Measuring Progress Towards a Socially Sustainable Steady State Economy

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The candidate confirms that the work submitted is his own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below:

- Section 1.2 of this thesis includes background material that was published in Chapter 2 of O'Neill et al. (2010). This chapter was written by the candidate and Rob Dietz, and draws on a presentation given by Peter Victor at the Steady State Economy Conference in Leeds.

The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

Within this thesis, I investigate how progress towards a socially sustainable steady state economy could be measured at the national scale. Following a review of four possible approaches, I suggest that separate biophysical and social indicators represent the best approach, but that a unifying conceptual framework is required to choose appropriate indicators and interpret the relationships between them. I propose a framework based on ends and means, and a set of biophysical and social indicators within this framework. The biophysical indicators are derived from Herman Daly's definition of a steady state economy, and measure the major stocks and flows in the economy–environment system. The social indicators are based on the stated goals of the degrowth moment, and measure the functioning of the socio-economic system, and how effectively it delivers human well-being.

I use these indicators to measure how close ~180 countries are to the idea of a steady state economy over a ten-year time period (1997–2007), and explore whether there is any relationship between a country's proximity to such an economy and its overall social performance. I find that the majority of countries in the world are biophysical growth economies, although a small number of countries achieve biophysical stability over the analysis period (e.g. Denmark, France, Japan, Poland, Romania, and the United States). In general, I find that countries with stable stocks and flows perform better on social indicators than countries with either growing or degrowing stocks and flows. However, I also find that social performance is higher in countries with greater per capita resource use. Taken together, these findings suggest that while a biophysically stable economy may be socially sustainable, the level of resource use required for a "good life" may be too high to extend to all people on the planet without surpassing ecological limits.

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1. Introduction

Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist.

— Kenneth Boulding

This thesis takes as its starting point the idea that economic growth is not sustainable due to biophysical limits, and no longer desirable (in wealthy nations at least), because it is failing to improve people's lives. As an alternative to economic growth, it explores the concept of a *steady state economy*—an economy where biophysical stocks and flows are stabilised, and kept within ecological limits. The thesis investigates how progress towards a socially sustainable steady state economy could be measured at the national scale. Moreover, it provides an empirical analysis of how close national economies are to a steady state economy, and what effect their proximity has on social performance.

Within the first chapter of the thesis, I provide a brief introduction and some background. I begin by discussing the concept of economic growth, and the arguments generally made in favour of its pursuit (Section 1.1). These arguments are followed by a discussion of the environmental and social failures of growth (Section 1.2), which have led to the call for a steady state economy (Section 1.3). Following this, I present the main research questions addressed in the thesis, which involve measuring progress towards a socially sustainable steady state economy (Section 1.4). Finally, I conclude the chapter by describing the organisation of the material that follows (Section 1.5).

1.1. Economic Growth

Economic growth is a primary policy goal of most modern governments. In developed countries, the general expectation is that the economy should grow by 2–3% per year. This is seen as the normal state of affairs. Lower rates of growth are viewed in a negative light, and often result in government policies designed to "stimulate" the economy. This was clearly demonstrated by the massive bank bailouts and economic stimulus packages that were enacted around the world in response to the global financial crisis (e.g. Draaisma, 2008).

The size of the economy is typically measured using Gross Domestic Product (GDP). GDP is the total expenditure on all final goods and services produced within the physical borders of a country over the course of a year (Goodwin et al., 2009, p. 56). Since one person's expenditure is another person's income, GDP is also the total income of everyone in the economy. GDP functions as an indicator of the overall level of economic activity—of money changing hands. Economic growth is therefore equivalent to an increase in the amount of money changing hands, or more precisely, to an increase in the total value of the final goods and services produced by an economy.

The popularity of economic growth as a policy goal is a relatively recent phenomenon. Prior to the Second World War, industrial nations did not maintain sophisticated systems of national accounts with indicators like GDP, and were therefore unable to track the level of economic activity, let alone attempt to maximise it. Gross National Product (GNP)—the precursor to GDP—was largely developed during the war, as a way to maximise wartime production. It was highly successful in this regard, and may have even helped the Allies win the war. Following the war, the Employment Act of 1946 turned the GNP and the theory it embodied into official policy in the United States (Cobb et al., 1995). An era of economic growth quickly followed as the U.S. and other nations attempted to maximise the new quantity that they were now measuring.

For the vast majority of human history, however, the size of the global economy was small compared to the size of the biosphere. But over the last hundred years or so, this balance has changed remarkably due to the increase in the number of people in the world and the growth in each person's consumption of goods and services. Between 1900 and 2008, world population increased from around 1.5 billion people to 6.8 billion people—more than a factor of four increase. At the same time, average per capita GDP increased from $1260 to $7600 per person—a factor of six increase. The result is that world GDP increased by an astounding factor of more than twenty-five times over the last century, from $2 trillion to $51 trillion (Maddison, 2010).

A number of arguments are often made in support of economic growth as a policy goal. The first argument is simply that earning more money is a good thing. After all, who doesn't want to be richer? If a country's GDP increases faster than its population, then per capita GDP (and hence average income) will also increase.[1] An increase in per capita GDP is seen as being equivalent to an increase in *standard of living*—the level of material comfort available to an individual. It is worth noting that an increase in standard of living does not necessarily imply an increase in *quality of life*—the degree of satisfaction that an individual has with his or her life. However, proponents of growth tend to argue that although per capita GDP should not be interpreted as an indicator of quality of life, it is highly correlated with such indicators (World Bank, 2001; Jones, 2002).

The second argument is that global economic growth is the best way to reduce poverty in developing countries. Reducing poverty without growth would require the redistribution of income from rich countries to poor countries. Given that the rich are generally more powerful that the poor, redistribution is often portrayed as being a less feasible option than growth (Woodward and Simms, 2006). In the view of Anne Krueger of the International Monetary Fund, "Poverty reduction is best achieved through making the cake bigger, not by trying to cut it up in a different way" (Krueger, 2004). One might argue that growth should be targeted towards developing countries in order to reduce poverty. However, continued economic growth in rich countries is often advocated as well in order to provide a market for the goods produced in developing countries. The idea is that it is possible for the rich to become richer and the poor to become less poor as total income increases. This is sometimes expressed using the metaphor "a rising tide lifts all boats".

The third argument is that, in the long run, economic growth benefits the environment. This is known as the Environmental Kuznets Curve (EKC) hypothesis, and it was popularised by the World Bank's (1992) *World Development Report*. The general idea is that at low levels of income, people are unable to focus on environmental protection because they must dedicate all of their income to meeting basic needs. Nevertheless, people's environmental impact is low because their resource consumption is low. As income increases so does the consumption of resources, and with it environmental degradation. Eventually, however, a turning point is reached where people have sufficient income to meet their basic needs. Environmental protection then becomes a priority, and as in-

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[1] Of course, whether an increase in average income results in a higher income for the average citizen depends on how equally the additional income is distributed. According to the U.S. Census, the real per-capita GDP in the United States increased by 71% between 1980 and 2006, but median household income increased by less than 20%.

come increases further, environmental degradation decreases. The hypothesis predicts an inverted-U-shaped relationship between per capita GDP and environmental degradation.

A relationship of this form has been found in studies of certain pollutants (e.g. sulphur dioxide) conducted during the early nineties (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992). For many pollutants, however, emissions have been shown to increase monotonically with income, particularly when analyses are conducted using a consumption-based approach that accounts for trade (e.g. Bagliani et al., 2008). This has caused many authors to question the validity of the Environmental Kuznets Curve hypothesis (e.g. Arrow et al., 1995; Stern, 2004), and some to question the pursuit of economic growth more generally.

1.2. The Critique of Economic Growth [2]

Early analyses that were critical of economic growth include *The Costs of Economic Growth* by Ezra Mishan (1967), *The Limits to Growth* by Donella Meadows and colleagues (1972), and *Steady-State Economics* by Herman Daly (1977). These critiques have been further developed by a number of more recent books, reports, and journal articles (e.g. Douthwaite, 1999; Czech, 2000b; Meadows et al., 2004; Woodward and Simms, 2006; Simms et al., 2010; Victor, 2010). Two recent books that make particularly strong contributions are *Managing Without Growth* by Peter Victor (2008) and *Prosperity Without Growth* by Tim Jackson (2009a).

It is worth stating up front that the objective of this thesis is *not* to provide a detailed critique of economic growth as a policy goal, as there is already a wealth of literature on this topic. Instead, this thesis takes as its starting point the assumption that economic growth cannot continue. Its focus is on what type of economy should replace the growth-based economies of today's world, and in particular, how progress towards a more sustainable economy should be measured. Nevertheless, there are two broad criticisms of economic growth that I will present briefly, as they contribute to a better understanding of the alternative that this thesis investigates. The first criticism is that economic growth is *not sustainable* due to biophysical limits. The second criticism is that economic growth is *no*

[2] The material in this section is largely drawn from O'Neill et al. (2010).

longer desirable (in wealthy countries at least) because it is failing to improve people's lives.

1.2.1. Economic Growth is Not Sustainable

Many ecological economists argue that there is a fundamental conflict between economic growth and environmental protection (e.g. Czech, 2000a; Rees, 2003). Their argument is based on the fact that we live on a finite planet, which contains a finite stock of non-renewable resources, and produces a finite stream of renewable resources. These resources provide the inputs to the human economy, which is a subsystem of the biosphere (Figure 1.1). The economy transforms "natural capital" (i.e. trees, minerals, fossil fuels) into "built capital" (i.e. buildings, computers, clothing) in order to provide services that are useful to human beings. In-so-doing it also produces wastes that must be absorbed by the natural environment. A conflict between economic growth and environmental protection exists because the biophysical requirements of the human economy are growing, while the biophysical assets of the planet are not.

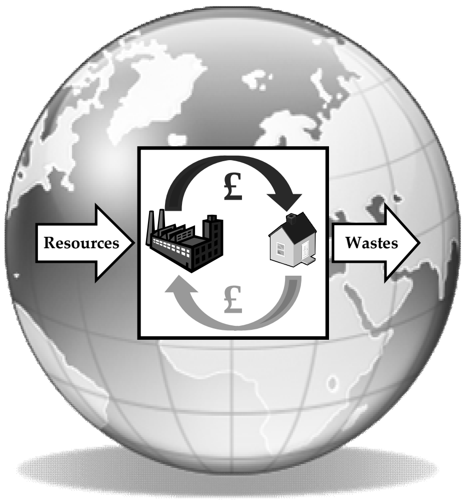

Figure 1.1: The economy is a subsystem of the biosphere.
Source: Image drawn by David Abson and published in O'Neill et al. (2010).

