explicitly "green" (*i.e.* environmental) policies.

Figure 1.1. Key environmental challenges



1. Including India.

Source: OECD (2008), *Environmental Outlook to 2030*, and OECD (2009), *The Economics of Climate Change Mitigation: Policies and Options for Global Action beyond 2012.*

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Underpinning this strategy is a framework for growth which is adapted to account for some of the shortcomings in conventional growth frameworks (Box 1.1). The starting point is that boosting growth means improving the quantity and quality of factors of production, and putting them to more productive use**.** These sources of growth remain the same whether or not we take account of environmental considerations. But the strategy explicitly recognises the dual role played by natural capital in both contributing to production of marketable goods and directly providing valuable ecosystem services to individuals and society at large.

The overarching goal of the framework is to establish incentives or institutions that increase well-being by: improving resource management and boosting productivity; enticing economic activity to take place where it is of best advantage to society over the long-term; leading to new ways of meeting these first two objectives, *i.e.* innovation. This requires drawing on mutually reinforcing aspects of environmental and economic policy. At the same time, some fundamental differences between these two policy domains need to be bridged. In markets the interaction of large numbers of producers and consumers and competition are an immensely powerful force for uncovering and creating value, driving productive efficiency, and rewarding creativity. However, when it comes to market decisions relating to the use of natural capital (and to some extent government decisions), these are influenced by payoffs which do not fully reflect the value of the entire asset base of the economy. Properly valuing natural capital is therefore an essential part of any green growth strategy. Properly valuing non-market benefits and costs, such as those related to health and life expectancy, will also be important when assessing policy options.

This framework will need to account for major social impacts of natural asset losses. Hence it will also involve achieving smooth and just adjustment in labour markets by ensuring that workers have the means to find opportunity in change. More generally, the success of a green growth strategy will rest on addressing political obstacles and distributional concerns about the costs of change.

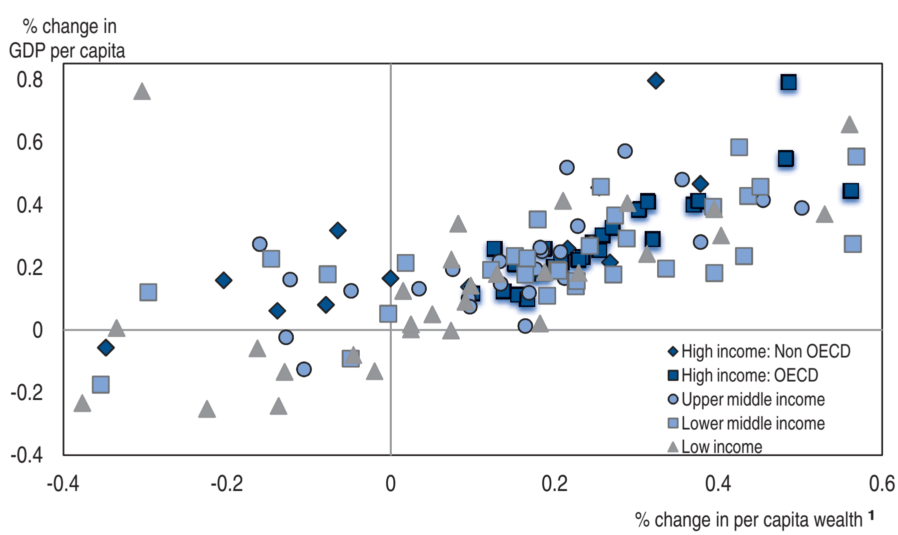
Poverty reduction objectives will also need to be addressed in adapting this framework to emerging and developing countries, with the aim of identifying synergies with green growth objectives. The greening of growth can contribute to poverty reduction by bringing more efficient infrastructure to people (*e.g.* in energy and transport) and by underpinning sustained long-term growth. It can contribute by alleviation of poor health associated with environmental pollution. And given the centrality of natural assets in providing incomes and economic opportunities to the world's poorest people, it can minimise the risks of a legacy of costly environmental degradation as development proceeds.

