Chapter 2
Sustainable Development and Climate Change

2.1 Defining Sustainable Development

Given my desire to situate the climate change problem within a sustainable development context, this chapter begins by establishing a broad definition of sustainable development. The chapter continues with an elucidation of the ecological and economic limits to growth and the rationale behind the steady-state economy as a means of achieving the sustainable development goal. What will emerge is not only the backdrop for the remainder of the book, but the basis for the policies and reform measures to be outlined in Chap. 3, including those closely associated with climate change mitigation.

The concept of sustainable development first gained notoriety following the release of the Brundtland Report by the World Commission on Environment and Development in the 1980s (WCED 1987).[1] However, it was not until the 1992 Earth Summit in Rio de Janeiro and the widespread promotion of the United Nations' Agenda 21 that sustainable development became firmly established as a desirable policy objective. Despite its general acceptance, sustainable development continues to mean different things to different people. There are multiple reasons for this. Firstly, the concept of sustainable development is used in many contexts, for different purposes, and by people from varying cultural backgrounds and disciplinary schools of thought. Secondly, the sustainable development concept has rapidly evolved over a relatively short period of time. Finally, debates about sustainable development have been influenced by a wide range of underlying views on the relationship between human beings, economic systems, and the natural environment of which they are a part. Consequently, there are various opinions as to how sustainable development should be measured and what is required to move toward the sustainable development goal.

Ecological economists believe that any definition of sustainable development must be premised on a concrete representation of the economic process.

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Unfortunately, most interpretations of sustainable development reflect the pre-occupation that many observers have with an atomistic-mechanistic world-view and their subsequent failure to recognise the coevolutionary nature of economic, social, and ecological change (Norgaard 1988; Mulder and van den Bergh 2001).

2.1.1 The Coevolutionary World-View

Coevolution is a term used to describe the evolving relationships and feedback responses typically associated with two or more interdependent systems. Coevolution takes place when at least one feedback loop is altered by within-system activity that, in turn, initiates an ongoing and reciprocal process of change (Norgaard 1985, 1988, 1994). A coevolutionary world-view offers a more realistic interpretation of the many critical relationships that bind together the various systems that make up the global system, including the Earth's climate system.

There are a number of basic features of the coevolutionary world-view worthy of elaboration. Firstly, the coevolutionary paradigm begins from the premise that the Earth is a system comprised of closely interacting and interdependent subsystems. Secondly, it recognises that the Earth and its constituent systems are dissipative structures in the sense that the Earth exists as an open system with respect to energy (a solar gradient), whereas the Earth's constituent subsystems exist as open systems with respect to energy, matter, and information.[2] Thirdly, because each system is connected to and dependent in some way on all other systems, everything evolves together over time. Fourthly, and given its complexity, the global system is far richer than the sum of its parts. Fifthly, coevolution is characterised by path-dependency—a proclivity of systems to be inextricably related to their past characteristics and to thus display a strong sense of structural inertia (David 1985; Arthur 1989). Sixthly, and despite the previous point, the coevolutionary world-view regards disequilibria and change as the rule rather than the exception. Finally, the coevolutionary world-view is based on a principle of system embeddedness that is sometimes referred to as the *logos* of nature. Metaphorically, logos is a term used to embrace the natural order of the universe. By acknowledging the logos of the global system, the coevolutionary world-view recognises, firstly, that the world is characterised by self-organisation (Capra 1982). Secondly, it recognises that systems exist at varying levels of complexity and are characteristically stratified and multi-levelled (Laszlo 1972). The logos of the global system and the embedded relationship between the three major spheres of influence—the economy, society, and ecosphere—are illustrated by way of Fig. 2.1.

In Fig. 2.1, the three major spheres of influence represent different systems at varying degrees of complexity. Each system can be considered a *holon* insofar as all systems exhibit the independent and autonomous properties of wholes and the dependent properties of parts.[3] In consequence, each sphere consists of smaller parts whilst simultaneously acting as the part of a larger whole (i.e., the economy constitutes a component of society whilst society constitutes a component of the

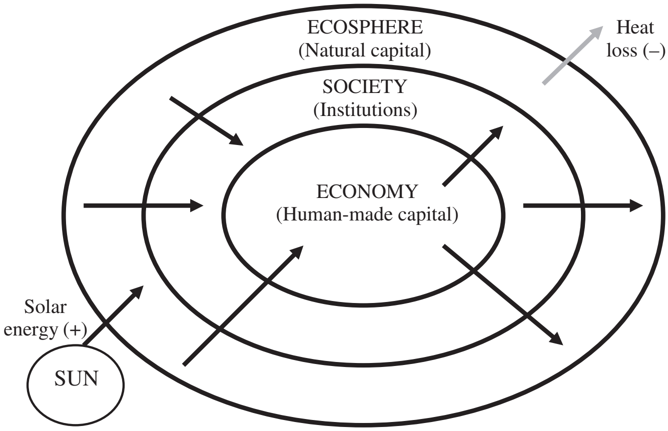


Fig. 2.1 A coevolutionary depiction of the interdependent relationship between the economy, society, and the ecosphere

ecosphere). In this sense, Fig. 2.1 represents society as the interface between the economy and the larger ecosphere, thus highlighting the crucial role played by institutions and social capital in promoting stable human behaviour in the face of indeterminacy, novelty, and surprise (Hodgson 1988; Faber et al. 1992).

2.1.2 The Linear Throughput Representation of the Economic Process

In order to convey the coevolutionary world-view in greater detail, consider the linear throughput representation of the economic process in Fig. 2.2. In keeping with the coevolutionary paradigm, the linear throughput model: (i) depicts the economy as a subsystem of society that, in turn, is depicted as a subsystem of the ecosphere; (ii) recognises the ongoing exchange of matter, energy, and information between the three major spheres of influence and all constituent subsystems; and (iii) acknowledges the evolving relationships and feedback responses typically associated with coevolutionary change.

Although the linear model comprises a multitude of individual elements, each element can be classified into five elemental categories. The first elemental category, *natural capital*, consists of mineral ores, fossil fuels, soil, forests, fisheries, rivers, oceans, lakes, wetlands, ecosystems, and the Earth's climate system. It is because natural capital is the only source of low-entropy resources, the ultimate waste-assimilating sink, and the sole provider of life-support services that natural capital constitutes the original source of all economic activity.

Human-made capital is the second elemental category and, in the Fisherian tradition (Fisher 1906), includes all human-made goods (i.e., producer goods

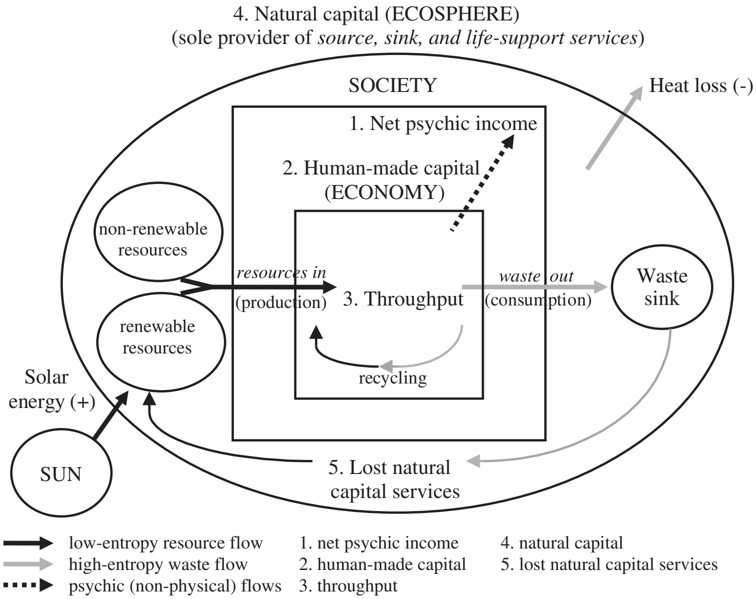


Fig. 2.2 A linear throughput depiction of the economic process

and consumer goods) plus human labour. Human-made capital is accumulated to increase human well-being beyond the level provided by natural capital alone.[4]

The third elemental category is the entropic *throughput* of matter-energy—the input into the economy of low-entropy resources and the subsequent output of high-entropy wastes. The throughput is the physical intermediary connecting natural capital and human-made capital.[5]

The fourth important elemental category is a psychic rather than physical category. Contrary to some opinions, human well-being depends not on the rate of production and consumption, but on what Fisher (1906) described as 'psychic income'.[6] Psychic income is more commonly referred to by economists as 'utility'. As the true benefit of all economic activity, psychic income has four main sources. The first source is the utility that emanates from the consumption and use of human-made capital. The second source of psychic income is derived from being engaged in production activities (e.g., the enjoyment and self-worth obtained from paid employment). A third source of psychic income comes from non-economic pursuits, such as time spent with family and friends, volunteer work, and leisure activities. The final source of psychic income is received from the natural environment in terms of its direct benefits, aesthetic qualities, and existence values. Of course, this final source of psychic income is not directly generated by economic activities. If anything, economic activities destroy rather than enhance these values. It is therefore better that these values be taken as a given and their subsequent destruction be counted as an opportunity cost of the economic process.