The pursuit of economic growth is problematic because economic activity (as measured by GDP) is tied very closely to energy and material use. While substantial gains have been made in the efficiency with which energy and materials are transformed into goods and services, these efficiency gains have not been great enough to offset the increase in the scale of economic activity. Between 1980 and 2007, for example, the material intensity of the global economy (i.e. the amount of biomass, minerals, and fossil fuels required to produce a dollar of world GDP) decreased by 33%. This is a remarkable improvement in efficiency, and yet, while this improvement was being made, world GDP grew by 141%, such that total material use still increased by 61% (SERI, 2010). The picture is almost identical for global energy use: energy intensity decreased by 29% over the same period, and yet total energy use rose by 70% (EIA, 2011).

Compounded over a few generations, the environmental impact of exponential economic growth is striking. Humanity now uses eleven times as much energy, and eight times the weight of material resources every year as it did only a century ago (Krausmann et al., 2009). Moreover, the vast majority of this increase occurred during the last fifty years, and it has been accompanied by an unsustainable shift from renewable materials such as biomass to non-renewable materials such as minerals and fossil fuels (Figure 1.2).

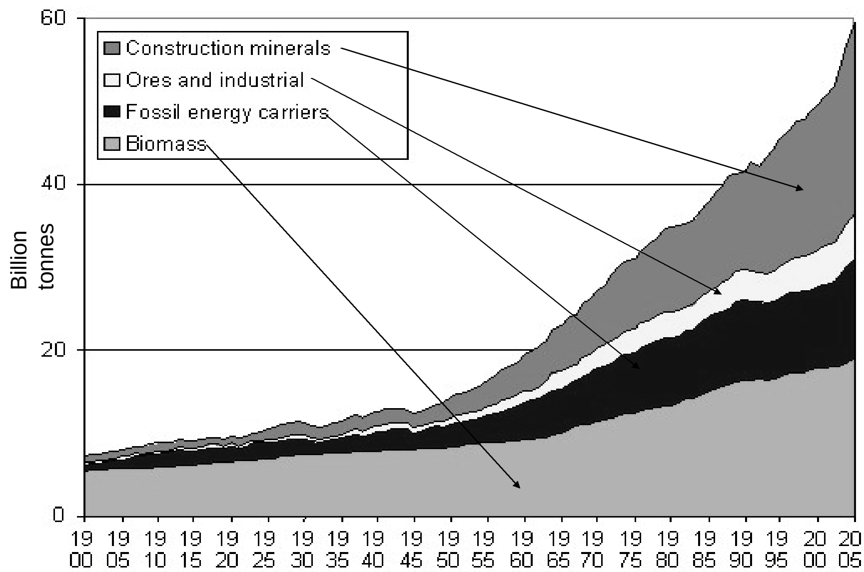

Figure 1.2: Global material use (including minerals, biomass, and fossil fuels), from 1900 to 2005. Source: Krausmann et al. (2009).

The concern is that if the scale of the global economy becomes too large, it will endanger the health of the containing biosphere, and with it the ecosystem services on which human society ultimately depends. In fact, there is a growing body of evidence that this is already happening. In a landmark study published in the journal *Nature* in 2009, Johan Rockström and colleagues attempted to identify the specific areas in which the global economy is placing an excessive burden on the biosphere (Rockström et al., 2009b). They analysed a set of nine "planetary boundaries", each of which defines the safe operating space for humanity on the planet. The nine boundaries relate to the following earth-system processes:

1. climate change;
2. biodiversity loss;
3. nitrogen and phosphorous cycles;
4. stratospheric ozone depletion;
5. ocean acidification;
6. global freshwater use;
7. change in land use;
8. atmospheric aerosol loading; and
9. chemical pollution.

The authors were able to estimate safe operating boundaries for the first seven of the above processes. For three of these processes (climate change, biodiversity loss, and the nitrogen cycle), humanity is now exceeding the planet's safe operating space, and by a large margin in some cases (Figure 1.3). The potential consequences are severe: the authors warn that transgressing one or more of the planetary boundaries could lead to catastrophic environmental change at the continental to planetary scale (Rockström et al., 2009a).

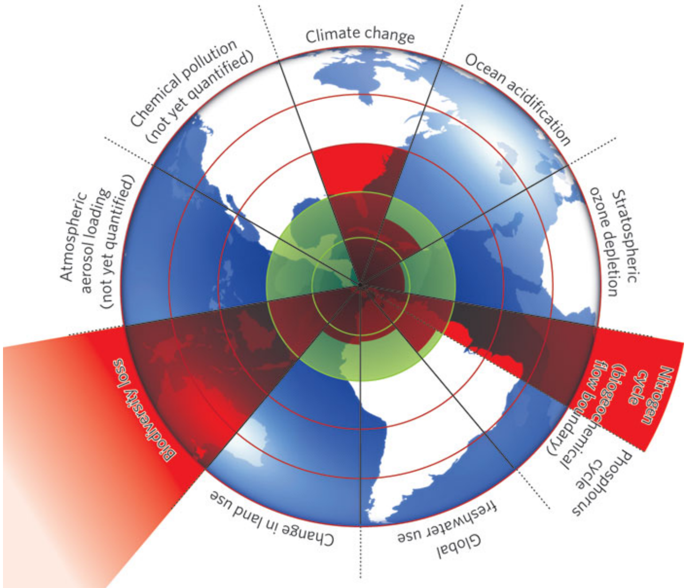

Figure 1.3: Planetary boundaries. The inner green shading represents the proposed safe operating space for planetary systems, and the red wedges represent the current position for each system. Source: Rockström et al. (2009b).

Other analyses, such as those conducted by the Global Footprint Network, support the Rockström study. The ecological footprint is a measure of how much biologically productive land and water a population requires to produce the biotic resources it consumes and absorb the carbon dioxide (CO_2) it generates, using prevailing technology and resource management practices. Ecological footprint studies suggest that many nations are currently using resources faster than they can be regenerated, and producing CO_2 faster than it can be assimilated. The combined result is a state of global "ecological overshoot" (Wackernagel et al., 2002; Ewing et al., 2010a). Large-scale studies such as the Millennium Ecosystem Assessment (2005) and the reports of the Intergovernmental Panel on Climate Change (e.g. IPCC, 2007) convey a similar message. Although it must be acknowledged that biophysical limits remain very difficult to quantify, these studies all suggest that such limits do exist, and that humanity is already transgressing some of them.

1.2.2. Economic Growth is No Longer Desirable

The second general argument against economic growth is that it is no longer a reasonable objective for wealthy countries to pursue because it is not improving people's lives in these countries. Data from surveys of happiness and life satisfaction are often used to make this argument (e.g. Layard, 2005). In these surveys, people are typically asked to rate their level of life satisfaction on a numerical scale (from 0 to 10 for example). When these data are compared against GDP, an interesting picture emerges. Although GDP per capita has more than tripled in countries like the UK and U.S. since 1950, data from life satisfaction surveys reveal that people have not become any happier (Figure 1.4). As Victor (2008, p. 125) remarks, "Americans have been more successful decoupling GDP from happiness than in decoupling it from material and energy."

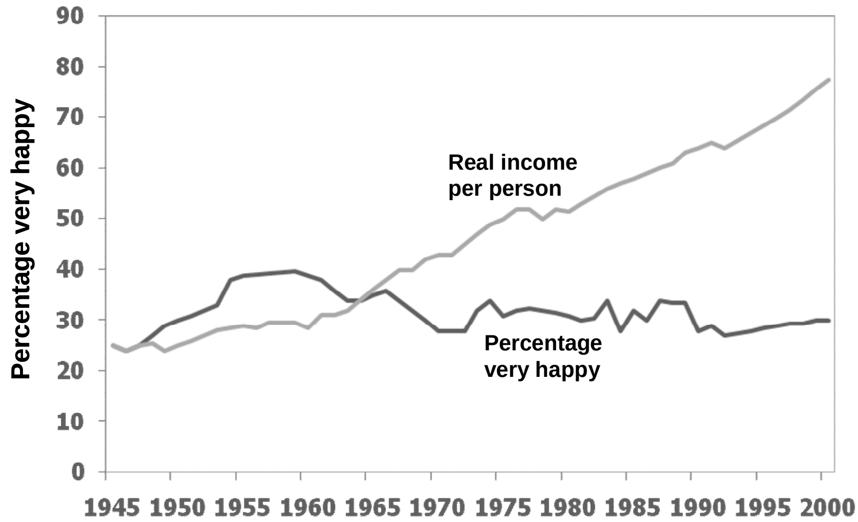

Figure 1.4: Income and happiness in the United States, 1945-2000. Source: Layard (2005).

When data are compared across countries, the picture becomes even more interesting. Happiness and life satisfaction *do* tend to increase with income, but only up until a point (Figure 1.5). Beyond an income of about $20,000 a year, additional money does not appear to contribute to additional happiness (Layard, 2005).

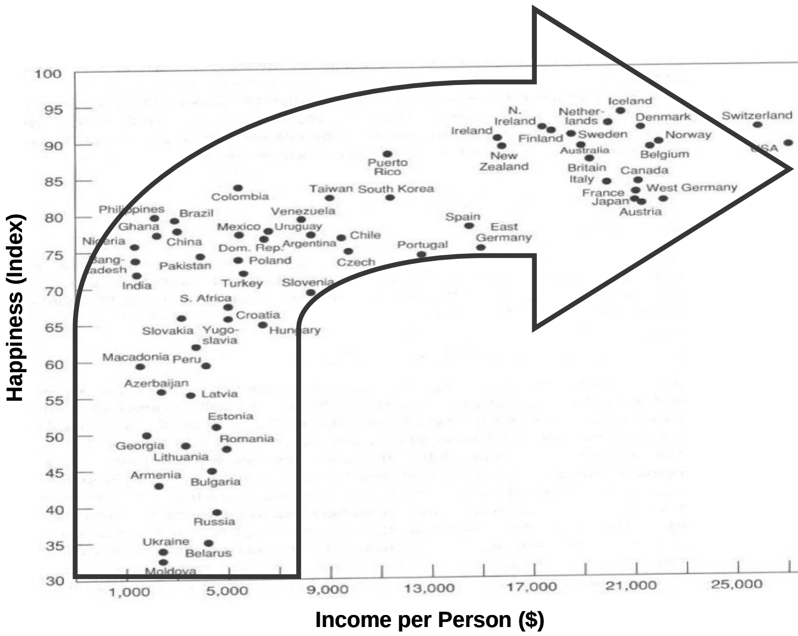

Figure 1.5: Income and happiness across different countries.