Reframing growth

The central feature of a green growth framework (Box 1.1) is recognition of natural capital as a factor of production and its role in enhancing well-being. Simple as this statement is, it has important implications for economic policy and the way we evaluate economic growth. A number of these can be highlighted by reflecting on shortcomings in the way that growth is usually judged. GDP remains an essential metric for understanding economic performance. However, it does not necessarily reflect changes in capital stocks, or wealth, which are key determinants of both current and future growth and welfare gains. If production is based on the liquidation of assets, then it can be increasing while wealth is declining. Indeed, in recent years, wealth in a number of economies from across the developmental spectrum has been declining even as output has increased (Figure 1.2). This could undermine future growth potential.

Figure 1.2. Rising GDP and declining wealth in some countries

1990-2005



1. The wealth estimates incorporate stocks of manufactured, human, social and natural capital. Measured natural capital in these data include agricultural land, protected areas, forests, minerals, and energy but exclude a range of assets which are difficult to measure and value including water resources.

Source: Based on data from World Bank (2010), *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium.*

Ideally, strategies for growth should take account of all types of capital: natural (*e.g.* ecosystems), human (*e.g.* education and skills), physical (*e.g.* machinery and equipment), and the intangible assets which are so crucial to human progress like ideas and innovation. Accounting for growth in this way can produce quite different results compared to growth more conventionally defined.[3]

Perceived trade-offs between economic growth and environmental protection are attenuated when new measures that better capture well-being are used alongside GDP to measure progress. For many years GDP has been taken as a reasonable indicator of such material well-being and even as a proxy for the quality of life more broadly. But there is now an important debate about whether this is still a useful approximation.[4]

Natural capital, encompassing natural resource stocks, land and ecosystems, is often undervalued and mismanaged. Even where outputs derived from its exploitation are priced in markets, the scarcity of natural resource stocks may not be fully reflected in the value of goods and services arising from their exploitation. Identifying and addressing where this is the case presents opportunities for improvements in efficiency that constitute net gains for society.

Undervaluing natural capital also has implications beyond economic inefficiency because, much like human capital, it contributes to both growth and the quality of growth with respect to human welfare. These contributions, such as the benefits of clean air to human health, are not fully taken into account when the value of natural capital and the services it provides are not fully priced in markets (Box 1.2).[5]

The need to reframe growth is becoming increasingly important due to imbalances being created by the impacts of economic activity on environmental systems. In many cases, substituting physical for natural capital is becoming increasingly costly. Limited substitution possibilities between natural and physical capital and the fact that the quality of natural capital can change abruptly also introduces the potential for bottlenecks which can choke off growth. Current commodity price strength, including food prices, is perhaps a case in point at the global level.

Furthermore, changes in natural ecosystems can occur quickly and drastically (as has happened to some fish stocks) leading to (unexpected) growth reversals. Attention to the natural asset base brings into sharp relief some of the risks to growth from mismanaging natural capital and undermining the productivity of natural systems, especially systemic risks exemplified by climate change and biodiversity loss.

The absence of coherent strategies to deal with these dynamic issues can place a further drag on growth because of uncertainty about future regulatory conditions that inhibit private sector initiatives and investments in greener growth opportunities. Such effects are likely to be especially pronounced in the current economic climate.

In addition, economic and policy decisions have long-lived consequences due to the slowly evolving nature of the physical capital stock. Indeed current patterns of growth, consumer habits, technology and infrastructure all reflect an accumulation of past innovations and also past incentives that misguide behaviour, partly reflecting inappropriate government policies. Inefficiencies referred to earlier are to some extent hard-wired into the way economies function. This “path dependency” may continue to exacerbate systemic environmental risks and economic inefficiencies even after more basic valuation and incentive problems have been addressed.

In this regard, a key element of any green growth strategy is to set incentives that will boost innovation along a growth trajectory which diverts from inefficient patterns of the past. In this context, sound economic policy, robust competition and private sector innovation remain central drivers of growth and necessary conditions for unleashing new economic opportunities. Similarly, labour market conditions and educational opportunities need to be supportive of emergent industries and structural change.

In sum, strategies for greening growth focus on a broader concept of progress than just GDP growth and aim to provide clear and stable policy signals to investors and consumers so as to:

- Achieve economic gains from eliminating sources of inefficiency in the use of natural capital.
- Encourage innovation which can deliver high rates of balanced growth.
- Foster new economic opportunities from the emergence of new green markets and activities.
- Ensure that eliminating inefficiencies, fostering innovation and seizing new growth opportunities avoid the risk of bottlenecks and systemic crises.

The next two sections explore these dimensions in more detail.