This last point reminds us that not all economic activity enhances the psychic enjoyment of life. Consumption of some portion of human-made capital can reduce psychic income if consumers make bad spending choices or if needs and wants have been inappropriately ranked. In addition, while benefits can be enjoyed by individuals at work, production activities are often unpleasant. Unpleasant things that lower one's psychic enjoyment of life represent the 'psychic outgo' of economic activity. It is by subtracting psychic outgo from psychic income that one arrives at the fourth elemental category—*net psychic income*.

In many ways, net psychic income constitutes the 'uncancelled benefit' of economic activity (Daly 1979). Why is this so? Imagine tracing the economic process from natural capital to its final psychic conclusion. Every intermediate transaction involves the cancelling out of a receipt and expenditure of the same magnitude (i.e., the seller receives what the buyer pays). Once a physical good is in the possession of the final consumer, there is no further exchange and no further cancelling out of transactions. Apart from the good itself, what remains at the end of the process is the uncancelled exchange value of the psychic income that the ultimate consumer expects to gain from consuming the good plus any psychic disbenefits and other costs associated with the good's production. Note, therefore, that if the costs are subtracted from the good's final selling price, the difference constitutes the 'use value' added to low-entropy matter-energy during the production process. Presumably the difference is positive otherwise the economic process has been a pointless exercise.

The fifth and final elemental category is the cost of *lost natural capital services* and arises because, in obtaining the throughput to produce and maintain human-made capital, natural capital must be manipulated and exploited both as a source of low-entropy and as a high-entropy waste-absorbing sink. Perrings (1986) has shown that no matter how benignly human beings conduct their exploitative activities, the resultant disarrangement of matter-energy and the inevitable coevolutionary feedback responses have deleterious impacts on the natural environment. Consequently, human beings must accept some loss of the ecosphere's source, sink, and life-support services as the low-entropy resources provided by natural capital are transformed into physical goods and then returned to the ecosphere, once the goods have been consumed, as high-entropy wastes.

In a similar way to net psychic income, lost natural capital services constitute the 'uncancelled cost' of economic activity (Daly 1979; Lawn and Sanders 1999). Why? Imagine, this time, tracing the economic process from its psychic conclusion back to natural capital. Once again, all transactions cancel out. What remains on this occasion is the opportunity cost of resource use or, more definitively, the uncancelled exchange value of any natural capital services sacrificed in obtaining the throughput of matter-energy required to fuel the economic process.[7]

In sum, the linear throughput model illustrates the following. Natural capital provides the throughput of matter-energy that is needed to produce and maintain the stock of human-made capital. Human-made capital is needed to enjoy a level of net psychic income greater than what would be experienced if the economic process did not take place. Finally, in manipulating and exploiting natural capital to obtain the throughput of matter-energy, the three critical services provided by natural capital are, to some degree, unavoidably sacrificed.

2.1.3 Ecological Constraints, Human Needs, and Intragenerational Equity

The above discussion places us in an ideal position to reflect on three aspects central to defining and achieving sustainable development. The first aspect is the importance of ecological factors and the need to adhere to ecological constraints to achieve ecological sustainability. The second and third aspects concern the hierarchy of human needs and the principle of intragenerational equity. As we shall see, both have a powerful influence on the 'development' side of the sustainable development coin.

2.1.3.1 Ecological Factors and Constraints

It was mentioned above that the throughput of matter-energy is the physical intermediary connecting natural capital and human-made capital. It was also pointed out that natural capital constitutes the original source of all economic activity. Given the obvious role that natural capital plays in achieving ecological sustainability, one must ask the following questions:

- How much natural capital is required to ensure the ecological sustainability objective is not recklessly put at risk?
- Should natural capital maintenance be a necessary sustainability tenet, what rules-of-thumb must humankind adhere to in order to prevent the decline in the quantity and quality of natural capital stocks?

I will endeavour to answer the first question by beginning with a consideration of production possibilities. Ever since Hicks (1946) defined income as the maximum amount that can be consumed in the present without compromising the ability to consume the same amount in the future, it has been widely recognised that sustaining the production and consumption of a particular quantity of physical output requires the maintenance of income-generating capital. However, a hot debate has longed raged over what form the capital should take. Whilst some observers believe that natural capital and human-made capital must be individually maintained (strong sustainability), others believe it is sufficient to maintain an appropriately combined stock of both forms of capital (weak sustainability). In the end, the most appropriate action depends on whether human-made capital and the technology embodied in it can adequately substitute for the low-entropy matter-energy and other crucial services provided by natural capital. If it cannot, it is necessary to follow the approach advocated by the proponents of strong sustainability—namely, 'keep natural capital intact'.

It is undeniably true that advances in the technology embodied in human-made capital can for some time reduce the incoming resource flow required to produce a given physical quantity of goods. However, for three related reasons, this does not amount to substitution. Firstly, technological progress only reduces the high-entropy waste generated in the transformation of natural capital to human-made capital. It does not allow human-made capital to "take the place of" natural capital. Secondly, because of the first and second laws of thermodynamics, there is a limit to how much production waste can be reduced by technological progress. This is because 100 per cent technical efficiency is physically impossible; there can never be 100 per cent recycling of matter; and energy cannot be recycled at all.[8] Thirdly, a value of one or more for the elasticity of substitution between human-made and natural capital is necessary to demonstrate the long-run substitutability of the former for the latter. Disconcertingly, recent studies have shown that the value of the elasticity of substitution derived from a production function obeying the first and second laws of thermodynamics is always less than one (Lawn 2007).

Thus, all things considered, human-made capital and natural capital are complements not substitutes. Consequently, the production of a given quantity of physical goods requires a minimum, irreducible rate of resource use and, therefore, a minimum quantity of resource-providing natural capital (Meadows et al. 1972; Pearce et al. 1989; Folke et al. 1994; Daly 1996; Lawn 2007). It is for this reason that ecological economists believe the strong sustainability approach to capital maintenance is necessary to sustain the economic process.

However, before a satisfactory answer can be given to the first of the above questions, it is necessary to consider the minimum amount of natural capital required to ensure ecological sustainability. It is at this point that we must go beyond production possibilities and turn our attention to the life-support function of natural capital.

The ability of natural capital to provide life-support services exists because the ecosphere, as a far-from-thermodynamic-equilibrium system characterised by a range of biogeochemical clocks and essential feedback mechanisms, has developed the self-organisational capacity to regulate the conditions necessary for life. There has, unfortunately, been a growing tendency for human beings to take the conditions for life for granted—a consequence of technological optimism and a growing detachment most people have from the vagaries of the natural world. In particular, two falsely held beliefs have emerged. The first is a widely held conviction that the Earth's current uniqueness for life was preordained. This is patently untrue, since, as Blum (1962) has explained, had any one of an infinite number of past events occurred only marginally differently, the evolution of living organisms on Earth might never have eventuated.

Secondly, it is widely believed that organic evolution is confined to living organisms responding to exogenously determined environmental factors. However, it is now transparently clear that 'fitness' is a byproduct of the coevolutionary relationship that exists between the ecosphere and its constituent species. Indeed, the ecosphere is as uniquely suited to existing species as are the latter to the ambient characteristics of the ecosphere. Hence, according to Blum (1962, p. 61), it is "impossible to treat the environment as a separable aspect of the problem of organic evolution; it becomes an integral part thereof." Clearly, just as current environmental conditions were not preordained, the environmental conditions of the future will always be strongly influenced by the evolution of constituent species and, in particular, the actions of recalcitrant specimens.

An awareness of the above brings to bear a critical point. Although human intervention can never ensure the Earth remains eternally fit for human habitability, humankind does have the capacity to bring about a premature change in its prevailing comfortable state. Many people believe that anthropogenic global warming is just one of many signs of a radical change in the planet's comfortable conditions. Nonetheless, there are some observers who argue that these events, if occurring, are of no great concern since they are little more than symptoms of a benign coevolutionary adjustment brought on by the eccentricities of humankind. That is, any malady caused by human activity will be short-lived because whatever may threaten the human habitability of the planet will induce the evolution of a new and more comfortable environmental state. For such observers, humankind is potentially immune from the consequences of its own actions.

Nothing, however, could be further from the truth. The quasi-immortality of the ecosphere prevails because of the informal association that exists between the global system and its constituent species. But quasi-immortality in no way extends to any particular species. Indeed, historical evidence indicates a tendency for the global system to correct ecological imbalances in ways that are invariably unpleasant for incumbent species. Hence, while the Earth has revealed itself to be immune to the emergence of wayward species (e.g., oxygen-bearers in the past), individual species—including human beings—are in no way immune from the consequences of their own collective folly. We can therefore conclude that the quantity of natural capital needed to ensure ecological sustainability is likely to greatly exceed the quantity needed for production purposes alone. Of course, this still leaves the first of the above questions unanswered.