Source: Inglehart and Klingemann (2000).

This finding seriously calls into question the continued pursuit of economic growth in wealthy countries like the UK and U.S. If global resource use is already at an unsustainable level (as suggested by the environmental indicators discussed in the previous section), then further growth in rich countries only serves to reduce the amount of ecological space available to poor countries, where further economic growth may still be needed to alleviate poverty.

As noted in Section 1.1, it is sometimes argued that *global* economic growth—as opposed to targeted economic growth in poor countries or redistribution between countries—is the best way to alleviate poverty. However, this assertion is called into question by authors such as Woodward and Simms (2006), who highlight the poor record of economic growth at alleviating poverty. Despite the 25-fold increase in the size of the global economy over the past century, more than one billion people in the world still live on less than $1 per day, and a total of 2.7 billion live on less than $2 per day (UNMP, 2006). Economic growth has been cited by the World Bank (2008) as the "essential ingredient" for achieving sustained poverty reduction. However, for every $100 of global economic growth that occurred between 1990 and 2001, only $0.60 contributed to reducing poverty below the $1 per day line. In other words, a $1 reduction in poverty required a $166 increase in global production and consumption (Woodward and

Simms, 2006). These data suggest that global economic growth is not an efficient way to alleviate poverty.

Finally, problems of distribution are not just limited to poor countries; they affect wealthy countries as well. Over the past thirty years, the gap between the richest and poorest 10% of the UK population grew by almost 40% (Wilkinson and Pickett, 2009). The richest tenth of the population now have incomes 14 times higher than the poorest tenth. In the U.S., the income gap is even larger at 16 times (UNDP, 2009). Such gaps are deeply problematic. As Wilkinson and Pickett (2009) show in their book *The Spirit Level*, high levels of inequality are associated with a variety of health and social problems across society, including decreased trust, increased mental illness, and higher crime rates. Based on their findings, the authors conclude that reducing inequality would be a much more effective way to improve quality of life in wealthy countries than growing the economy.

1.3. The Call for a Steady State Economy

The general arguments discussed above (and others that I have not presented) have led a number of authors to seriously question the continued pursuit of economic growth, and many to call for an alternative economic model. As early as 1848, classical economist John Stuart Mill suggested that after a period of growth the economy would eventually reach a "stationary state", characterised by a constant population and constant stocks of capital. He described the resulting economy in very positive terms:

> It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living and much more likelihood of its being improved, when minds cease to be engrossed by the art of getting on (Mill, 1848, pp. 311-312).

Following on from Mill, economist Herman Daly developed the idea of a "steady state economy" as an alternative to economic growth in the 1970s. The definition of a steady state economy (SSE) will be discussed in more detail in Chapter 2, but briefly it is an economy where biophysical stocks and flows are stabilised, and kept within ecological limits. Moreover, it is an economy where the goal of increasing GDP is replaced by other goals, such as improving quality of life (Daly, 1977; 2008).

While studies published in the 1970s warned of the need to stabilise the size of the global economy before biophysical limits were reached (e.g. Meadows et al., 1972; Daly, 1977), it now seems probable that ecological limits have been exceeded in at least some areas. This has led a number of authors to suggest that economic *degrowth* is required before any kind of sustainable economy can be established (Latouche, 2009; Martínez-Alier, 2009; Schneider et al., 2010; Kallis, 2011). Although the exact meaning of the term "degrowth" is subject to some debate, it is increasingly interpreted as a socially sustainable and equitable reduction of society's material and energy throughput (Kallis, 2011). There are important differences between the degrowth and steady state perspectives (to be discussed in Chapter 2), but there is also a growing consensus that degrowth is a process of transition whose end goal is a steady state economy (Martínez-Alier, 2009; Kerschner, 2010; Research & Degrowth, 2010; Schneider et al., 2010; Kallis, 2011).

1.4. Research Questions

This thesis takes as its starting point the claim that economic growth cannot continue. It accepts the argument that a steady state economy is required for ecological sustainability, and that in order to establish a SSE, degrowth may be needed in some nations. Although much has been said about the impossibility of endless economic growth, and the social problems associated with its pursuit, far less is known about the alternative, or how it would work. This thesis aims to contribute to the development of a new "macro-economics for sustainability", by (1) providing a clear definition of a steady state economy, (2) determining how progress towards such an economy could be measured, (3) assessing how close current economies are to a steady state economy, and (4) analysing the social performance of countries closer to, and further away from, such an economy.

The two main research questions explored in this thesis are:

1. How can progress towards a steady state economy be measured at the national level?
2. What is the relationship between a country's proximity to a steady state economy and its social performance?

This thesis also touches on a number of related sub-questions, including:

- Which economies are biophysically growing, degrowing, and approaching a steady state economy?
- Are degrowing and steady state economies likely to be better or worse places to live than growing economies?
- What lessons can be learned from those countries that are closest to a steady state economy?

In order to answer these questions it is necessary to select and analyse a number of *indicators*. An indicator is a small piece of information that reflects the status of a larger system. The power of indicators is that they allow us to condense and summarise the enormous complexity of the real world into a manageable amount of information. However, indicators are *not* the real system, only a partial reflection of it. Moreover, even assuming it is possible to transform an abstract idea such as a steady state economy into a measurable set of indicators (no easy task as we shall see), indicator analyses are inevitably limited by issues of data availability and data quality. Nevertheless, indicators remain a powerful analysis tool.

Although it seems doubtful that any modern-day economies have achieved a true steady state economy, some countries are undoubtedly closer to this goal than others, even if it is not their explicit objective. A key assumption made in this thesis is that it is possible to learn something about how to achieve a steady state economy by analysing the biophysical and social conditions in the countries that are closest to this goal. It is my hope that such information will contribute to a better understanding of economic systems, and provide valuable insights into the reforms needs to achieve—not just a biophysical steady state economy—but one that is socially sustainable as well.

1.5. Organisation

The remainder of this thesis is organised into eight chapters, which proceed as follows. Chapter 2 discusses existing definitions of both degrowth and a steady state economy, explores the similarities and differences between these two concepts, and investigates a number of policies that have been proposed for achieving a SSE. Chapter 3 discusses the issue of measurement and examines a number of approaches that could be used to measure progress towards a steady state economy. The chapter suggests that separate biophysical and social indicators represent the best approach, but that a unifying conceptual framework based on ends and means is required to choose appropriate indicators and interpret the relationships between them.

Prior to selecting specific indicators, Chapter 4 explores some of the ways that specific aspects of Herman Daly's definition of a steady state economy could be interpreted, and presents a list of criteria that any set of biophysical indicators should aim to satisfy. Following this, Chapter 5 proposes a set of biophysical indicators that reflect these criteria and the key elements in Daly's definition, and proposes one or more measurable proxies for each of these based on the best data currently available. Chapter 6 takes a similar approach to generating social indicators: based largely on the declaration from the first international degrowth conference, it identifies eight intermediate ends to work towards in a SSE, and a single ultimate end to help prioritise these. For each of these social objectives, the chapter proposes a measurable proxy based on the best data currently available.

Chapter 7 compiles and analyses the full set of biophysical and social indicators. The analysis shows how close national economies are to a steady state economy, and the relationship between a country's proximity to a steady state economy and its social performance. Chapter 8 discusses the implications of the main findings of the thesis, and makes a number of recommendations—both for a new system of accounts to replace GDP, and for how to achieve a steady state economy that is socially sustainable. Finally, Chapter 9 concludes the thesis by discussing its main theoretical and empirical contributions, presenting its limitations, and making suggestions for future work.

2. What is a Steady State Economy?

Here is a point in time where out institutions are wrong. Our economics is not fit for purpose. The outcomes of this economic system are perverse. But this is not an anthem of despair. It's not a place where we should give up hope. It's not an impossibility theorem. The impossibility lives in believing we have a set of principles that works for us. Once we let go of that assumption anything is possible.

—Tim Jackson

To be able to explore the concept of a "steady state economy" (SSE), it is first necessary to define what is to be held "steady". The logical starting point is Herman Daly's definition of a SSE—a definition that has evolved somewhat over time. Within this chapter, I explore the key aspects of this definition (Section 2.1), discuss the related concept of degrowth (Section 2.2), and look at the complementary nature of these two ideas (Section 2.3). As further context to the research, I also investigate a number of policies that have been proposed for achieving a SSE (Section 2.4). These include policies to limit resource use and waste production, stabilise population, reduce inequality, secure employment, reform the monetary system, rethink business and investment, address global relationships, dismantle the culture of consumerism, and change the way we measure progress.

2.1. *Defining a Steady State Economy*

One of the earliest definitions of a SSE by Daly that I have found is from an essay entitled "The steady-state economy: toward a political economy of biophysical equilibrium and moral growth", which was reprinted in part from a 1971 lecture. The essay identifies four characteristics of a SSE:

> 1. A constant population of human bodies.
> 2. A constant population or stock of artifacts (exosomatic capital or extensions of human bodies).
> 3. The levels at which the two populations are held constant are sufficient for a good life and sustainable for a long future.
> 4. The rate of throughput of matter-energy by which the two stocks are maintained is reduced to the lowest feasible level. (Daly, 1993, p. 325)

In this definition, the emphasis is on *constant stocks* (of people and artefacts). Flows of matter and energy are also mentioned, but the target for these is simply to reduce them to the "lowest feasible level". There is no requirement that the flows also be held constant, nor is there an explicit requirement that they be maintained within ecological limits. The lowest feasible flow could still be higher than ecosystems could support. The definition is largely biophysical in nature, although the third list item does include a social element by requiring that the stocks be sufficient for "a good life". Later in the same essay, Daly also makes a point of emphasising what is *not* to be held constant in a steady state economy, namely "technology, information, wisdom, goodness, genetic characteristics, distribution of wealth and income, product mix, and so on" (Daly, 1993, pp. 325-326).