Box 1.1. A framework for thinking about green growth

Economic growth is conventionally thought of as the process through which workers, machinery and equipment, materials and new ideas and technologies contribute to producing goods and services that are increasingly valuable for individuals and society. A framework for thinking about green growth builds on this with four additional elements:

- Capturing the importance of changes in the comprehensive wealth of an economy. That means attention to all types of capital: natural (*e.g.* ecosystems), human (*e.g.* education and skills), physical (*e.g.* machinery and equipment), and the intangible assets which are so crucial to human progress like ideas and innovation. This captures some important aspects of growth including the nature of tradeoffs which arise at the frontier of production possibilities. For example, substituting environmental assets in production or consumption is not necessarily a smooth process: critical thresholds can be crossed after which assets that are renewable cease to be so (*e.g.* fisheries or soil) or assets that are non renewable are depleted to a point that substitution with other inputs or goods and services becomes impossible (*e.g.* climate or biodiversity), potentially short-circuiting growth in well-being. This introduces uncertainties about thresholds, irreversible outcomes and discontinuities that complicate policy design.
- Incorporating the dual role played by natural capital in this process. Natural capital contributes to production by providing crucial inputs, some of which are renewable and others which are not. It also influences individual and social welfare in various ways, through the effect that the environment has on health, through amenity value and through provision of ecosystem services.
- Acknowledging that investment in natural capital is an area in which public policy intervention is most needed because market incentives are weak or non-existent. This is largely because the contribution of natural capital to production is often not priced and the contribution of natural capital to individual welfare is not appropriately valued. The lack of proper valuation and market incentives or signals can affect behaviour and truncate the foresight of households and firms in ways that set the economy on trajectories that are unsustainable (or conversely that miss growth opportunities) or that are not necessarily maximising well-being. This means that in many cases, better management of natural capital (*e.g.* via proper valuation of pollution) will be consistent with higher GDP and a lower environmental impact of economic activities. A clear example is when an inefficient energy mix (involving excessive use of fossil fuels) is improved upon by eliminating harmful fossil fuel subsidies.
- Recognition that innovation is needed to attenuate tradeoffs that arise between investing in (depleting) natural capital and raising consumption or investing in other forms of capital. Indeed, once resource productivity is raised and inefficiency eliminated a "frontier" is reached along which these tradeoffs become more pronounced. Through innovation, the frontier at which tradeoffs start to bind can be pushed outwards; essentially greening growth.

Integrating these elements into policy is at the heart of green growth. In terms of well-being, policy decisions need to reflect the relative value to households of services from natural capital relative to other goods, and thus the tradeoffs that occur at the frontier. Tradeoffs need to be evaluated and re-evaluated over time to weigh the impacts of a decline in natural capital for current and future generations. These tradeoffs vary geographically depending on available technologies, the natural resource base and on households' and societal preferences; hence, policies have to be adapted to different circumstances.

From a production perspective, an assessment needs to be made of the extent to which natural capital can be depleted and replaced by other forms of capital. Different considerations will apply for different environmental assets (*e.g.* renewables and non-renewables); there is no single rule for determining whether assets should be preserved or not.

Most importantly, policies that aim to push out the frontier of economic growth need to grapple with existing incentives to innovate which are heavily biased towards improving the efficiency of currently dominant production techniques (e.g. in energy and transport) due to the tendency of innovation to build on previous innovations and existing technologies. Overcoming this kind of "path dependency", which contributes to inhibit the development of green technology (other factors are learning-by-doing effects and economies of scale) through appropriate innovation policies is therefore crucial for green growth.

Green growth dividends

Servicing higher living standards for 9 billion, increasingly urban, and increasingly wealthy, people will mean massive expansion in the markets for goods and in investment demand, especially for buildings and network infrastructure. On the current trajectory, global agricultural production will need to increase by over 50% by 2030 to feed the rising number of people with changing dietary preferences and world primary energy use is expected to rise by over 54% (OECD, 2008a).

Under "business as usual", we would certainly see increased pollution, negative impacts on human health, and constraints on the improvement of living standards due to increasing prices of essential commodities like food and energy, though not at a rate that would be sufficient to spur greener behaviour without targeted policy intervention. In reality, business is never "as usual". Markets, societies, and policies are constantly changing. The rapid economic progress of the last 150 years saw periods of major technological and social change that some regarded as major risks, but that on balance turned out to be opportunities. We can reasonably expect that such changes will occur again, and again will generate opportunities.