Deeper insight into the minimum required natural capital can be gained by considering what bestows natural capital with the unique capacity to support life. Is it the quantity of natural capital or is it some particular aspect of it? Lovelock leaves us in no doubt by emphasising that a minimum number and complexity of species are required to establish, develop, and maintain the Earth's biogeochemical clocks and essential feedback mechanisms. To wit:

> The presence of a sufficient array of living organisms on a planet is needed for the regulation of the environment. Where there is incomplete occupation, the ineluctable forces of physical or chemical evolution would soon render it uninhabitable (Lovelock 1988, p. 63).

It is, therefore, a combination of the interactions and interdependencies between the various species, the diversity of species, and the complexity of ecological systems—in all, the *biodiversity* present in natural capital—that underpins its life-supporting function. This doesn't mean that the quantity of natural capital is unimportant. The quantity is vital if only because the biodiversity needed to maintain the Earth's habitable status requires a full, not partial, occupation by living organisms. But the quantity of natural capital, itself, should never be equated with biodiversity.

If the sheer magnitude of natural capital is an inadequate indication of the effectiveness with which it can support life, what is the minimum level of biodiversity needed to maintain the ecosphere's life-support function? Unfortunately, this is not known, although there is general agreement that some semblance of a biodiversity threshold does exist. What we do know is that in the same way biodiversity begets greater biodiversity, so do diminutions in biodiversity beget further diminutions (Norton 1986). It is also known that the present rate of species extinction is far exceeding the rate of speciation—indeed, so much that biodiversity has, on any relevant time scale, become a non-renewable resource (Daily and Ehrlich 1992).

Given that a rise in the global rate of extinction increases the vulnerability of human beings to its own extinction, a sensible risk-averse strategy for humankind to adopt is a rigid adherence to a biodiversity 'line in the sand'.[9] Ehrlich (1993) provides a hint as to where this line should be drawn by pointing out that humankind knows enough about the value of biodiversity to operate on the principle that "all reductions in biodiversity should be avoided because of the potential threats to ecosystem functioning and its life-support role". As a corollary of Ehrlich's dictum, a line should be drawn at the currently existing level of biodiversity, especially given the magnitude of the loss of biodiversity over the past century. Conscious efforts should also be made to preserve remnant vegetation and important ecosystems.

We are now in a position to answer the second of the above questions—that is, what sustainability precepts should humankind follow to prevent the decline in the quantity and quality of natural capital stocks? There are essentially four fundamental rules-of-thumb or precepts requiring adherence:

1. The rate of renewable resource extraction should not exceed the regeneration rate of renewable resource stocks.
2. The depletion of non-renewable resources should be offset by the cultivation of renewable resource substitutes.
3. The rate of high-entropy waste generation should not exceed the ecosphere's waste-assimilative capacity. This third precept is of great relevance to the phenomenon of anthropocentric global warming.
4. Native vegetation and critical ecosystems should be preserved, rehabilitated, and/or restored. In addition, future exploitation of natural capital should be confined to areas already strongly modified by previous human activities.

2.1.3.2 Human Needs and the Principle of Intragenerational Equity

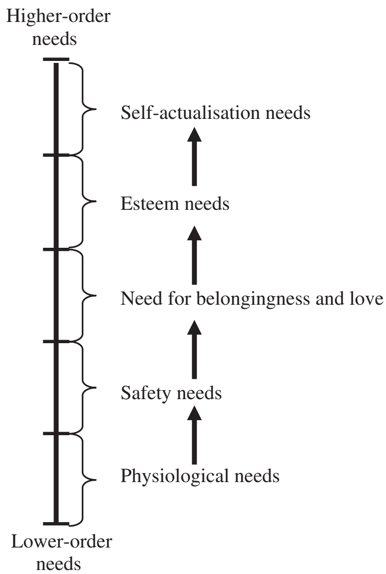
It has already been explained that human well-being depends critically on the psychic enjoyment of life. Despite having a good sense of what contributes directly to net psychic income, it is worth contemplating the extent to which each contributing factor is likely to advance the human condition. Although this will differ from culture to culture, a greater understanding can be gained by considering Maslow's (1954) hierarchy of human needs (Fig. 2.3).

Maslow's hierarchical framework is underpinned by a rigorous psychological theory of human motivation in which human needs are classified into five distinct categories. Beginning with lower-order needs and ascending through to higher-order needs, the five categories of human needs are:

- Basic *physiological needs*—i.e., one's basic need for food, clothing, and shelter.
- *Safety needs*—i.e., the need for physical and mental security; freedom from fear, anxiety, and chaos; and the need for stability, dependency, and protection.
- The need for *belongingness and love*—i.e., the need for affectionate relationships with people in general; the hunger for contact and intimacy; the desire for a sense of place in one's family or peer group; and the need to avoid the pangs of loneliness, ostracism, rejection, and rootlessness.
- The need for *esteem*—i.e., the desire for strength, achievement, adequacy, mastery, and competence; the need for independence and freedom; and the desire for recognition, attention, importance, dignity, and appreciation.
- *Self-actualisation needs*—i.e., the desire for self-fulfilment or, equivalently, the desire to become fully actualised in what one is capable of becoming.

By organising human needs into a hierarchy of relative prepotency, Maslow's needs hierarchy represents the human personality as an integrated whole in which every part, level, and dimension is interdependent. The framework itself indicates that human endeavour is initially devoted to the satisfaction of basic physiological needs. Once satisfied, the greater part of one's endeavours shifts to the next tier of

Fig. 2.3 Maslow's needs hierarchy (Maslow 1954)



human needs. The process ultimately culminates with the need for self-actualisation, which, according to Maslow, is the most creative and rewarding phase of the human development process. Overall, Maslow's needs hierarchy highlights that a healthy human existence requires the satisfaction of emerging higher-order needs as well as basic physiological needs. Achievement of this desirable human state has previously been described as a healthy 'existential balance' (Weisskopf 1973).

It is important to realise that the economic process need not always operate in a manner consistent with the adequate satisfaction of emerging higher-order needs. There are two reasons why. Firstly, physiological need satisfaction (such as being well fed) has no enduring qualities. Hence, the satisfaction of lower-order needs requires frequent engagement in physiological need-satisfying activities (such as eating regularly). Secondly, if higher-order needs are being inadequately satisfied, it is still possible to obtain a sense of equilibrium—albeit an unhealthy, unbalanced one—by engaging in more physiological need-satisfying pursuits (such as increased consumption). Because physiological need satisfaction quickly evaporates, the desire for more consumption requires greater production, which in turn reduces the time available to satisfy their higher-order needs. The increased lack of psychological need satisfaction further intensifies the desire for higher rates of production and consumption. Eventually, an illusionary need for continued growth becomes self-perpetuating. In a coevolutionary world characterised by path-dependency, a growth addiction can arise even though it may be contrary to the betterment of the human condition. This growth addiction is commonly referred to as 'consumerism' or the 'treadmill of production' (Schnaiberg 1980).

What does this all mean in terms of the human developmental process? To begin with, it is patently obvious that increasing the supply of intermediate means along one level of need at the expense of needs on a different level disturbs the balance of human existence (Kenny 1999). Thus, once lower-order needs have been satisfied, it follows that attempts to expand the stock of human-made capital should largely cease once it begins to impede the satisfaction of higher-order needs. Moreover, it suggests that human development demands, at the very least, a widespread concern for posterity and an ongoing need to address intragenerational inequities and injustices. Clearly, this means upholding various universal rights and privileges, one of which must be the eradication of absolute poverty. Not only does poverty alleviation ensure the satisfaction of basic physiological needs, it provides the foundation upon which higher-order needs can be subsequently satisfied.

One of the best ways to uphold the principle of intragenerational equity is to ensure access to paid employment for anyone who seeks it. Although unemployed people in high-GDP countries are rarely deprived of basic lower-order needs, they are often deprived of their safety and esteem needs. In almost all instances, they are starved of the means required to satisfy their self-actualisation needs. This invariably leads to alienation, disillusionment, depression, and the increased likelihood of committing a serious crime (Fryer 1995; Feather 1997; Sen 1997; Theodossiou 1998; Harvey 2000; Watts and Mitchell 2000; Biddle 2001; Layard 2005). Unemployment also results in the loss of human capital skills and the depreciation of a nation's productive capacity (Mitchell and Muysken 2008). There is little doubt, therefore, that the negative side-effects of unemployment constitute a welfare-reducing cost that impacts on society generally, not just on the unemployed. For this reason, the cost of unemployment should be included in aggregate measures of economic welfare. Moreover, unemployment should be given more consideration by policy-makers than it is at present. Indeed, since it can be argued that access to paid employment is a basic human right (Burgess and Mitchell 1998; Lawn 2009), full employment should be viewed as an obligatory objective of any nation aiming to achieve sustainable development.