The definition provided in the first edition of Daly's book *Steady-State Economics*, published in 1977, is very similar to the definition above. It defines a SSE as:

> an economy with constant stocks of people and artifacts, maintained at some desired, sufficient levels by low rates of maintenance "throughput", that is, by the lowest feasible flows of matter and energy from the first stage of production (depletion of low-entropy materials from the environment) to the last stage of consumption (pollution of the environment with high-entropy wastes and exotic materials). It should be continually remembered that the SSE is a *physical* concept. If something is nonphysical, then perhaps it can grow forever. If something can grow forever, then certainly it is nonphysical. (Daly, 1977, p. 17)

The definition in the second edition of the book, published in 1991, also maintains the requirement for constant stocks. Constant stocks imply that input flows and output flows be equal, and this is emphasised in the definition. However, equal flows could still increase over time (so long as both flows increased at the same rate), without violating the constant stocks condition. The definition in the second edition does, however, introduce a further condition, which is that the flows be kept within the regenerative and assimilative capacities of ecosystems:

> A steady-state economy (SSE) is an economy with constant stocks of artifacts and people. These two populations (artifacts and people) are constant, but not static. People die, and artifacts depreciate. Births must replace deaths, and production must replace depreciation. These "input" and "output" rates are to be equal at low levels so that life expectancy of people and durability of artifacts will be high. Since the input flow of matter-energy equals the output flow when both populations are constant, the flows may be merged into the concept of "throughput." The throughput flow begins with depletion, followed by production, depreciation, and finally pollution as the wastes are returned to the environment. The economy maintains itself by this throughput in the same way that an organism maintains itself by its metabolic flow. Both economies and organisms must live by sucking low-entropy matter-energy (raw materials) from the environment and expelling high-entropy matter-energy (waste) back to the environment. In the SSE this

> throughput must be limited in scale so as to be within the regenerative and assimilative capacities of the ecosystem, insofar as possible. (Daly, 1991, pp. 180-182)

In his 1996 book *Beyond Growth*, Daly makes another change to the definition, by shifting the focus from constant stocks to constant flows, and suggesting that stocks of people and artefacts may increase temporarily provided that flows do not. He also reiterates the biophysical nature of the definition, and points out that zero growth in energy and material flows is not equivalent to zero growth in Gross National Product (GNP):

> It is necessary to define what is meant by the terms "steady-state economy" (SSE) and "growth economy." Growth, as here used, refers to an increase in the physical scale of the matter/energy throughput that sustains the economic activities of production and consumption of commodities. In an SSE the aggregate throughput is constant, though its allocation among competing uses is free to vary in response to the market… By this definition, strictly speaking, even the stocks of artifacts or people may occasionally grow temporarily as a result of technical progress that increases the durability and reparability (longevity) of artifacts. The same maintenance flow can support a larger stock if the stock becomes longer-lived. The stock may also decrease, however, if resource quality declines at a faster rate than increases in durability-enhancing technology.
>
> The other crucial feature in the definition of an SSE is that the constant level of throughput must be ecologically sustainable for a long future for a population living at a standard of per capita resource use that is sufficient for a good life. Note that an SSE is not defined in terms of gross national product. It is not to be thought of as "zero growth in GNP." (Daly, 1996, p. 31-32)

And finally, in a recent report to the UK Sustainable Development Commission, Daly acknowledges the validity of both the constant stock and constant flow definitions, but points out that a definition based on constant flows is easier to operationalise:

> Following Mill we might define a SSE as an economy with constant population and constant stock of capital, maintained by a low rate of throughput that is within the regenerative and assimilative capacities of the ecosystem. This means low birth equal to low death rates, and low production equal to low depreciation rates. Low throughput means high life expectancy for people and high durability for goods. Alternatively, and more operationally, we might define the SSE in terms of a constant flow of throughput at a sustainable (low) level, with population and capital stock free to adjust to whatever size can be maintained by the constant throughput beginning with depletion and ending with pollution. (Daly, 2008, p. 3)

In summary, a steady state economy is an economy that is defined in biophysical terms by three quantities: constant flows, constant stocks, and sustainable scale. Although Daly has altered the relative emphasis placed on these quantities over time, I would argue that all three are important to the definition (a topic I return to in Chapter 4 when I begin to operationalise the definition).

2.2. *Defining Degrowth*

While the concept of a steady state economy was largely developed by Daly in an American context (and has primarily spread to other English-speaking countries), the degrowth movement emerged in France (as *la décroissance*), and has primarily spread to other European countries. According to Serge Latouche (2009), one of the main proponents of degrowth, the movement has two main sources of inspiration. The first is the ecological critique of economics, largely originating with the work of Nicholas Georgescu-Roegen. In his 1975 paper "Energy and economic myths", Georgescu-Roegen argued that the biophysical arguments that were being used by Daly and others to promote a steady state economy suggested the most desirable type of economy, from a thermodynamic perspective, was in fact one in which resource use was "declining" (not stable), due to the impossibility of perfect recycling (Georgescu-Roegen, 1975). The term *décroissance* (degrowth) appeared in 1979 when Jacques Grinevald and Ivo Rens translated some of the major works of Georgescu-Roegen into French, under the title *Demain la décroissance* (Tomorrow, degrowth).

The second source of inspiration for degrowth is the culturalist critique of economics, which criticises the notion of "development" itself. According to Martínez-Alier et al. (2010), Ivan Illich is probably the main source of this critique, although others such as André Gorz, Francois Partant, Jacques Ellul, Bernard Charbonneau, and Cornelius Castoriadis are important as well. The failure of development in the global South, and the loss of a sense of direction in the global North, led these thinkers to question the consumer society, and its focus on progress, science, and technology (Latouche, 2009).

According to Latouche, degrowth is "not a concept", but a "political slogan with theoretical implications… primarily designed to make it perfectly clear that we must abandon the goal of exponential growth" (Latouche, 2009, pp. 7-8). He emphasises that degrowth should not be interpreted as "negative growth", and that in fact it would be more accurate to use the term "a-growth" (in the same sense as the word "atheism") because abandoning the pursuit of economic growth is akin to abandoning a religion, and this is what degrowth is really calling for (Latouche, 2009; 2010). In Latin languages such as French, the verb for "to degrow" (*décroître*) and "to disbelieve" (*décroire*) are very close. Latouche suggests that in order to degrow it is first necessary to disbelieve, i.e. to abandon the religion of the economy, growth, progress, and development (Latouche, 2010).

Despite Latouche's (2004) further claim that degrowth is "not a concrete project", there seems to be an increasing desire to transform it into one. This is evidenced by the wealth of articles in the proceedings of the first international degrowth conference held in Paris in 2008 (Flipo and Schneider, 2008), and the strong focus on policy proposals at the second international conference held in Barcelona in 2010 (http://www.degrowth.eu).

Van den Bergh (2011) identifies five main interpretations of degrowth within the literature, which he labels as (1) GDP degrowth, (2) consumption degrowth, (3) work-time degrowth, (4) radical degrowth, and (5) physical degrowth. He is critical of degrowth, arguing that these multiple interpretations make degrowth a rather ambiguous and confusing concept.

Kallis (2011), however, argues that degrowth is less ambiguous than suggested by van den Bergh. He defines degrowth from an ecological-economic perspective as "a socially sustainable and equitable reduction (and eventually stabilisation) of society's throughput" (Kallis, 2011, p. 874). Of the five interpretations provided by van den Bergh, this definition most closely resembles "physical degrowth". However, Kallis attempts to link the various interpretations together. He notes that physical degrowth is effectively equivalent to a decrease in material production and consumption (i.e. "consumption degrowth"), which can in turn be expected to lead to a decline in GDP (i.e. "GDP degrowth")—although the latter is not the goal *per se*. Furthermore, he argues that in order to actually achieve degrowth, new policies such as a reduction in working hours will be required (i.e. "work-time degrowth"), and a fundamental rethink of capitalist institutions may also be needed ("radical degrowth"). In other words, van den Bergh's five seemingly conflicting interpretations of degrowth may be reinterpreted as mutually-reinforcing elements of a strategy with a clear goal, i.e. to reduce society's material and energy throughput in a socially sustainable and equitable manner.

The most detailed definition of degrowth published to date is probably the one contained in the declaration from the first international conference on degrowth, held in Paris in 2008. The declaration is the result of a workshop entitled "Toward a Declaration on Degrowth", whose goal was to produce a statement that would not only reflect the points of view of conference participants, but also articulate their shared vision of the degrowth movement (Research & Degrowth, 2010). The following excerpts from the Paris Declaration provide a succinct definition of degrowth:

> We define degrowth as a voluntary transition towards a just, participatory, and ecologically sustainable society… The objectives of degrowth are to meet basic human needs and ensure a high quality of life, while reducing the ecological impact of the global economy to a sustainable level, equitably distributed between nations… Once right-sizing has been achieved through the process of degrowth, the aim should be to maintain a "steady state economy" with a relatively stable, mildly fluctuating level of consumption. (Research & Degrowth, 2010, p. 524)

The full text of the declaration includes elements from all of van den Bergh's interpretations, with the notable exception of "GDP degrowth". The declaration is in agreement with other degrowth literature (e.g. Martínez-Alier et al., 2010; Schneider et al., 2010; Kallis, 2011) which sees a decrease in GDP as a likely *result* of degrowth, but not as one of its goals. As Kallis (2011) states, "degrowth is not equivalent to negative GDP growth in a growth economy. This has its own name: recession, or if prolonged, depression."

2.3. The Complementary Nature of Degrowth and a SSE

An important outcome of the Paris conference, which is reflected in the declaration and other recent literature (e.g. Martínez-Alier, 2009; Kerschner, 2010; Schneider et al., 2010; Kallis, 2011), is that degrowth is a *process* whose end goal is something resembling a steady state economy. This message is elaborated on by Kerschner (2010), who explores the relationship between the ideas of degrowth and a steady state economy in detail, and concludes that the two concepts are complementary. He argues that degrowth in the global North provides a way to achieve the goal of a globally equitable steady state economy by providing the environmental space needed for a certain amount of economic growth in the global South. Broadly speaking, countries in the global North must follow a degrowth path to reach a steady state economy (Figure 2.1), while countries in the global South must follow a path of decelerating growth (or perhaps a new model of development altogether).