Fostering new markets and activities

Aware of environmental and economic challenges, governments have already implemented policies or promulgated strategies to affect a shift towards cleaner production, to promote greener business practices and green innovation. But it must be kept in mind that achieving higher living standards depends not only on doing things differently, but also on doing them better. This depends much less on where resources flow through a "green" economy but rather how efficiently those resources are used by businesses.

Greener business practices will have important economic pay-offs in terms of resource efficiency. Many of these are in the energy sector or related to energy use. The International Energy Agency (IEA), for example, estimates that the 17% (USD 46 trillion) increase in energy investment required globally between 2010 and 2050 to deliver low-carbon energy systems would yield cumulative fuel savings equal to USD 112 trillion (IEA, 2010). Energy conservation is one of the first steps that some companies have taken to reduce their GHG emissions (OECD, 2010), as it often leads to cost reductions. By using less energy, for instance, Dow Chemicals saved some USD 9 billion over 15 years (Dow, 2010) and DuPont some USD 5 billion since 1990 (DuPont, 2010).

More generally, a number of companies seek competitiveness gains through clean technology investment. Realising that environmental performance will be a major competitive factor in the future, leading companies are increasingly finding innovative ways of mainstreaming sustainability considerations into their core business. For instance, in a survey of 300 top executives from large global corporations by Ernst & Young (2009), more than 75% of respondents project their annual clean energy technology spending to rise over the next five years.

New and improved technologies in energy production, such as solar power, biomass, micro-hydro power and biofuels, linked with new approaches to electricity generation and distribution, could reduce the costs and improve the technical feasibility of energy supply in poor developing countries and allow non-oil producing countries to become more energy self sufficient. They would also bring a range of benefits, including reduced dependence on fossil fuels, reduced poverty and lower energy bills for firms and households.

Environmental action also generates new business opportunities. For instance, firms see the search for environmental performance as an opportunity to gain advantage over less technologically advanced rivals and to capture market shares. In natural resource sectors alone, commercial opportunities related to environmental sustainability could be between USD 2.1 and 6.3 trillion by 2050 - assuming that sufficient changes are made to ensure that standards of living can be sustained within the limits of available natural resources and without further harm to biodiversity, climate and other ecosystems (WBCSD, 2010).

Business opportunities have also emerged from the sustainable use of biodiversity and ecosystem services including the global market for certified organic food which exceeds USD 30 billion. Valuable new biodiversity related asset classes have also emerged; in the United States for example, wetland banking credits range in value from USD 7 000 – 850 000 per hectare and have attracted substantial entrepreneurial investment (TEEB, 2010). There is arguably greater scope for economic growth in this sector.

New business models are also emerging. Energy-saving companies, for example, provide energy-saving solutions to other firms and public buildings. These firms are paid from the savings achieved, not by an up-front payment, facilitating the uptake of costly technologies. Other emerging business models include product service systems where the value proposition shifts more to the services delivered by products rather than the products themselves, such as car sharing schemes (EPA, 2009).

Raising resource efficiency to sustain growth

Mismanagement of natural assets leads to high economic costs for society. Examples of the cost of mismanagement are perhaps most stark in the case of resources with undefined or unenforced property rights, and incentives to “free-ride”. Over-exploitation of fish stocks and groundwater are cases in which depletion frequently exceeds the natural rate of regeneration, involving significant associated costs of overuse:

- The World Bank (2007) has estimated that in China the cost of excessive use of groundwater was in the range of 0.3% of GDP, with those costs falling largely on the agricultural sector.
- In Mexico’s coastal aquifer of Hermosillo, annual withdrawals three to four times the recharge rate resulted in a 30 meter drop in water tables and saltwater intrusion at the rate of 1 kilometre per year, causing large agribusiness firms to relocate to other regions. (World Bank, 2008).
- According to the USDA (2007), declining groundwater supplies were largely responsible for the loss of an estimated 1.435 million acres of irrigated cultivated cropland in the State of Texas between 1982 and 1997.