Having said this, there is the potential for the full employment objective to conflict with the goal of ecological sustainability (Lawn 2009). Under the current institutional arrangements in virtually every country, there is a well-established link between real GDP and employment levels. This link compels governments to expand the economy to prevent the rise in unemployment.[10] Because, as we shall see, the continued expansion of the economy is both undesirable and ecologically unsustainable, it will become increasingly important to discover ways to sever the GDP-employment nexus so that full employment can be achieved without the perceived need for continued growth.[11]

2.1.4 A Broad Definition of Sustainable Development

Taking account of the aforementioned, the following will serve as our broad definition of sustainable development: "A nation is achieving sustainable development if it undergoes a coevolutionary process that improves the total quality of life of every citizen, both now and into the future, while ensuring its rate of resource use does not exceed the regenerative and waste-assimilative capacities of the natural environment. It is also a nation that ensures the survival of the biosphere and all its evolving processes while recognising, to some extent, the intrinsic value of sentient non-human beings."

Despite this definition being open to individual interpretation, its strength lies in its emphasis on: (i) the quality of human life, not simply the material standard of living; (ii) the welfare of *all* people, present and future; and (iii) the need to preserve the ecosphere upon which all welfare-related activities depend—a critical factor given the complementary relationship between human-made capital and natural capital. The emphasis on these three aspects suggests that sustainable development can be defined more narrowly as *non-declining economic welfare*, which, at the very least, requires natural capital to be kept intact (Lawn 2007). Provided we do not stray from the central tenets of the broad definition above, this narrow view of sustainable development can be of great practical use in that it is possible to measure natural capital and a nation's aggregate economic welfare. As we shall see, this makes it feasible to determine whether a nation is operating sustainably and whether the economic welfare being generated by its economic activities is rising over time.

2.2 Sustainable Development and the Ecological and Economic Limits to Growth

2.2.1 Economic and Uneconomic Growth

In view of the above definition of sustainable development, two further questions naturally emerge:

- Firstly, how big can the economy get before the throughput of matter-energy required to maintain it can no longer be ecologically sustained?
- Secondly, how big can the economy get before the additional costs of growth begin to exceed the additional benefits, at which point the economic welfare generated by a physically expanding economy begins to decline?

Unbeknown to many, the answers to these questions are not the same. This is because the first question relates to a physical scale of the economy that ought to be avoided at all costs whereas the second question relates to a physical scale we would be better off avoiding even if the long-term consequences of reaching it are not ecologically catastrophic. As we shall see, the desirable or optimal scale of the economy (the answer to the second question) is considerably smaller than the economy's maximum sustainable scale (the answer to the first question). This has important consequences for how humankind should deal with climate change.

To answer the above questions, the two elemental categories of net psychic income (uncancelled benefits) and lost natural capital services (uncancelled costs) can be diagrammatically presented to demonstrate the economic and ecological impacts of a growing economy. Consider Fig. 2.4 where we shall ignore efficiency-increasing technological progress for the moment and assume that all technological advances are of the throughput-increasing kind. Throughput-increasing technological progress enables a nation to augment the rate of resource throughput that, in turn, allows it to physically expand its economy. In Fig. 2.4, the

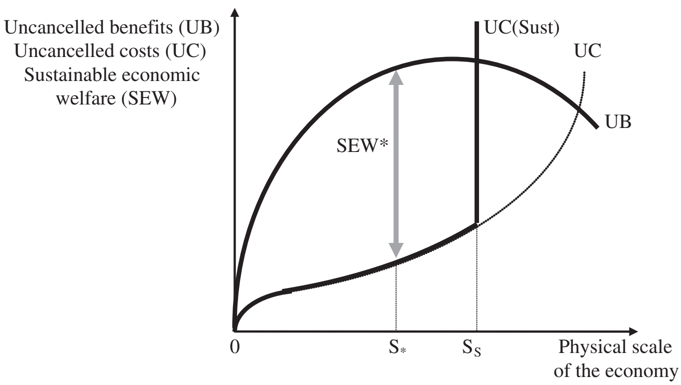


Fig. 2.4 The sustainable economic welfare generated by a growing economy

physical expansion of the economy is represented by a rightward movement along the horizontal axis. The uncancelled benefits and uncancelled costs are respectively represented by the UB and UC curves.

In keeping with the principle of diminishing marginal benefits, we can expect the uncancelled benefits associated with a growing economy to increase at a declining rate. Conversely, due to the principle of increasing marginal costs, we can expect the uncancelled costs to rise at an increasing rate.[12] The shapes of the UB and UC curves in Fig. 2.4 reflect these two standard economic principles. From a sustainability perspective, the UC curve is vertical at the point where the economy reaches its *maximum sustainable scale* of S_S (i.e., the largest physical scale of the economy consistent with a sustainable rate of resource throughput). As Fig. 2.4 shows, growth of the economy up to a physical scale of S_S is ecologically sustainable. Although growth beyond S_S is technically feasible for a short period of time (i.e., by drawing down stocks of natural capital), it is ecologically unsustainable in the long-run.

From an economic perspective, matters differ considerably. The economic welfare generated by a growing economy is measured by the vertical distance between the UB and UC curves. Figure 2.4 indicates that growth up to a physical scale of S_* increases benefits faster than costs. As such, it increases a nation's economic welfare and thus constitutes a form of 'economic' growth. However, growth beyond S_* reduces economic welfare. That is, physical expansion beyond the *optimal macroeconomic scale* (i.e., where sustainable economic welfare is maximised) increases costs faster than benefits. It therefore constitutes a form of 'uneconomic' growth and ought to be avoided. The critical message here is that growth beyond the optimal scale becomes economically undesirable even though the physical expansion of the economy between S_* and S_S is ecologically sustainable. In all, Fig. 2.4 demonstrates that an economic limit to growth (S_*) is likely to precede an ecological limit to growth (S_S).

2.2.2 *Efficiency-Increasing Technological Progress*

The previous analysis was somewhat over-simplified in that it ignored the possibility of efficiency-increasing technological progress. Technological advances of the efficiency-increasing kind bring about an upward shift of the UB curve or a downward/rightward shift of the UC curve. To explain how, we can arrange the uncancelled benefits and uncancelled costs to arrive at a macro measure of efficiency—sometimes referred to as 'ecological economic efficiency' (EEE):

$$\text{EEE} = \frac{\textit{Uncancelled benefits}}{\textit{Uncancelled costs}} = \frac{\textit{Net psychic income}}{\textit{Lost natural capital services}} \tag{2.1}$$

For a given physical scale of the economy, an increase in the EEE ratio indicates an improvement in the efficiency with which natural capital and the low-entropy resources it provides are transformed into service-yielding human-made capital. A multitude of factors can contribute to an increase in the EEE ratio.

To demonstrate how, the EEE ratio can be decomposed to reveal the following four eco-efficiency ratios (Daly 1996):

$$\text{EEE} = \frac{\text{NPY}}{\text{LNCS}} = \overset{\text{Ratio 1}}{\frac{\text{NPY}}{\text{HMK}}} \times \overset{\text{Ratio 2}}{\frac{\text{HMK}}{\text{RT}}} \times \overset{\text{Ratio 3}}{\frac{\text{RT}}{\text{NK}}} \times \overset{\text{Ratio 4}}{\frac{\text{NK}}{\text{LNCS}}} \tag{2.2}$$

where:

- EEE = ecological economic efficiency
- NPY = net psychic income
- LNCS = lost natural capital services
- HMK = human-made capital
- RT = resource throughput
- NK = natural capital.

The order in which the four eco-efficiency ratios are presented in Eq. (2.2) is in keeping with the nature of the economic process—that is, net psychic income is enjoyed as a consequence of the creation and maintenance of human-made capital (Ratio 1); the maintenance of human-made capital requires the continued throughput of matter-energy (Ratio 2); the throughput of matter-energy is made possible thanks to the three instrumental services provided by natural capital (Ratio 3); and, in exploiting natural capital, the three instrumental services provided by natural capital are to some degree sacrificed (Ratio 4). Each eco-efficiency ratio represents a different form of efficiency pertaining to a particular sub-problem contained within the larger problem of achieving sustainable development. The four eco-efficiency ratios will now be individually explained along with the implications they have for the UB and UC curves.