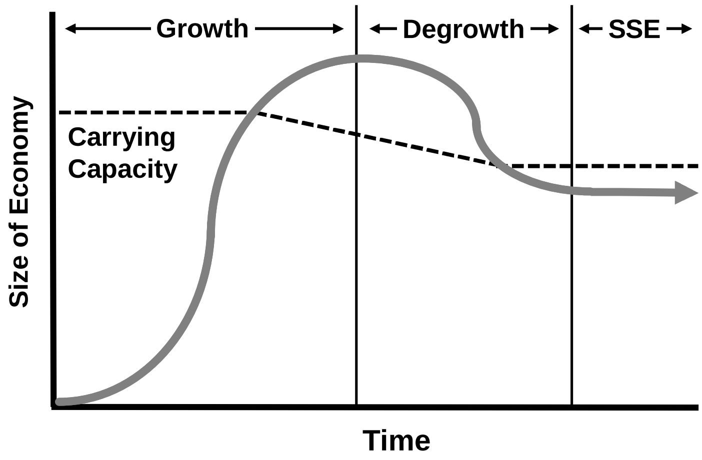

Figure 2.1: The degrowth transition to a steady state economy. The figure illustrates the transition that wealthy nations must go through to arrive at a steady state economy (SSE). The figure also represents the overall global transition that must occur.

The term "social metabolism" (Ayres and Simonis, 1994; Fischer-Kowalski, 1998) may be used to describe the flow of materials and energy that are necessary to sustain economic activity. Haberl et al. (2011) describe two major transitions that have occurred (and are still occurring) in the social metabolism of human societies. The first is the transition from a hunter-gatherer regime to an agrarian regime, and the second is the transition from an agrarian regime to an industrial one. The authors also describe the need for a third great transition towards sustainability—a notion that has much in common with what I refer to in this thesis as the "degrowth transition to a steady state economy". Degrowth may be seen as an attempt to envision this third transition, and a steady state economy an attempt to operationalise the new regime.

An important point to emphasise is that a steady state economy is not just an economy where throughput is kept constant; it is also an economy where throughput is maintained within ecological limits. If flows of matter or energy exceed ecological limits, then degrowth is *required* before a steady state economy can be established (Figure 2.1). An economy with constant throughput that exceeded the regenerative and/or assimilative capacities of the containing ecosystem would not, by definition, be a steady state economy.[3]

[3] That said, it would still be an improvement over an economy that continued to grow even further beyond ecological limits.

Although a steady state economy is defined in biophysical terms, Daly and other steady state economists often claim that certain progressive social policies would be needed in order to actually achieve a steady state economy. For example, the report of the Steady State Economy Conference, held in Leeds, UK in 2010, describes ten key areas where change would be needed to achieve a steady state economy. Among others, the report includes policies to reduce income inequality, reform the monetary system, secure full employment, and change consumer behaviour (O'Neill et al., 2010). In this way the concept of a steady state economy is increasingly becoming associated with certain social goals as well, such as fair distribution of income and a high quality of life.

In general, though, more emphasis is placed on social goals by proponents of degrowth than by steady state economists. For example, the Paris Declaration states that degrowth is to be characterised by an emphasis on quality of life, the fulfilment of basic human needs, equity, increased free time, conviviality, sense of community, individual and collective health, participatory democracy, and a variety of other positive social outcomes (Research & Degrowth, 2010).

Although degrowth and a steady state economy are increasingly being seen as complementary concepts, there is still some disagreement on how the transition to a steady state economy might be achieved in practice. Kallis (2011) identifies three areas where degrowth builds on, or potentially diverges from, steady state economics. First, he identifies a concern in the degrowth community about whether the transition to a steady state economy can be achieved through economic reforms such as cap-and-trade mechanisms, which are advocated by Daly as a way to limit resource use. As Schneider et al. (2010, p. 511) explain, "degrowth theorists and practitioners support an extension of human relations, instead of market relations". Second, degrowth opens up the possibility of a selective downscaling of the stock of built capital. This is a topic that has not been discussed by steady state economists, but it seems unlikely that they would object to it in principle. Third, and perhaps most importantly, degrowth scholars see a potential incompatibility between the foundational institutions of market economies, and the goal of a degrowth transition to a steady state economy. In particular, degrowth scholars are sceptical that a steady state economy can be achieved in a capitalist system (Latouche, 2009; Kallis, 2011), while steady state economists tend to be more optimistic about this possibility (Czech and Daly, 2004; Lawn, 2005b; 2011). That said, there are also advocates of a steady state economy who believe that such an economy is incompatible with capitalism (e.g. Smith, 2010).

The three areas discussed by Kallis (2011) are arguably places where degrowth proposes more radical changes than steady state economics. A fourth area, not mentioned by Kallis, where steady state economics proposes more radical changes, is with respect to population growth. A key element of a steady state economy is a stable population. Although the Paris Declaration states that the aim of degrowth is to achieve a steady state economy, it never explicitly mentions stabilising (or reducing) population.[4] In fact, Latouche (2009) argues that reducing population is "a false solution" (p. 25), because it shifts attention away from the real problem, which is "the logic of excess that governs the economic system" (p. 28). He argues that it is necessary to deal with over-consumption before dealing with demographic issues. This perspective is not shared by all degrowth scholars, however. Martínez-Alier (2009) and Schneider et al. (2010) both argue that the degrowth transition would be helped if the human population would peak at around 8 billion, and then decline somewhat, while Kerschner (2010) argues that population must inevitably decrease or be stabilised if the economy is to degrow or be stabilised, respectively. In general, though, degrowth authors emphasise that if population is to decrease or be stabilised, this outcome must be the result of bottom-up processes that empower women, and not the result of state-imposed population control policies.

It is also worth touching on the differences between the notion of a degrowth transition to a SSE, and the concept of sustainable development. Following the Brundtland Report, sustainable development is generally taken to mean "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). In his book *Beyond Growth*, Daly attempted to operationalise sustainable development as "development without growth", and thus steer the sustainable development agenda towards the goal of a steady state economy (Daly, 1996).

[4] Population growth was a divisive topic within the working group that drafted the declaration on degrowth (of which I was a member). Early drafts of the declaration included stable population as an explicit goal, but this goal was removed in the final version due to the debate it caused.

This interpretation was not widely adopted, however, and sustainable development continues to be a vague concept which some would argue equates to little more than business as usual. Jim MacNeill, the chief architect and lead author of the Brundtland Report, has remarked that the most important imperative of the report, "to merge environment with economics in our processes of decision-making", has been completely forgotten (MacNeill, 2006, p. 6). More than twenty years after the start of the sustainable development era, humanity is still faced with the same problems that sustainable development was supposed to solve. It is perhaps not surprising then that proponents of degrowth tend to shy away from the concept of sustainable development, viewing it as a false project that delays the urgent changes that are needed (Martínez-Alier et al., 2010). While steady state economists generally use the word "development" in a positive way, interpreting it to mean "qualitative improvement" (e.g. Daly, 1996; Lawn, 2011), proponents of degrowth often interpret the word more negatively, associating it with attempts by the global North to impose a particular economic model on the global South. As Latouche (2009, pp. 10-11) writes, "The word 'development' is toxic, no matter which adjective we use to dress it up."

Finally, it is important to state that a steady state economy should not be viewed as a panacea for all environmental problems. Many of today's most pressing problems (e.g. climate change, biodiversity loss, and groundwater depletion) are caused by the overall growth in material and energy throughput (Giljum et al., 2009; Krausmann et al., 2009). The end of economic growth, and the establishment of a SSE, would greatly reduce the pressure on ecosystems by limiting the quantity of this material and energy throughput. However, a SSE would not solve problems related to the quality (or composition) of this throughput. Certain substances have a much greater environmental impact than others (e.g. heavy metals versus sand). Even in a world where aggregate throughput was constrained, conventional environmental regulation would still be needed to limit the use of harmful substances, protect species at risk, and manage land cover change. In short, a SSE is best viewed as a necessary, but not sufficient, condition for sustainability.

2.4. *Achieving a Steady State Economy*

Despite the longstanding critique of the economic growth model, the alternative (i.e. a steady state economy, or the degrowth transition to one) remains relatively undeveloped. Numerous books and articles have been written that criticise economic growth as a policy goal, and conclude that something resembling a SSE is needed (e.g. Douthwaite, 1999; Czech, 2000b; Woodward and Simms, 2006; Victor, 2008; Jackson, 2009b; 2009a; Simms et al., 2010). However, in the vast majority of these sources, the focus is on the problem (economic growth), rather than the solution (a SSE). Books in this area typically contain eight or ten chapters that describe the biophysical and social problems associated with the pursuit of economic growth, followed by just one or two chapters that provide a flavour of the alternative.

Although the dominant focus in the literature is on the problem and not the solution, there are some texts that do focus on the latter. The earliest (and still one of the most important) is Herman Daly's book *Steady-State Economics*. In this book, Daly (1977) suggests that three institutions would be required in order to achieve and maintain a steady state economy: (1) an institution for stabilising the stock of built capital and keeping throughput within ecological limits, (2) an institution for stabilising population, and (3) a distributionist institution to limit inequality. In his more recent writings, Daly (2008; 2010) proposes ten policy reforms for achieving a SSE. The first three of these are essentially modified versions of the three institutions proposed in his earlier work, but the remaining seven introduce new ideas (these are discussed later).

Other authors such as Peter Victor and Tim Jackson have also contributed valuable ideas on how to achieve a successful economy without growth. Victor's (2008) main contribution is a model of the Canadian economy which he uses to test what would happen in various low-growth scenarios over a thirty-year period (from 2005 to 2035). Although he acknowledges the biophysical nature of Daly's definition of a steady state economy, Victor examines what might be achieved if constant GDP were used as the definition. In support of this approach he writes, "Providing energy and material intensities (measured as physical amounts per dollar) do not increase when GDP is constant, then a steady-state defined in terms of GDP will coincide with constant or declining material and energy throughput so that all agendas are satisfied" (Victor, 2009).[5] Using his model of the Canadian economy, Victor (2008) shows that if the right policies are phased in over time, unemployment can be reduced to historically low levels, leisure time can be increased, poverty can be virtually eliminated, greenhouse gas emissions can be reduced, and government debt can be kept at a healthy level—all without the need for economic (i.e. GDP) growth.