More generally, there is growing evidence of the costs of losses in ecosystem function (OECD, 2008b; TEEB, 2010). Existing loss of biodiversity and degradation of ecosystems has already had dramatic consequences for business. Soil erosion in Europe is estimated to cost EUR 53 per hectare per annum (EEA, 2005). In Ghana, it is estimated that soil erosion will cost around 5% of total agricultural GDP over the 10 years from 2006 to 2015 (Diao and Sarpong, 2007). Similar and some even larger impacts are reported for other countries (OECD, 2009b).

Loss of ecosystem services has strong negative effects on welfare and human capital. Impairment of human health through environmental degradation reduces well-being but not necessarily GDP (or only to the extent that impaired health reduces available labour resources and productivity) (Box 1.2). The negative impacts of uncontrolled pollution are large and often felt strongest in the developing world and amongst the most vulnerable. Water pollution has been estimated to be responsible for 1.7 million deaths annually, concentrated (90%) amongst children under 5 years old. Air pollution is estimated to lead to a loss of 6.4 million years of life each year (Cohen *et al.,* 2004). On the other side of the coin, benefits can be considerable. In the United States the measurable public health benefits from the Clean Air Act in 2010 are estimated to be USD 1.3 trillion and outweigh related costs by a factor of 30 to 1 (USEPA, 2010). Annual economic losses caused by introduced agricultural pests in the United States, the United Kingdom, Australian, South Africa, India and Brazil exceed USD 100 billion (TEEB, 2010).

While clean-up after the fact is sometimes an option, preventing losses to ecosystem function is often significantly more cost-effective than remediation. In the United States and the European Union, for example, estimates of the costs of cleaning up contaminated soils and oil spills run into the billions (OECD, 2008b). And many developing countries may not have the means to pay for remediation. Moreover, while some environmental impacts may be potentially "reversible" – allowing for the restoration of environmental conditions to their prior state – there are many areas in which this is not the case – once degraded, environmental and economic values are lost permanently. Clear-cutting of primary forests and groundwater contamination are two examples.

A mixture of market and regulatory failures contribute to imperfect management of many natural assets. For instance, ecosystem services are often overlooked because they come at a limited cost or zero cost to producers even though the value of these services is in fact large, albeit difficult to measure (Box 1.2). For example, it has been estimated that the worldwide economic value of pollination services provided by insect pollinators (mainly bees), was EUR 153 billion in 2005 for the main crops that feed the world (Gallai *et al*, 2009). Accounting for the value of natural capital can help to avoid patterns of development that lock-in high costs or resource bottle-necks; such as urban development in metropolitan Mexico City which has locked-in demand for fresh water from distant lowland sources which has to be pumped at high cost.

Indeed, beyond the estimated costs, mismanagement of natural capital can lead to declining productive potential and bottlenecks that can choke off growth. Moreover, the dampening effect that inefficient resource use can have on growth is exacerbated by imperfections in markets associated with natural resources, such as transport and energy where the presence of natural monopolies, state control, or subsidies can worsen environmental damage and support inefficient economic activity. Better management of natural capital will help avoid some of the economic costs that arise from excessive demands on the environment, thereby improving growth prospects.

Box 1.2. Valuing non-market benefits

In the presence of externalities and/or incomplete property rights the economic "value" of natural capital will not be fully reflected in the prices faced by agents in the market, and as a result the natural capital base will be over-exploited. In order to make choices about the optimal extent and rate of exploitation of resources, it is necessary to attach a value to changes in environmental conditions.

In economics, relative preferences are the principal source of value. For goods and services exchanged on markets, value is reflected in people's "willingness-to-pay" – the amount of money an individual is willing to pay for a good or service - or "willingness-to-accept" – the amount of money an individual is willing to accept as a compensation for foregoing a good or service. Where environmental assets are used directly, this source of value is generally well captured by markets. However, the value of environmental assets is not only in direct use, but also indirect (or non-consumptive) use and in "non-use". These latter values are the subject of much research and debate.

Direct use includes the acquisition of materials, energy or space for human activities; *e.g.* the value of timber from a forest or energy in an oil field. Indirect use, where the physical characteristics of an asset do not change, includes recreational use of a body of water and ecosystem services from waste assimilation, carbon sequestration, fish habitat, and flood control. Use values include the actual or planned use of the good or service in question (that is, as a source of water for irrigation purposes) or possible use (that is, a spawning ground for development of fisheries in the future). Non-use values incorporate those values which people attach to a good or service even though he or she does not have (or foresee) any actual, planned or possible, use for the good or service for him or herself. These include "existence" values which arise from a sense that the good or service should not cease to be (*i.e.* perhaps because the wetland supports the existence of a threatened species).