2.2.2.1 Beneficial Shifts of the Uncancelled Benefits (UB) Curve

Ratio 1 is a measure of the *service efficiency* of human-made capital. It increases whenever a given amount of human-made capital yields a higher level of net psychic income. An increase in Ratio 1 causes the UB curve to shift upwards (see Fig. 2.5). This can be achieved by improving the technical design of all newly produced goods, altering the composition of final output (i.e., producing a greater proportion of goods with higher service-yielding qualities), or by advancing the means by which human beings organise themselves in the course of producing and maintaining the stock of human-made capital. The latter is important because it can reduce such things as the disutility of labour, the cost of commuting, and the cost of unemployment. A beneficial shift in the UB curve can also be achieved by redistributing income from the low marginal service or psychic income uses of the rich to the higher marginal service uses of the poor (Robinson 1962).[13]

Figure 2.5 illustrates what happens to sustainable economic welfare when the UB curve shifts upwards. Because an increase in Ratio 1 augments the net psychic

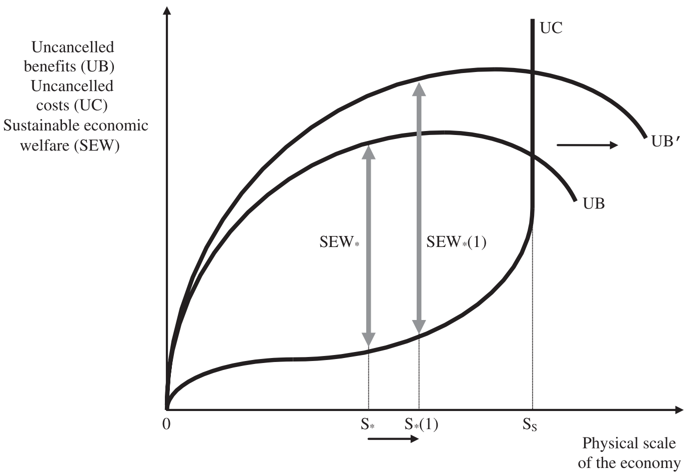


Fig. 2.5 An increase in sustainable economic welfare brought about by an upward shift of the UB curve

income yielded by a given amount of human-made capital, the UB curve shifts up to UB′. As a consequence, sustainable economic welfare is no longer maximised at the prevailing scale of S*. In the circumstances depicted in Fig. 2.5, it is economically desirable to expand the economy to the new optimal scale of S*(1).[14] In the process, sustainable economic welfare increases to SEW*(1).

2.2.2.2 Beneficial Shifts of the Uncancelled Costs (UC) Curve

Shifts of the UC curve arise as a consequence of changes in Ratios 2, 3, and 4. Ratio 2 is a measure of the *maintenance efficiency* of human-made capital. It increases whenever a given physical magnitude of human-made capital can be maintained by a lower rate of resource throughput. This can be achieved via any one of the following advances: (i) an increase in the technical efficiency of production; (ii) increased rates of material recycling; (iii) greater product durability; and (iv) improved operational efficiency (Lawn 2000). An increase in Ratio 2 causes the UC curve to shift downwards and to the right by enabling a given physical scale of the economy to be sustained by a reduced rate of resource throughput. This lessens the natural capital that needs to be exploited, including the Earth's greenhouse gas-absorbing sinks, which correspondingly results in the loss of fewer natural capital services.

Ratio 3 is a measure of the *growth efficiency* or productivity of natural capital. This form of efficiency is increased whenever a given amount of natural capital can sustainably yield more low-entropy resources and/or assimilate a greater quantity of high-entropy waste. Better management of natural resource systems and the preservation of critical ecosystems can lead to a more productive stock of natural capital. From a climate change perspective, an increase in the productivity of natural capital would be reflected by an increased capacity of the ecosphere to sequester greenhouse gases. An increase in Ratio 3 leads to a downward and rightward shift of the UC curve because a more productive stock of natural capital reduces the quantity of natural capital that must be exploited to obtain the throughput of matter-energy needed to sustain the economy at a given physical scale. This allows an economy of a particular scale to be sustained at the expense of fewer natural capital services.

Ratio 4 is a measure of the *exploitative efficiency* of natural capital. An increase in Ratio 4 occurs whenever there is a reduction in the natural capital services lost from directly exploiting a given quantity of natural capital. Once again, advances of this nature allow an economy of a particular physical scale to be sustained at the expense of fewer natural capital services. Increases in Ratio 4 can be obtained through the development and execution of more sensitive resource-extraction techniques, such as the use of underground rather than open-cut mining practices.

Figure 2.6 illustrates what happens following a beneficial shift of the UC curve. Because increases in Ratios 2, 3, and 4 reduce the uncancelled cost of maintaining an economy at a given physical scale, the UC curve shifts down and out to UC′. In doing so, the maximum sustainable scale of the economy increases from S_S to $S_S(1)$. At the same time, it becomes economically desirable to grow the economy to $S_*(2)$. Expansion to the new optimum increases sustainable economic welfare to $SEW_*(2)$.

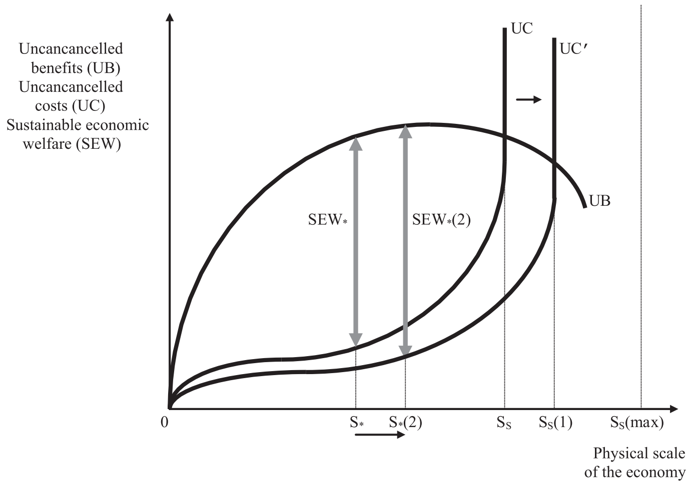


Fig. 2.6 A change in sustainable economic welfare brought about by a rightward/downward shift of the UC curve

2.2.2.3 Limits to the Beneficial Shifts of the UB and UC Curves and the Necessity of the Steady-State Economy

There is considerable debate surrounding how much and for how long humankind can beneficially shift the UB and UC curves. Because of biophysical constraints, there are many observers who correctly point out that humankind's ability to shift the UC curve is ultimately limited. As previously stressed, the first and second laws of thermodynamics preclude the 100 per cent technical efficiency of production and the 100 per cent recycling rate of waste materials. Both laws also forbid any recycling of waste energy. Consequently, both laws limit increases in Ratio 2. On top of this, it is impossible to continuously increase the productivity of natural capital (Ratio 3) and prevent the loss of at least some of the ecosphere's three instrumental services (Ratio 4). In view of these constraints, it follows that an upper limit must exist on the maximum sustainable scale of economic systems. This ultimate ecological limit is represented in Fig. 2.6 by the dotted line at the physical scale of S_S(max).

What about the UB curve? Is there a limit on its upward adjustment? This is a more complex issue because net psychic income is not subject to the same physical laws as physical goods. Having said this, the following should be borne in mind. Firstly, because human-made capital is required to experience the welfare generated by human activities, net psychic income always has a physical foundation. Hence, growth in the physical basis of human well-being always remains biophysically limited. Secondly, there is a probable limit on the human capacity to experience a sense of psychic well-being. A human being can only be so happy, contented, and fulfilled. Finally, efforts to increase human well-being by altering the composition of what humans consume are severely restricted. Thus, even if the information provided by cyberspace can offer wonderful welfare-increasing opportunities, a hungry person requires a meal to be fed, not a recipe. The same person also requires physical shelter, clothes, and heating/cooling to remain dry and comfortable. No amount of downloaded images or information can directly supply these physiological requirements.

Although there is, as a consequence, a clear limit on the human capacity to experience a sense of psychic well-being, there are good reasons to believe that the potential to shift the UB curve is far from exhausted. Moreover, because of impending ecological limits to growth (i.e., severe limits to the beneficial shift of the UC curve), achieving sustainable development will require all nations to eventually make the transition to a steady-state economy—preferably settling somewhere near the optimal scale. Given this steady-state imperative, it is clear that the goal of physically expanding the economy (growth) must give way to an emphasis on qualitative improvement (development). This means that all nations will need to shift their focus towards qualitatively advancing the stock of physical goods; ensuring the stock is more equitably distributed; minimising the rate of resource throughput; and reorganising the production process to increase job satisfaction and reduce any associated social costs. Provided these advances can be made, the necessity of the steady-state economy should not be a cause for concern. In fact, unlike growing the economy beyond its ecological and economic limits, there is no reason why a qualitatively-improving steady-state economy should not deliver increasing levels of sustainable economic welfare for many years to come.

2.3 Empirical Evidence of the Ecological and Economic Limits to Growth

2.3.1 Ecological Limits to Growth: Ecological Footprint Versus Biocapacity

As important as it is to recognise the inevitability of a steady-state economy, it is equally important to know where a nation's economy is in relation to its maximum sustainable scale (S_S) and optimal scale (S_*). Without this information, it is impossible to ascertain when to initiate the transition to a steady-state economy. Furthermore, it is impossible to know whether the transition will require a nation to gradually slow the growth of its economy (i.e., decelerate towards a larger economy) or reduce its physical scale (i.e., settle at a smaller economy).