Jackson's (2009a; 2009b) main contribution is probably his analysis of the "social logic of consumerism" and its role as a driver of economic growth. He proposes that in order to achieve a prosperous non-growing economy we must replace our narrow definition of materialistic prosperity with one centred on providing the capabilities for people to flourish—within ecological limits.

Harris (2010), on the other hand, describes an "eco-Keynesian" vision of a steady state economy that rejects the notion of market optimality and calls for greater government intervention to both stabilise economic systems and preserve essential ecosystem functions. He suggests that moving away from the single (neoclassical) goal of utility maximisation would allow for the creation of an economy with different, pluralistic goals such as full employment, the provision of basic needs, social and infrastructure investment, and income equity.

Despite these (and other) important contributions, a detailed blueprint for how to achieve a SSE is still lacking. For this reason, I began working with a small team of volunteers to organise the first "Steady State Economy Conference", which was held in Leeds in June, 2010. The conference had two main aims. The first was to raise awareness about the growing volume of evidence showing that economic growth is (a) not environmentally sustainable, and (b) not improving people's lives in wealthy countries like the UK. The second—and arguably more important—aim was to identify specific, implementable policies to achieve a steady state economy within the UK. Over 250 economists, scientists, NGO members, business leaders, government employees, and interested citizens attended and contributed.

[5] Victor has also indicated that he wanted to explicitly engage with pro-growth advocates, whose arguments are always made in terms of growth in real GDP (P. Victor, pers. comm., 2011). Not all agendas are satisfied by this approach, however, as Victor's model does not incorporate the additional steady state requirement for material and energy throughput to be kept within ecological limits.

The conference used interactive workshops to investigate ten key areas where change is likely required to achieve a steady state economy. The results of the conference are documented in a multi-author report entitled *Enough is Enough: Ideas for a Sustainable Economy in a World of Finite Resources* (O'Neill et al., 2010), and were further publicised by a short letter in the journal *Nature* (O'Neill, 2010). Rob Dietz and I have recently expanded the material in the report into a book, which will be published later this year (Dietz and O'Neill, in press). Although far from comprehensive, the report and book include the most detailed discussion of policies for a steady state economy written to date.

In the following subsections, I discuss policy reforms in a number of different areas that have been proposed for achieving a steady state economy. These policy proposals are based in part on the work of ecological economists such as Herman Daly, Peter Victor, and Tim Jackson, and also on the results of the Steady State Economy Conference and the report that followed it. I present these policy proposals here primarily as background for the research conducted in this thesis. As we shall see in Chapters 7 and 8, some of the empirical findings of the thesis support the policy proposals, while others call them into question.

2.4.1. Limiting Resource Use and Waste Production

As discussed in Section 2.1, a steady state economy is defined as an economy in which resource use and waste production are stabilised and brought within ecological limits. A common recommendation for how to achieve a SSE is to establish firm targets for the use of specific resources, based on the best scientific evidence available about ecological limits. Daly (1990; 2005) suggests three general principles of resource management that could be applied in a SSE. These principles acknowledge the different nature of renewable and non-renewable resources:

1. Limit the use of all resources to rates that ultimately result in levels of waste that can be absorbed by the ecosystem.
2. Exploit renewable resources at rates that do not exceed the ability of the ecosystem to regenerate the resources.
3. Deplete non-renewable resources at rates that, as far as possible, do not exceed the rate of development of renewable substitutes.

Two strategies that have been proposed to limit the rate of renewable and non-renewable resource use are (1) cap-and-trade systems, and (2) ecological tax reform. Cap-and-trade systems work by setting an overall cap on the use of a resource, dividing this cap into permits that are distributed (or potentially auctioned) to industries, and then allowing permit holders to trade their shares on an open market. Ecological tax reform, on the other hand, involves reducing taxes on things like labour and income (which people generally want more of), while increasing taxes on things that society wants to actively discourage or limit, such as CO_2 emissions or vehicle miles travelled.[6] Advocates of ecological tax reform usually recommend that the taxes should be fiscally neutral, otherwise government may become reliant on the income generated by them, and not set the tax level high enough to discourage the activity in question (Daly, 2008; Victor, 2008; Jackson, 2009a).

As Victor (2008) points out, the two strategies are symmetric: under a cap-and-trade system, the quantity of resource use is set by government, and the price of resource use is established by the market (through auction and/or trade). With ecological taxes, the price of resource use is set by government (via the tax imposed), while the quantity used is determined by the market, based on how willing firms are to pay this price.

The advantage of a cap-and-trade system is that—if successfully implemented—it guarantees that ecological limits are respected, which taxation does not. The advantage of ecological tax reform is that it is probably easier to implement, since governments already have plenty of experience with taxation (Victor, 2008). Most authors who discuss ways of limiting resource use recommend applying both approaches (e.g. Daly, 2008; Victor, 2008; Jackson, 2009a). As Victor (2008, pp. 207-208) notes, "In the end, what really matters for managing without growth is that quantitative targets on resource inputs and waste outputs be established based on Daly's principles."

Daly (1977; 2008; 2010) generally argues that the main controls on resource use should be imposed at the input end because depletion is more spatially concentrated than pollution, and hence easier to monitor. In his words, "there are fewer mines, wells, and ports than there are smokestacks, garbage dumps, and

[6] In his LowGrow model, Victor (2008) uses a $200 per tonne tax on geenhouse gas emissions, which reduces projected emissions in Canada considerably.

drainpipes" (Daly 1977, p. 61). He argues that by limiting aggregate resource depletion, pollution would also be limited due to the law of conservation of matter and energy. However, he also notes that ecosystems may have a lower capacity to assimilate wastes than to (re)generate resources, and therefore caps on resource use should be set based on whichever factor is more limiting (Daly, 2010).

Finally, O'Neill et al. (2010) stress that any new resource use policy must ensure that all members of society receive a fair share of the limited supply of resources. They note that a detailed accounting system will be required to measure—not just the material throughput of the economy—but also the social and environmental consequences of this throughput.

2.4.2. Stabilising Population

In his early writings, Daly (1977) proposes a system of transferable birth licences as a way to stabilise population—an idea first put forward by Kenneth Boulding. The proposal involves issuing every person (or perhaps only every woman) with a number of birth licences equal to replacement fertility. If the licences were issued only to women, each woman might receive 2.1 licences. The licences would be divided into units of one-tenth, and could be transferred between individuals by sale or by gift. Thus couples who wanted to have families larger than two children could do so by obtaining licences from those with smaller families, and individuals having fewer than two children could potentially be rewarded. Given that many people would probably object to such a system due to the way in which it curtails what is seen to be a basic human freedom, Daly (1977) notes that other population stabilisation plans could be substituted instead. In his more recent writings, he suggests that net migration has become more of a problem for many wealthy countries than natural increase in population (i.e. births minus deaths). He therefore stresses the importance of achieving a balance between births plus immigration, and deaths plus emigration (Daly, 2008).

Victor (2008) notes that immigration is one of the main drivers of economic growth in wealthy nations such as Canada. He points out that Canada admits immigrants for three reasons: (1) to reunite families, (2) to protect refugees, and (3) to contribute to the growth of the economy. Of these three categories, the last is the largest, with 60% of immigrants being admitted for economic reasons (Victor, 2008, p. 197). Canada, and many other wealthy countries, attempt to attract the most productive and well-educated people. By doing so, however, they deprive poorer countries of these people. Victor suggests that Canada could move a long way towards stabilising its population by reducing the number of immigrants accepted solely for economic reasons. Such a policy would likely reduce economic growth in Canada, while at the same time redirecting it to poorer nations where growth is still needed.

O'Neill et al. (2010) suggest that wealthy nations should develop, adopt, and implement a *non-coercive* population policy. They state that this policy should aim to balance immigration and emigration, and promote incentives to limit family size to two or fewer children. To stabilise population globally, O'Neill et al. suggest working towards providing education, access to birth control, and equal rights for women everywhere. There are roughly 80 million unplanned pregnancies a year worldwide—a number that is almost equal to global population growth (Guillebaud, 2007). If access to family planning could be provided to all women worldwide, this single step would go a long way towards stabilising global population.

Interestingly, Jackson does not discuss the need to stabilise population in either the book or report version of *Prosperity Without Growth* (Jackson, 2009a; 2009b). The topic is conspicuously absent from an otherwise extensive list of policies to achieve a prosperous non-growing economy.

2.4.3. Limiting Inequality

Daly argues that it would be necessary to limit the degree of inequality in a SSE. To do so, he proposes a minimum and maximum limit on income, and a maximum limit on wealth (Daly, 1977). He argues that limits on inequality would be required in a SSE for two reasons. First:

> Without such limits, private property and the whole market economy lose their moral basis, and there would be no strong case for extending the market to cover birth quotas and depletion quotas as a means of institutionalizing environmental limits. Exchange relations are mutually beneficial among relative equals. Exchange between the powerful and the powerless is often only nominally voluntary and can easily be a mask for exploitation (Daly, 1977, pp. 53-54)

Second, Daly argues that without aggregate growth, the only way to alleviate poverty is through redistribution (Daly, 2008). Since there would be a limit to the stock of built capital and the flow of resources in a SSE, there would also be a limit to the total income in the economy. Therefore it would be necessary to impose a limit on per capita income and wealth in order to ensure that the non-growing supply of income did not unfairly accrue to a small group of individuals.

Other authors, such as Wilkinson and Pickett (2009), have made even stronger arguments in favour of reducing inequality. In their book *The Spirit Level,* they show that high inequality is associated with a multitude of health and social problems, including increased mental illness, more prevalent drug use, poorer physical health, lower life expectancy, inferior educational performance, heightened violence, and higher rates of imprisonment. Moreover, they also suggest that high levels of inequality lead to unhealthy status competition (as everyone tries to "keep up with the Joneses"), and therefore to higher levels of material consumption than are necessary to meet people's needs.