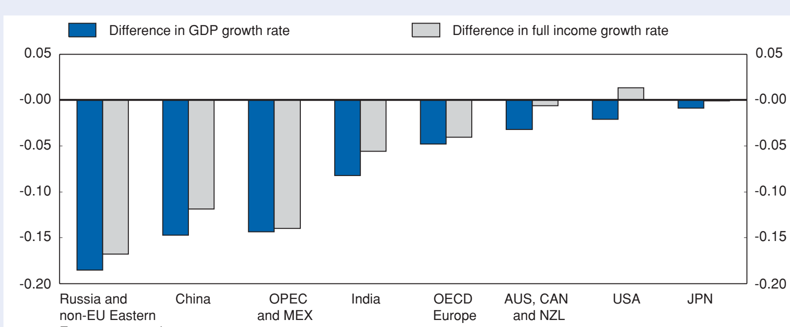
The notion of possible use is particularly important in the context of environmental irreversibilities. For example, once a wetland is converted to commercial property use, alternative possible uses are lost forever. The option is foreclosed – hence the term, option value.

For any given change in environmental conditions, direct use, indirect use and non-use values can, be aggregated into a "total economic value" (TEV) for society; albeit not without some practical difficulties and ambiguity, especially in terms of quantifying non-use and option values. Nonetheless all these sources of value remain important and are not fully counted by markets.

Non-market benefits also include improvements in health and life expectancy from pollution reduction. For example, Bollen *et al*. (2009) find that air pollution would be dramatically reduced following the reduction of GHG emissions by 50 %, resulting in substantial gains in life expectancy relative to a business-as-usual scenario. Using an index of economic progress (welfare) that combines the changes in GDP per capita and the value of living longer, Murtin and de Serres (2011) find that, on average, the estimated gains in life expectancy would halve the welfare loss associated with climate change mitigation cost (Figure 1.3). In China and India, this loss would be reduced by respectively 20% and 32%, and in developed economies such as Australia, Canada, Japan and New Zealand, by more than 80%. In the United States, large gains in life expectancy would overcome the monetary cost of climate change mitigation by a significant margin.

Figure 1.3 Health benefits from climate mitigation

Percentage points



Source: Murtin, F and A. de Serres (2011), "Welfare Analysis of Climate Change Mitigation Policies", *OECD Economics Department Working Papers* (forthcoming).

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Appropriately valuing natural resources and ecosystem services is important for growth in all countries, because increased global trade, capital flows and the movement of people mean that issues manifesting themselves locally, such as waste management, can have international roots and vice versa. For instance, the capacity for domestic policies to have adverse effects internationally was highlighted by the role of biofuel support policies which, in conjunction with a number of other factors including bad weather and export restrictions, helped contribute to a rapid rise in world food prices between 2005 and 2008, which in turn created food crises in many parts of the developing world. More recently, commodity export restrictions have contributed to driving up food prices. Similarly, mismanagement of waterways can affect water quality and supply in other countries.

The relative importance of efficient use of natural capital is, however, much higher in some countries than others. In low-income countries, natural capital constitutes 25% of total per capita wealth, as compared to 12% in middle-income countries and 2% in OECD countries (World Bank, 2010b). Agriculture, which is dependent on fertile soil and availability of water, is Africa's largest economic sector generating over USD 100 billion annually and representing 15 percent of the continent's total GDP (McKinsey, 2010).

In resource-dependent countries, leveraging natural resources is also an important contributor to GDP. However, long-term growth prospects rest on reinvestment of some portion of the rents from natural asset depletion into physical capital such as infrastructure or into human capital through education or health care – essentially so that resource-led output growth is not undermining the overall asset base of the economy.

In areas where property rights can be attributed and enforced, activities that maintain the natural capital stock can be just as commercially attractive as those that damage the environment without the beneficiaries paying for the harm. In many places, however, the development of commercial activities to promote the preservation of forests and natural habitats may not be sufficiently attractive without properly pricing the negative externalities caused by logging and farming. Moreover, weak institutional arrangements and ineffective governance of natural resources often prevents maintenance of capital values.