A number of indicators have been developed to determine whether economic systems are nearing or have surpassed their ecological limit (Vitousek et al. 1986; Yale Center for Environmental Law and Policy et al. 2005; Pearce and Atkinson 1993; Wackernagel et al. 1999). Despite its conservative nature, many people believe that the ecological footprint is the best indicator of ecological limits so far established.[15] A country's ecological footprint represents the area of land *required* to generate the resources, absorb the wastes, and provide the critical ecosystem services needed to sustain economic activity at its current level (Wackernagel and Rees 1996). To determine if a nation's economy has exceeded its maximum sustainable scale, the ecological footprint is compared to its biocapacity. A nation's biocapacity is indicated by the quantity of land *available* to generate an ongoing supply of resources, absorb wastes, and maintain critical ecosystem services. Ecological unsustainability (ecological deficit) occurs if a nation's ecological footprint exceeds its biocapacity.

Table 2.1 reveals that, in 2005, 78 of 143 surveyed nations had ecological footprints in excess of their biocapacities (Global Footprint Network 2008). Some observers have suggested that ecological deficits are not a problem given that countries with ecological surpluses can aid deficit nations by exporting their surplus resources and/or by importing deficit countries' surplus wastes. However, Table 2.1 shows that the global ecological footprint exceeded the Earth's biocapacity by an amount equal to 0.6 global hectares per person. It also shows that 1.3 Earths are required to sustain the rate of global consumption at 2005 levels (Global Footprint Network 2008).[16] Since this situation cannot continue indefinitely, it follows that the ecological surpluses enjoyed by some nations are insufficient to 'finance' the combined ecological deficits of the remainder. Overall, it is

Table 2.1 Ecological footprint (EF) and biocapacity (2005)

	Ecological footprint *(gha per person)*	Bio-capacity *(gha per person)*	Ecological deficit (−) surplus (+) *(gha per person)*		Ecological footprint *(gha per person)*	Bio-capacity *(gha per person)*	Ecological deficit (−) surplus (+) *(gha per person)*		Ecological footprint *(gha per person)*	Bio-capacity *(gha per person)*	Ecological deficit (−) surplus (+) *(gha per person)*
World	2.7	2.1	−0.6								
Africa											
Algeria	1.7	0.9	−0.7	Gabon	1.3	25.0	23.7	Namibia	3.7	9.0	5.3
Angola	0.9	3.2	2.3	Gambia	1.2	1.2	0.0	Niger	1.6	1.8	0.2
Benin	1.0	1.5	0.5	Ghana	1.5	1.2	−0.3	Nigeria	1.3	1.0	−0.4
Botswana	3.6	8.5	4.8	Guinea	1.3	3.0	1.8	Rwanda	0.8	0.5	−0.3
Burkina Faso	2.0	1.6	−0.4	Guinea-Bissau	0.9	3.4	2.5	Senegal	1.4	1.5	0.2
Burundi	0.8	0.7	−0.1	Kenya	1.1	1.2	0.1	Sierra Leone	0.8	1.0	0.2
Cameroon	1.3	3.1	1.8	Lesotho	1.1	1.1	0.0	Somalia	1.4	1.4	0.0
Cent Afr Rep	1.6	9.4	7.8	Liberia	0.9	2.5	1.6	South Africa	2.1	2.2	0.1
Chad	1.7	3.0	1.3	Libya	4.3	1.0	−3.3	Sudan	2.4	2.8	0.4
Congo	0.5	13.9	13.3	Madagascar	1.1	3.7	2.7	Swaziland	0.7	1.7	0.9
Congo Dem Rep	0.6	4.2	3.6	Malawi	0.5	0.5	0.0	Tanzania	1.1	1.2	0.1
Cote d'Ivoire	0.9	2.2	1.3	Mali	1.6	2.6	0.9	Tunisia	1.8	1.1	−0.6
Egypt	1.7	0.4	−1.3	Mauritania	1.9	6.4	4.5	Uganda	1.4	0.9	−0.4
Eritrea	1.1	2.1	0.9	Morocco	1.1	0.7	−0.4	Zambia	0.8	2.9	2.1
Ethiopia	1.4	1.0	−0.3	Mozambique	0.9	3.4	2.5	Zimbabwe	1.1	0.7	−0.4
Asia-Pacific											
Australia	7.8	15.4	7.6	Korea DPRP	1.6	0.6	−0.9	New Zealand	7.7	14.1	6.4
Bangladesh	0.6	0.3	−0.3	Korea Republic	3.7	0.7	−3.0	Pakistan	0.8	0.4	−0.4
Cambodia	0.9	0.9	0.0	Laos	1.1	2.3	1.3	Papua NG	1.7	4.4	2.8
China	2.1	0.9	−1.2	Malaysia	2.4	2.7	0.3	Philippines	0.9	0.5	−0.3
India	0.9	0.4	−0.5	Mongolia	3.5	14.6	11.2	Sri Lanka	1.0	0.4	−0.6
Indonesia	0.9	1.4	0.4	Myanmar	1.1	1.5	0.4	Thailand	2.1	1.0	−1.2
Japan	4.9	0.6	−4.3	Nepal	0.8	0.4	−0.4	Vietnam	1.3	0.8	−0.5

(continued)

Table 2.1 (continued)

	Ecological footprint *(gha per person)*	Bio-capacity *(gha per person)*	Ecological deficit (−) surplus (+) *(gha per person)*		Ecological footprint *(gha per person)*	Bio-capacity *(gha per person)*	Ecological deficit (−) surplus (+) *(gha per person)*		Ecological footprint *(gha per person)*	Bio-capacity *(gha per person)*	Ecological deficit (−) surplus (+) *(gha per person)*
Latin America											
Argentina	2.5	8.1	5.7	Dominican Rep	1.5	0.8	−0.7	Mexico	3.4	1.7	−1.7
Bolivia	2.1	15.7	13.6	Ecuador	2.2	2.1	−0.1	Nicaragua	2.0	3.3	1.2
Brazil	2.4	7.3	4.9	El Salvador	1.6	0.7	−0.9	Panama	3.2	3.5	0.3
Chile	3.0	4.1	1.1	Guatemala	1.5	1.3	−0.2	Paraguay	3.2	9.7	6.5
Colombia	1.8	3.9	2.1	Haiti	0.5	0.3	−0.3	Peru	1.6	4.0	2.5
Costa Rica	2.3	1.8	−0.4	Honduras	1.8	1.9	0.1	Uruguay	5.5	10.5	5.0
Cuba	1.8	1.1	−0.7	Jamaica	1.1	0.6	−0.5	Venezuela	2.8	3.2	0.3
North America											
Canada	7.1	20.0	13.0	USA	9.4	5.0	−4.8				
M-E & Cent Asia											
Afghanistan	0.5	0.7	0.3	Israel	4.6	0.4	−4.2	Syria	2.1	0.8	−1.2
Armenia	1.4	0.8	−0.6	Jordan	1.7	0.3	−1.4	Turkey	2.7	1.7	−1.1
Azerbaijan	2.2	1.0	−1.1	Kazakhstan	3.4	4.3	0.9	Turkmenistan	3.9	3.7	−0.2
Georgia	1.1	1.8	0.7	Kuwait	8.9	0.5	−8.4	UAE	9.5	1.1	−8.4
Iran	2.7	1.4	−1.3	Lebanon	3.1	0.4	−2.7	Uzbekistan	1.8	1.0	−0.8
Iraq	1.3	0.3	−1.1	Saudi Arabia	2.6	1.3	−1.4	Yemen	0.9	0.6	−0.3

(continued)

Table 2.1 (continued)

	Ecological footprint (*gha per person*)	Bio-capacity (*gha per person*)	Ecological deficit (−) surplus (+) (*gha per person*)		Ecological footprint (*gha per person*)	Bio-capacity (*gha per person*)	Ecological deficit (−) surplus (+) (*gha per person*)		Ecological footprint (*gha per person*)	Bio-capacity (*gha per person*)	Ecological deficit (−) surplus (+) (*gha per person*)
EU25											
Austria	5.0	2.9	−2.1	Germany	4.2	1.9	−2.3	Netherlands	4.4	1.1	−3.3
Belg. and L/bourg	5.1	1.1	−4.0	Greece	5.9	1.7	−4.2	Poland	4.0	2.1	−1.9
Czech Republic	5.4	2.7	−2.6	Hungary	3.5	2.8	−0.7	Portugal	4.4	1.2	−3.2
Denmark	8.0	5.7	−2.3	Ireland	6.3	4.3	−2.0	Slovakia	3.3	2.8	−0.5
Estonia	6.4	9.1	2.7	Italy	4.8	1.2	−3.5	Spain	5.7	1.3	−4.4
Finland	5.2	11.7	6.5	Latvia	3.5	7.0	3.5	Sweden	5.1	10.0	4.9
France	4.9	3.0	−1.9	Lithuania	3.2	4.2	1.0	UK	5.3	1.6	−3.7
Rest of Europe											
Albania	2.2	1.2	−1.0	Croatia	3.2	2.2	−1.0	Russia	3.7	8.1	4.4
Belarus	3.9	3.4	−0.4	Macedonia	4.6	1.4	−3.2	Serbia and Mont.	2.6	1.6	−1.0
Bosnia Herzeg.	2.9	2.0	−0.9	Norway	6.9	6.1	−0.8	Switzerland	5.0	1.3	−3.7
Bulgaria	2.7	2.8	0.1	Romania	2.9	2.3	−0.6	Ukraine	2.7	2.4	−0.3

Notes
- Totals may not add up due to rounding
- gha denotes global hectares

Source Global Footprint Network (2006) apparent that the economies of most nations, as well as the global economy as a whole, have surpassed their maximum sustainable scale.