As noted in Section 1.1, a number of arguments are often made in support of economic growth as a policy goal. A rather bold one comes from Henry Wallich, a former governor of the Federal Reserve in the U.S., who said, "Growth is a substitute for equality of income. So long as there is growth there is hope, and that makes large income differential tolerable" (Wallich, 1972). As Wilkinson and Pickett (2009) point out, however, if this relationship is true, then it is also valid the other way around. If growth is a substitute for equality, then greater equality is a substitute for growth—and possibly a precondition for a steady state economy.

In order to reduce inequality, Jackson (2009a) makes a number of suggestions. In addition to a minimum and maximum income, he suggests revised income tax structures, improved access to education, anti-discrimination legislation, anti-crime measures, and improvements to the local environment in deprived areas. O'Neill et al. (2010) recommend that a concerted effort should be made to democratise the institutions where inequalities originate, in particular the places where people work. They suggest that policies that promote employee ownership, co-operatives, and other model of democratic control should be pursued to reduce inequality over the long term.

2.4.4. Securing Full Employment

Over time, technological progress has allowed businesses to become more efficient at producing goods and services, such that a given volume of goods can be produced with much less labour today than was previously possible. Instead of using new technologies to reduce working hours, however, we have largely used them to produce more goods and services (i.e. grow the economy), while keeping working hours relatively constant. The choice to use labour productivity in this way has made economic growth a requirement for creating and maintaining jobs. As Peter Victor remarks:

> The shortage of employment has become more important than the shortage of products. Whereas in the past we needed to have more people at work because we needed the goods and services they produce, now we have to keep increasing production simply to keep people employed (Victor, 2008, pp. 12-13).

In a steady state economy, however, it would not be possible to continue to increase production if it resulted in an increase in resource use and waste emissions. Indeed, for wealthy countries to make the transition to a SSE, resource use and waste emissions will likely need to be reduced to be within ecological limits (i.e. a process of degrowth). If improvements in resource efficiency cannot achieve these reductions on their own (and there is little evidence to suggest that they will be able to do so), [7] then reductions in production and consumption will also be required. All else being equal, with less production, there will be less work to be done, which would result in rising unemployment unless specific policies are adopted to prevent this from happening.

The solution recommended by almost all authors commenting on how to achieve a SSE is to use gains in labour productivity to increase leisure time—instead of production—by gradually shortening the paid working day, week, year, and career (Hayden, 1999; Lintott, 2004; Sanne, 2007; Daly, 2008; Victor, 2008; Jackson, 2009a; O'Neill et al., 2010). Instead of technological progress causing some people to lose their jobs while others keep theirs, the reduced amount of labour required could be spread more evenly throughout the population. Everyone would work a bit less, but no one would lose their jobs. Moreover, a number of authors suggest that reducing working hours would also improve people's well-being by giving them more time to spend with friends and family, partici-

[7] See, for example, "Chapter 5: The Myth of Decoupling", in Jackson (2009a; 2009b).

pate in community, engage in creative activities, volunteer, and pursue personal and spiritual development (Hayden, 1999; Lintott, 2004; Speth et al., 2007; O'Neill et al., 2010).

In order to encourage a reduction in working hours and improve work–life balance, Jackson (2009a) suggests providing greater flexibility to employees with regard to their working hours, reducing discrimination against part-time work, and providing incentives for employees to take parental leave and sabbatical breaks. O'Neill et al. (2010) go somewhat further and suggest that (1) individuals should be given the right to adjust their working patterns to their preferences, (2) rules should be introduced at the sectoral and/or national level to set a cap on the amount of paid working hours, and (3) support and incentives should be offered to encourage an overall reduction in paid working time that exceeds increases in labour productivity.

Although working time reduction is the most frequently-cited proposal for securing employment in a SSE, other proposals have also been put forward. One such proposal is to shift the structure of the economy towards sectors where labour productivity growth is low (or even negative), such as personal and social services (Jackson and Victor, 2011). Another proposal is for the state to act as "employer of last resort" and create jobs for those wishing to work but unable to find employment—a so-called "job guarantee" (Lawn, 2004; 2005a; O'Neill et al., 2010; Alcott, in press). Other authors, such as Daly (2008), argue that it may even be necessary to rethink how people earn income. If there is simply not enough work to go around, then the principle of distributing income through jobs becomes untenable. If a minimum income were instituted (as proposed in the previous section), then the link between having a job and being able to meet one's basic needs would be broken, reducing the importance of achieving full employment in the conventional sense.

2.4.5. Reforming the Monetary System

A particularly important driver of economic growth, which has only recently started to receive the attention of ecological economists, is the way that money is created. In modern economies, most of the money in circulation is created by private banks in the form of interest-bearing loans. In the UK, for example, this money—which is created electronically and loaned into existence by private banks—accounts for about 97% of the money in circulation, dwarfing the 3% of money created by the Bank of England and the Royal Mint in the form of banknotes and coins (Robertson and Bunzl, 2003).

Banks are able to create money because they can issue loans far in excess of their deposits. Historically, UK banks were restricted to lending certain multiples of their deposits (i.e. "fractional reserve banking"), but there is now very little restriction on how much money banks can create (Ryan-Collins et al., 2011).

Money that is created by banks as loans must eventually be paid back by the borrower. This means that the borrower must go out into the real economy and earn this money, generating economic activity in the process. Furthermore, in addition to the principal, borrowers must also pay back interest on their loans. When a loan is paid back the principal ceases to exist, but the same does not apply to the interest. This accrues to the bank.

Because more money must be paid back than was borrowed in the first place, the total money supply must expand over time if loan defaults are to be avoided. This additional money can only come from one place: more loans. In other words, for the monetary system as it is currently set up to function, the total amount of debt must increase over time.

This debt-based monetary system drives three things: (1) *economic growth*, as the need to pay back an increasing amount of debt requires an increasing amount of economic activity, (2) *inflation*, as the money supply tends to increase faster than the volume of goods and services produced, and (3) *economic instability*, because if the banks stop lending, the system collapses (Douthwaite, 2006).

In order to eliminate these drivers and facilitate the transition to a SSE, a number of authors have proposed that the current debt-based banking system should be gradually transformed into a full-reserve banking system (Douthwaite, 2006; Cato, 2008; Daly, 2008; Lawn, 2010; O'Neill et al., 2010; Douthwaite, in press). In such a system, private banks would be prohibited from issuing money as debt, and the power to create money would be transferred to a public authority. This authority would determine the amount of money necessary to facilitate exchange in the economy, create it debt-free, and transfer it to the government to spend into existence.

Under such a system, savings and investment would be separated. A customer could choose to save money by depositing it in a bank, where it would remain. This money would not earn interest and the customer might be charged by the bank for this safe-keeping service. Alternatively, the money could be invested, through a bank or other financial intermediary, and potentially earn interest. In this case, the customer would have no access to the money until the loan was repaid, in contrast to the current system where deposits can be redeemed on demand, even if they have been loaned by the bank to someone else (Daly, 2010; Dyson et al., 2010).

Proponents of a full-reserve banking system suggest that in order to prevent inflation, government taxation and expenditure could be linked to the system of money creation (Huber and Robertson, 2000; Daly, 2010; Dyson et al., 2010). If prices started to rise, money could be removed from circulation using taxes. If prices started to fall, additional money could be created and spent into existence. Dyson et al. (2010) argue that such a system would allow the size of the money supply, and hence inflation, to be controlled more effectively than is possible with the current debt-based monetary system.

2.4.6. Rethinking Business and Investment

Very little has been written about how businesses would function in a steady state economy. It is a topic that is absent from most of the main sources that provide some vision of what a steady state economy might look like (e.g. Daly, 2008; Victor, 2008; Jackson, 2009a).[8] One of the few sources to discuss the topic is O'Neill et al. (2010), who propose two theories on what effect a SSE would have on business.

The first theory is that the current model of shareholder-owned profit-making corporations is adaptable to a steady state economy because profit and growth are two different things. Profit is the difference between a firm's revenue and its costs, whereas growth is an increase in total production. Thus a firm can grow without increasing profits, and increase profits without growing. Furthermore, even if growth and profits are linked at the level of the firm, it is possible to imagine a situation where as some companies grow, others go out of business, such that the total size of the economy remains the same.

[8] Recent articles such as Smith (2010) and Lawn (2011), which discuss whether steady state capitalism is viable, do touch on issues related to business in a SSE, however.

The second theory opposes the first. It argues that the context in which businesses operate is very important, and that there is a connection between profit and growth. Companies must compete against one another for market share (or simply to survive), and it is possible to make greater profits through economies of scale (i.e. the more a company produces, the cheaper unit costs become, and the easier the company can reach the financial break-even point). Furthermore, investors are unlikely to invest in a company that is not growing. Thus the profit motive itself may be a problem for a steady state economy.

O'Neill et al. (2010) suggest that achieving a SSE will require a shift towards alternative forms of business organisation such as co-operatives, foundations, and community interest companies. These organisational forms are not preoccupied by growth in the same way as profit-maximising shareholder corporations. The primary goal of community interest companies, for example, is to achieve a socially beneficial aim; financial profit is a secondary motive. The authors recommend that policy makers should encourage these alternative forms of business by (1) making it simpler to set up (or change to) these forms, and (2) by taxing away excess profits in shareholder corporations.

The role of investment in a steady state economy is also important to consider. Victor (2008, pp. 214-215) notes that positive net investment increases aggregate demand, and also adds to aggregate supply by increasing the stock of produced assets. Both of these result in economic growth. In order to limit net investment, he suggests using three taxes which have traditionally been criticised by economists because they discourage investment in built capital: (1) the corporate income tax, (2) the capital gains tax, and (3) the capital tax. The first two of these are relatively well-known, while the third is a tax on the stock of capital employed by a firm. Victor suggests that imposing these taxes would lead to less investment in built capital, and more investment in human capital.

Daly (2008) suggests that in a SSE investment in built capital would be for replacement purposes only, or to make improvements in the quality of the stock (but not its quantity). He emphasises that where investment is really needed in the transition from an "empty world" to a "full world" is not in built capital but in natural capital (Daly, 1996, p. 79). He goes on to write:

> Since natural capital is by definition not man-made, it is not immediately obvious what is meant by "investing" in it. Yet the term "investment" applies because the

> concept involves the classical notion of "waiting" or refraining from current consumption as the way to invest in natural capital (Daly, 1996, p. 80).