Where property rights are enforced, markets have a capacity to react spontaneously to the gradual build-up of economic and environmental tensions that reduce resource productivity, such as resource scarcity and pollutants. But this will only happen where these pressures are reflected in prices or consumer demand and can be foreseen. Therefore the "appropriate response to substantial market failure is not to abandon markets but to act directly to fix it through taxes, other forms of price correction, or regulation" (Stern, 2009).

Translating better management of natural capital into growth will require economy-wide strategies encompassing not just green policies, as conventionally recognised, but also growth policies. The business environment needs to be conducive to adjustment and growth. Businesses are well aware of looming environmental challenges. Uncertainty about how governments will deal with these challenges will dampen investment both in cleaner production and investment more generally. There is also a risk that if policy proceeds in an ad hoc way, picking one or two problems to address through one or two policy responses, then it will be ineffective in addressing some of the major environmental risks.

Strategies are required to prevent resource efficiency improvements from leading to greater resource consumption, more pollution and worse overall environmental outcomes. For instance, this could occur due to so-called "rebound effects" where improvements in resource efficiency reduce the relative price of resources and people use more of them (*e.g.* more efficient heating resulting in warmer homes rather than lower energy use).

Systemic risks and imbalances

For a large number of countries, especially in the OECD, natural capital does not at a first glance appear to be a large part of the overall capital base of the economy and therefore is not a major contributor to growth. But this can be misleading because natural systems are complex and interdependent. Like institutions and networks, the value of natural systems is greater than the sum of the parts and their contribution to growth is essential.

Life adapts to varying amounts of water and nutrients in natural systems, and to the varying rates at which these essential materials are cycled. Leveraging one part of the system – speeding up the rate of natural flows or cycles – affects other parts of the system and imbalances can emerge. This raises risks to future growth as economic activity depletes and erodes natural assets at rates in excess of regeneration, threatening to undermine the regenerative balance or productive capacity of environmental systems. While an analogy with economic systems is necessarily incomplete, the crisis of 2007 and 2008 did illustrate that when systemic imbalances emerge, whether through excessive leverage and risk taking or some other means, they may be large and unexpected and they may not resolve themselves in an orderly fashion.

In natural systems, responses to stressors such as pollutants are non-linear. Fertiliser use, for example, can increase nitrogen levels in waterways to a point at which abrupt, non-linear changes occur in structure and function of ecosystems, *e.g.* excessive algae in surface waters and/or the loss of biodiversity including fish stocks. Bio-magnification of hazardous substances in the food chain can lead to concentrations in top predators (*e.g.* tuna) that are thousands of times those in the surrounding environment (*e.g.* the ocean), with consequent risks to human health of consumers.

Thresholds might manifest on a much larger scale. In the case of climate change, there may be a "tipping point" at which the thermohaline circulation of the oceans is disrupted, with significant negative implications for climate regulation in the northern hemisphere and the global economy. Other risks of tipping points could arise from deglaciation and ocean acidification. That said, it is important to recognise that there is not always broad-based consensus on where exactly critical limits lie from a scientific viewpoint. Rockström (2009) proposes a number of planetary boundaries based on the lower bound of estimated critical limits, and concludes that these boundaries have been crossed on climate change, biodiversity and the nitrogen cycle (Table 1.1).

Table 1.1. Planetary boundaries

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	***i)* Atmospheric carbon dioxide concentration (parts per million by volume)**	**350**	**387**	**280**
	***ii)* Change in radiative forcing (watts per metre squared)**	**1**	**1.5**	**0**
Rate of biodiversity loss	**Extinction rate (number of species per million species per year)**	**10**	**>100**	**0.1–1**
Nitrogen cycle (part of a boundary with the phosphorus cycle)	**Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)**	**35**	**121**	**0**
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5–9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4 000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11. 7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	To be determined		
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof	To be determined		

Note: Boundaries for processes in bold have been crossed. A detailed description of the boundaries and the analysis behind them can be found in: www.stockholmresilience.org/download/18.1fe8f33123572b59ab800012568/pb_longversion_170909.pdf

Source: Rockström, J. et al. (2009), "A safe operating space for humanity", *Nature*, Vol. 461, 24 September 2009, pp. 472-475. Reprinted by permission from Macmillan Publishers Ltd, copyright 2009.

The uncertainty about when non-linear changes arise, the costs associated with them, and the irreversibility of such changes fundamentally alters the usual calculus of trade-offs.