2.3.2 Economic Limits to Growth: The Genuine Progress Indicator

Unlike biophysical indicators, less work has been undertaken to determine whether economic systems have exceeded their optimal scale. However, an indicator has recently emerged that incorporates around twenty-five benefit and cost items of the economic, social, and environmental variety. Known as the Genuine Progress Indicator (GPI), this indicator involves subtracting the costs of economic activity from the benefits it generates to obtain a macroeconomic estimate of economic welfare.[17] From a diagrammatical perspective, the GPI is equivalent to the vertical distance between the UB and UC curves in Fig. 2.4.

GPI studies have been predominantly conducted on high-GDP nations. A recent project involving seven countries in the Asia-Pacific region has boosted the number of GPI studies of poor nations (Lawn and Clarke 2008). The results of the Asia-Pacific study are very illuminating and I shall refer to the significance of them soon. For now, consider Fig. 2.7 which reveals the results of GPI studies conducted on six wealthy nations in the 1990s. In all six cases, the GPI initially rises in unison with real GDP. A point is then reached where the GPI decreases or plateaus, although the timing of this turning point differs between nations. What doesn't alter significantly is that the rise in the GPI ceases once a nation's per capita GDP reaches Int$15,000 to Int$20,000 (2004 prices).[18]

Although real GDP is not strictly an indicator of the physical scale of a nation's economy, the initial decline in the GPI within this per capita GDP range suggests that all six countries have surpassed their optimal scale (S_* in Fig. 2.4). This implies they have all exceeded their economic limit to growth. Disturbingly, the GPI results of other wealthy nations reveal a similar pattern (see Diefenbacher 1994; Moffatt and Wilson 1994; Rosenberg and Oegema 1995; Jackson et al. 1997; Stockammer et al. 1997; Guenno and Tiezzi 1998; Makino 2008).[19]

The uniform trend displayed in Fig. 2.7 was first recognised in the mid-1990s. It led Max-Neef (1995) to put forward a 'threshold hypothesis'—namely, when a nation's per capita GDP exceeds a critical threshold, one can expect its per capita economic welfare to plateau or decline. As disconcerting as this was for countries at or beyond the threshold, the hypothesis offered comfort to the world's poorest nations. That is, with the per capita GDP of poor countries well below Int$15,000, the theory suggested that a positive relationship should exist for some time between the growth of their economies and the economic welfare they generate. Unfortunately, this does not appear to be occurring. Recent GPI studies on China and Thailand indicate that the per capita GPI of both countries has already begun to fall—China's per capita GPI peaking in 2002 (Wen et al. 2008); Thailand's peaking in 2001 (Clarke and Shaw 2008). Crucially, these declines took place when the per

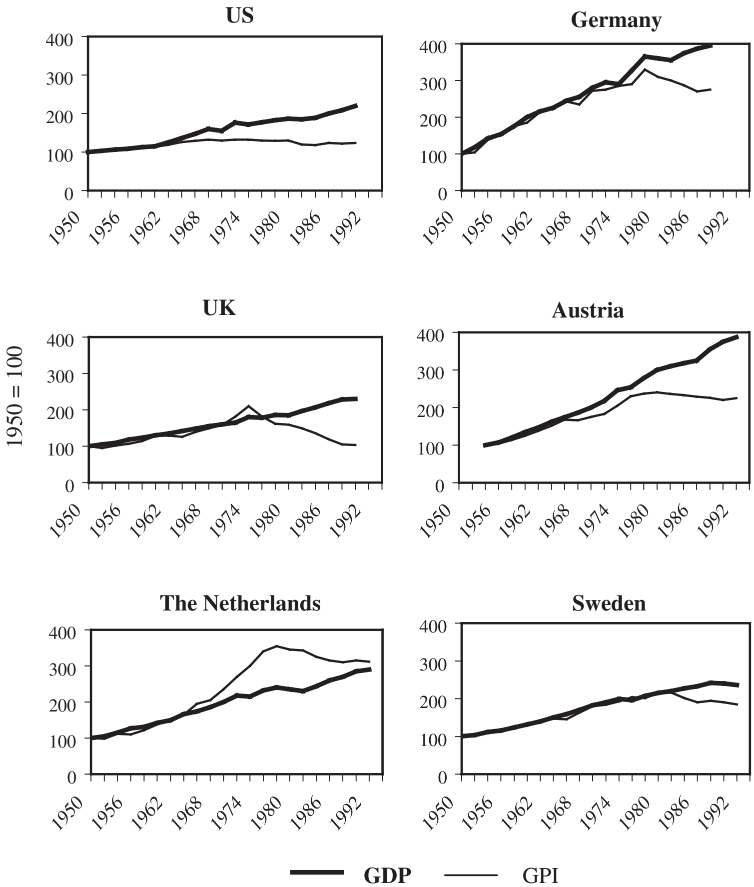


Fig. 2.7 The GPI and GDP for the USA and a range of European countries. *Source* Jackson and Stymne (1996)

capita GDP for China and Thailand was just \$Int4926 and \$Int7373 respectively (Lawn and Clarke 2008). In addition, the per capita GPI of China and Thailand peaked well short of the value currently being enjoyed by high-GDP nations.

In an endeavour to examine the relationship between growth and economic welfare in the Asia-Pacific region, Lawn and Clarke (2008) plotted the annual per capita GPI values of the seven countries included in the Asia-Pacific GPI study against their corresponding per capita GDP values. Figure 2.8 is the result of this comparison. It reveals that the three wealthy countries—Australia, New Zealand, and Japan—have all reached a threshold level of per capita GDP (Lawn 2008a; Forgie et al. 2008; Makino 2008). The figure also shows that China and Thailand have reached an apparent GDP threshold. Alarmingly, Fig. 2.8 suggests that the later a nation begins to rapidly expand its economy, the lower is its per capita GDP when its

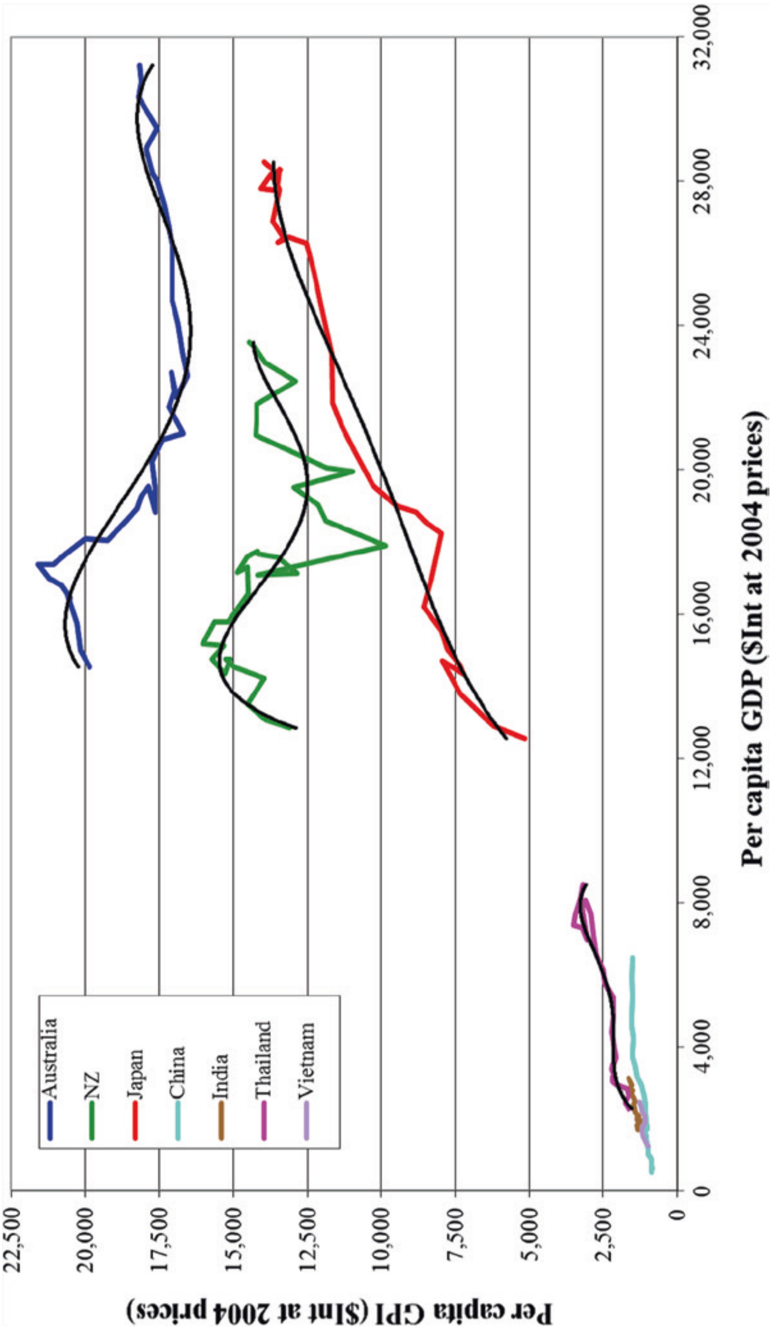


Fig. 2.8 Per capita GPI versus per capita GDP of selected Asia-Pacific countries. *Source* Lawn and Clarke (2008)

per capita GPI begins to decline. This is no better exemplified than by the tunnelling of each country's per capita GPI-GDP curve below that of its growth predecessor.

Lawn and Clarke (2008) believe the phenomenon revealed in Fig. 2.8 can be largely attributed to three factors. The first is the low level of consumption in poor nations relative to domestic production—very much the consequence of export-led growth strategies. This policy, which the Chinese Government is presently reconsidering, reduces the consumption benefits that poor nations enjoy from their productive endeavours.[20] The second factor is the migration of manufacturing operations to countries with low wages and feeble environmental regulations. Although this has helped poor countries to increase their real GDP, it has left many of them bearing a disproportionately large share of the world's social and environmental costs. Finally, as growth 'late-comers', low-GDP nations are attempting to expand their economies in a world replete with human beings and human-made capital, yet one with much less natural capital and fewer pristine ecosystems. Consequently, the marginal cost of an increment of GDP growth is far higher than it was when the world's high-GDP countries underwent their initial expansion phase.

It is because of the above factors that Lawn and Clarke (2008) have extended Max-Neef's theory to propose a *contracting threshold hypothesis*. The hypothesis is essentially this: As the economies of the world collectively expand in a globalised economic environment, there is a contraction over time in the threshold level of per capita GDP. As such, growth late-comers face the prospect of never attaining the economic welfare enjoyed by the early growth-movers.

Despite this new hypothesis, Lawn and Clarke still believe it is possible for poor nations to experience higher levels of economic welfare. However, they argue that progress will only occur if an extension can be made to the threshold at which the per capita GPI of the world's poor countries begins to decline. This, according to Lawn and Clarke (2008), will necessitate dramatic policy changes on the part of the world's low-GDP countries. Just as importantly, it will require rich nations to cease growing their economies in order to provide the 'ecological space' that poor nations need to enjoy a phase of welfare-increasing growth before they, too, must make the transition to a steady-state economy.

Should this self-imposed check on growth be a cause for concern for rich nations? Not at all, since many rich countries already need to reduce the physical scale of their economies to advance the economic welfare enjoyed by their own citizens. As will be revealed in Chap. 4, this is likely to be very important in terms of resolving the climate change crisis. Economic downsizing or de-growth (see Martinez-Alier 2009) will not only render it easier for rich nations to reduce their own greenhouse gas emissions, it will allow some poor countries to increase emissions as they complete their economic development process.

Notes

1. The WCED (1987, p. 43) defined sustainable development as "…. development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

2. In the natural world, information exists as genetic information coded in the DNA molecule. In the anthropocentric world, information exists as knowledge encoded in various institutions and organisations, and on physical objects, such as books and computer disks.
3. A holon is a term made popular by Arthur Koestler. See Capra (1982), p. 303.
4. Human-made capital constitutes the intermediate means depicted in Fig. 1.11.
5. The throughput is equivalent to the ultimate means depicted in Fig. 1.11.
6. Fisher (1906) described psychic income as the subjective satisfaction that emerges in the stream of human consciousness from consumption and other benefit-yielding endeavours.
7. There are two things worthy of note here. Firstly, uncancelled costs are often undervalued because many natural capital values escape market valuation. Secondly, uncancelled costs should reflect the higher of two distinct classes of opportunity costs. The first is the cost of transforming a unit of low-entropy resources into a physical good in terms of the next best alternative good forgone. For example, if a unit of resource X is used to produce good A, it cannot be used to produce good B. The second class of opportunity cost involves the reduced capacity of natural capital to provide a flow of resources required to produce future goods. For example, if the extraction of a unit of resource X reduces the capacity of natural capital to provide a unit of X over time, which it will if X is a non-renewable resource or if a renewable resource is unsustainably harvested, a unit of X will be unavailable to produce goods of any type in the future. It is the larger of the two classes of opportunity costs that constitutes the true uncancelled costs of economic activity.
8. The technical efficiency of production (E) can be written as the ratio of energy-matter embodied in physical goods (Q) to the energy-matter embodied in the low-entropy resources used to produce them (R). That is, $E = Q/R$. While the value of E can be increased via technological progress, the first and second laws of thermodynamics dictate that E must be less than a value of one.
9. The concept of a 'line in the sand' is very similar to Ciriacy-Wantrup's (1952) notion of a 'safe minimum standard'. See, also, Crowards (1998).
10. It is invariably argued that a growth rate of 2–3 per cent of real GDP is required just to prevent the unemployment rate from rising.
11. Some of the ways to sever the GDP-employment nexus are outlined in Lawn (2009).
12. Why does the principle of increasing marginal costs apply to the entire economy? Firstly, it is customary for nations to extract the more readily available resources first and be left with the more complicated task of extracting lower quality resources later. Secondly, the cost of the undesirable ecological feedbacks associated with each incremental disruption of natural capital increases as the economy expands relative to a finite natural environment.
13. Having said this, there is a limit on the capacity for income redistribution to increase Ratio 1 because, at some point, excessive redistribution is likely to adversely dilute the incentive structure built into a market-based economy.

14. Importantly, the new optimal scale need not necessarily be physically larger as a consequence of the UB curve shifting upwards. The size of the optimal scale will depend upon the nature of the UB and UC curves—in particular, the extent to which the shape of the UB curve alters following its upwards shift.
15. There are a number of critics of the ecological footprint (e.g., see *Ecological Economics* (2000), volume 32(3); and Fiala (2008)). A major weakness of the ecological footprint is the use of land area as a numeraire for sustainability. There is no doubt that if a nation was compelled to generate its entire resource flow in the form of renewable resources, land area and fertility would constitute critical limiting factors. However, there are other factors that also impinge on a nation's renewable resources, such as water availability (Patterson 2006). Because factors other than land area can restrict the generation of renewable resources, ecological footprint studies almost certainly overestimate a nation's biocapacity (and underestimate ecological deficits). As such, the ecological footprint can be regarded as a conservative indicator, which is all the more concerning given the ecological footprint estimates revealed in Table 2.1. It is worth pointing out that, following the work of Lenzen and Murray (2001), a number of improvements have been made to ecological footprint estimates to better account for additional limiting factors.
16. 1.3 Earths = 2.7 hectares ÷ 2.1 hectares. A value of 1.3 is only possible because: (i) non-renewable resources constitute a major portion of all resource use at present, and (ii) resource limits can be exceeded in the short-run by liquidating natural capital stocks.
17. The GPI was originally labelled an Index of Sustainable Economic Welfare (Daly and Cobb 1989). To view the items typically used to calculate the GPI, see Lawn (2007).
18. These figures are based on international dollars (Int$). An international dollar is a fictitious monetary unit which equilibrates the purchasing power that a nation's currency has over its own GDP with that of the US dollar over America's GDP. Two people living in different countries earning the same international dollar-valued income would be able to purchase an equivalent basket of goods and services.
19. Although the per capita GPI of some wealthy countries has recovered slightly since the early-1990s, in virtually every case it has failed to reach its earlier peak value.
20. It is also unnecessary because, if the central government is the monopoly owner and issuer of the nation's currency, it can always purchase the difference between exports and imports and provide the same goods to its citizens rather than have them enjoyed by foreigners. Better still, the government can redirect the resources involved to provide more schools, hospitals, and other critical infrastructure with public goods characteristics. In doing this, the nation's real output would not change, but the goods consumed or used would increase, thereby raising the per capita economic welfare of the nation (Lawn 2011).

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