There are two related aspects of greenhouse gas emissions that lead to irreversibility. On the one hand, the build up of greenhouse gases in the atmosphere is in large part irreversible due to the long lifetime of many greenhouse gases in the atmosphere. Once emitted, they can contribute to the stock of pollutants for over a century. On the other hand, some of the environmental damages that arise from a given stock of pollutants can be irreversible. While uncertainty exists about the precise timing and magnitude of damages, once they become fully known it will be largely impossible to avoid them.

Irreversibility or inertia also exists in the capacity of markets to adapt to a changing climate. Many important infrastructural assets which are carbon intensive are also very long lived. This raises the risk of being locked into growth with high environmental impact from which it will be very costly to change.

Business-as-usual growth in global greenhouse gas (GHG) emissions implies an increase of about 70% between now and 2050 with continued growth thereafter (OECD, 2009a). While the Cancun Agreements laid down a shared long-term vision which recognises a need to keep increases in global average temperature below 2° C and provided the foundations for meaningful long-term global action, uncertainty about the level of ambition and domestic political constraints remains a challenge. To meet this target, carbon productivity globally needs to increase ten-fold. To achieve that while maintaining standards of living implies large-scale innovation and structural economic change.

The costs of breaching the 2° C threshold may be large. This includes substantial destruction of physical capital through more intense and frequent storms, droughts and floods, for example from a rise in sea level and storm surge in heavily populated coastal areas (Nicholls *et al.*, 2008). The estimated costs of these impacts vary widely by location and region, but may be as much as the equivalent of 14.4% of per capita consumption when all market and non-market impacts are taken into account (Stern, 2006).

Biodiversity loss is also an instructive case of extreme uncertainty or indeed ignorance. Without more ambitious policy, a considerable number of today's known animal and plant species are likely to become extinct. Biodiversity loss is expected to continue, with particularly significant losses expected in Asia and Africa, and the loss of species as yet un-catalogued is, by definition, unknowable.

In the longer term, continued loss of biodiversity is likely to limit the Earth's capacity to provide the ecosystem services such as carbon sequestration, water purification, protection from extreme meteorological events, and the provision of common genetic material that support economic growth and human well-being.

The management of systemic risks will be viewed differently depending on whether the focus is on a single industry, the stewardship of an economy at large, or even the global economy. From an economy-wide perspective, there are clear downsides to acting too slowly. Priorities will vary depending on local environmental and developmental context. In low income countries, local health and environmental problems may take precedence over other issues such as the amenity value of local biodiversity or perhaps even damage from climate change.

Tensions exist between when to act and where to act and there is doubtless a trade-off between taking on adjustment today and taking it on tomorrow: act too slowly and the costs of inaction are high; too fast and the costs of action are high. There may be uncertainty about the optimal means and timing of interventions, since many of the investments undertaken are "sunk", embodied in long-live capital stocks and infrastructure. Taking rapid action in the short term to shift to low-carbon economies implies a degree of irreversibility and opportunity cost, to the extent that there is, at least hypothetically, some value in waiting for further information about the severity of the impacts or availability of new abatement technologies. These considerations, however, must be weighed against the potential for extreme non-linear, possibly catastrophic, changes to natural and human systems. Policies can influence the trade-offs (Jamet and Corfee-Morlot, 2009). With respect to climate change, adaptation will limit damages, and the risk of irreversible, catastrophic damage justifies action through the use of cost-effective policies even if the marginal costs exceed the margin benefits of action.

Notes

1. Data from Maddison (2011), United Nations (1999), Kling and Shulz (2009) and Fogel (2004).
2. For the purpose of this report, "environmental services" are defined as all services or functions provided by natural assets, and which contribute directly and indirectly to human well-being. This includes the provision of water, energy, raw materials, land and ecosystem inputs to produce goods and services, the regulatory capacity of the environment, and its roles in supporting life and biodiversity, and in providing amenities and cultural benefits. Environmental services are also referred to as "ecosystem services".
3. For instance, Jones and Klenow (2010) show that adding health, leisure and inequality to the definition of well-being can lead to significant differences in the ranking of world countries and in growth rates of this more comprehensive measure than GDP.
4. See for instance Stiglitz, Sen and Fitoussi (2009).
5. Furthermore, environmental improvement which raises health status can increase labour force productivity and lift the rate of growth.

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