Daly (1996) also suggests that any investment that reduces material throughput is effectively an investment in natural capital. In this respect, he identifies two important classes of investment: (1) investments that reduce population growth (such as in female literacy, social security systems, and access to contraceptives), and (2) investments that improve resource efficiency.

Jackson (2009a) provides some examples of investments that would improve resource efficiency such as renewable energy technologies and public transport. However, he also suggests that an entirely new "ecology" of investment may be needed which addresses the conditions of investment, rates of return, and the structure of capital markets. Based on Jackson's keynote address at the Steady State Economy Conference, O'Neill et al. (2010) suggest that a SSE would require embracing a much deeper view of investment than the conventional interpretation. Instead of viewing investment only as a way to generate financial returns, they suggest investment should be re-envisaged as a way to generate social and environmental returns as well.

2.4.7. Addressing Global Relationships

A number of biophysical indicators, such as those discussed in Section 1.2.1, suggest that global resource use is at an unsustainably high level. Yet many nations still need to increase their consumption of resources to alleviate poverty and allow people to meet their basic needs. These nations stand in stark contrast to wealthy countries like the UK and U.S. where the benefits of growth have already been realised. This situation has led a number of authors to suggest that wealthy countries must stabilise, if not degrow, their economies in order to provide the ecological space needed for poorer nations to grow (Daly, 1977; Jackson, 2009a; Kerschner, 2010).

However, problems could arise if some nations make the transition to a steady state economy, while others are still pursuing growth. These problems could affect both developed countries making the transition to a SSE, and developing countries still pursuing growth. Daly (2008) suggests that producers in a SSE would likely have to account for environmental and social costs in their production processes that producers in a growth economy would not. As a result, products in a SSE could become more expensive than those produced in growth-based economies, and investment capital could flee due to fears of lower profits. He suggests that the first of these potential problems could be solved by employing compensating tariffs on cheap imports. The objective of the tariffs would be to protect efficient national industries from competition with industries in countries where environmental and social costs were not being internalised. The second potential problem (capital flight) could be addressed by instituting minimum residency times for foreign investment, creating a small tax on foreign exchange transactions (i.e. a "Tobin tax"), or by implementing Keynes' proposal for an international multilateral clearing union that would penalise imbalances in nations' current accounts (Daly, 2008).

Both Daly (2008) and Victor (2008) are critical of free trade in general because the theoretical justification behind it (i.e. David Ricardo's principle of "comparative advantage") is undermined by the free mobility of capital associated with globalisation. Victor (2008, pp. 219-220) points out that "Export-led growth is something that all countries seem to want but globally net exports must be zero." He suggests that poorer nations who can benefit from exporting goods should do so, while wealthy nations such as Canada should moderate their efforts to export more than they import.

Jackson (2009a) and O'Neill et al. (2010) note that if wealthy countries make the transition to a steady state economy, this could also have a negative effect on developing countries pursuing growth. A shift to a steady state economy would mean lower resource use, and greater self-reliance in countries that currently import many products. This could have an effect on developing countries that are following a model of export-led growth, requiring these countries to make adjustments as well. As one possible solution, O'Neill et al. (2010) suggest promoting South–South trade as a means of growing poorer economies (instead of continually expanding rich, high-consuming economies). They also propose that where practical, goods and services should be produced locally.

More generally, however, O'Neill et al. (2010) stress that wealthy, non-growing economies and developing, expanding economies need to work together on the specific mechanisms to allow them to co-exist and co-develop in a mutually supportive, fair, and flourishing manner. They propose that international organisations such as the United Nations, World Bank, International Monetary

Fund, and World Trade Organisation should be democratised so that they better represent the interests of the majority of people on the planet. Both Jackson (2009a) and O'Neill et al. (2010) also recommend that wealthy nations should promote technology transfers to developing nations, to (1) reduce the dependency of the global South on the global North, and (2) help countries in the South to develop in less materially-intensive ways. Jackson (2009a) further suggests establishing a global technology fund to invest in renewable energy, energy efficiency, low-carbon infrastructures, and the protection of forests and biodiversity.

2.4.8. Dismantling the Culture of Consumerism

The proposals discussed up until this point have largely been changes to the economic system that national governments could implement. But these reforms are only half the battle. The economic system is a product of our society and culture. In order to achieve a steady state economy it is also necessary to dismantle the culture of consumerism that has co-evolved with, and co-supports, the current economic system.

As the "engine of growth" in modern economies, Jackson (2009a, pp. 87-102) identifies two interrelated features of the socio-economic system that positively reinforce each other. The first is the continual production of new products by firms, through a process of innovation and creative destruction that is largely driven by the profit motive. The second is the expanding demand for these products, driven by our desire as human beings for novelty. This desire is in turn linked to the role that consumer goods play in our lives as both status symbols and as a way of communicating information about ourselves. Jackson refers to this self-reinforcing system as the "iron cage of consumerism".

In order to dismantle this cage, Jackson (2009a, p. 153) proposes two types of structural change. The first is to remove the perverse incentives that promote unsustainable status competition. The second is to establish new structures that provide the capabilities for people to flourish and participate fully in the life of society, in less materialistic ways.

Jackson recommends a number of measures that fall under these two types of structural change. Besides measures to reduce working hours and limit inequality (which were discussed in previous sections), he also proposes measures to strengthen social capital and remove incentives that support consumerism.

Specific measures to strengthen social capital include creating and protecting public spaces, encouraging community-based sustainability initiatives, offering better access to education, placing more responsibility for planning at the local level, and protecting public services. Specific measures to reverse the culture of consumerism include regulating commercial media, banning advertising to children, creating commercial-free zones, supporting public media, and creating trading standards that are fair to producers and encourage more durable products (Jackson, 2009a, pp. 182-184).

Victor (2008) suggests that both the development of new technologies and the use of advertising should be more carefully regulated. He suggests that new technologies should be assessed by an independent agency before being introduced in order to identify and prevent potential problems. He also suggests that advertising should be made to be more informative and less intrusive, noting that "subjecting people to advertising whether or not they want it or like it may be good for economic growth but it does not promote well being" (Victor 2008, p. 220).

O'Neill et al. (2010) stress that dismantling the culture of consumerism will require the rapid diffusion of new values through the many networks that make up society. To bring about this diffusion of values the authors recommend recruiting influential individuals as agents of change, supporting organisations with objectives that challenge or contradict consumerism, publicising the benefits of non-materialistic lifestyles, enabling new forms of business and civic organisation, and directly confronting the powerful interests that advocate consumerism.

While consumerism is a powerful social norm that drives behaviour, O'Neill et al. (2010) point out that not all behaviours are subject to this social norm. Older people, for example, often spend less of their income on "things" and more on "experiences", which tend to have a lower material impact. Increasing numbers of people, either as individuals or as groups, are choosing to live "downshifted" lifestyles or to live "off-grid". While consumerism may be a powerful social norm, it only appeals to some of the core human motivations (i.e. hedonism, status, and achievement). Love, connectedness, friendship, spirituality, and creativity are also powerful sources of motivation, and tapping into these may help to dismantle the culture of consumerism (O'Neill et al., 2010).

2.4.9. Changing the Way We Measure Progress

I have left this topic until last because the question of how to measure progress towards a socially sustainable steady state economy is the focus of the next four chapters of this thesis. The main economic indicator in use today, and probably the most politically influential of all indicators, is Gross Domestic Product (GDP). New policies are assessed in terms of their impact on GDP. Government budgets are evaluated in terms of their predicted effect on GDP. Even sustainability is frequently framed in terms of reducing environmental impact per unit of GDP. In short, national progress has become synonymous with increasing GDP (O'Neill et al., 2010).

But progress in a SSE would likely mean something very different than progress in a growth-based economy. This has led a number of authors to suggest that new indicators would be needed in a SSE. For example, Daly (2008) suggests that two sets of accounts would be required: one that measures the benefits of physical growth in scale, and one that measures the costs of that growth. He argues that the goal in a SSE would be to stop growing the physical scale of the economy as soon as marginal costs equal marginal benefits. In practice this proposal would likely involve using an indicator such as the Index of Sustainable Economic Welfare (ISEW; to be discussed in Section 3.3.2).

Jackson (2009a; 2009b) also recommends adopting new measures of economic welfare. Although he does not make specific indicator recommendations, his analysis suggests an approach similar to the ISEW. In addition to calling for improved measures of economic welfare, however, Jackson also calls for the inclusion of social indicators that measure people's capabilities for flourishing. As sample indicators he cites healthy life expectancy, educational participation, trust, community resilience, and participation in the life of society (Jackson, 2009a, pp. 181-182). As a potential single indicator he points to a "capabilities index" being developed by the Netherlands Environmental Assessment Agency (Robeyns and van der Veen, 2007).

With reference to degrowth, Martínez-Alier (2009) suggests that GDP should be replaced by social and environmental indicators, although he does not specify which indicators. Kallis (2011) argues that sustainable degrowth could be measured by a decrease in throughput indicators and an increase in social welfare indicators. As examples of throughput indicators he lists CO_2 emissions, urban land area, hazardous waste, and distance travelled by food from farm to plate. As examples of social welfare indicators he lists poverty levels, inequality, and self-reported happiness.

In general, however, the existing literature fails to provide a concrete proposal for how progress towards a steady state economy could be measured in practice. This is one of the main research questions that this thesis attempts to answer.

2.5. *Summary*

As described by Herman Daly, a steady state economy is defined by three quantities: constant stocks, constant flows, and sustainable scale. There are two important characteristics of this definition: (1) it is biophysical in nature, and (2) both biophysical stability and biophysical scale are included. In other words, a SSE is not just an economy where stocks and flows are kept constant; it is also an economy where resource use is maintained within ecological limits.

Compared to a steady state economy, the concept of degrowth is not as clearly defined. A number of different interpretations exist within the literature, which, on the surface at least, make degrowth seem to be a rather ambiguous and confusing concept. However, these different interpretations may be viewed as mutually-reinforcing elements of a strategy with a clear goal—to reduce society's material and energy throughput in a socially sustainable and equitable manner. Along these lines, degrowth is increasingly being interpreted as a *process* whose end goal is something resembling a steady state economy.

Although a steady state economy is defined in biophysical terms, Daly and other steady state economists often claim that certain progressive social policies would be needed in order to achieve a SSE. In general, though, more emphasis is placed on social goals by proponents of degrowth than by steady state economists. The Paris Declaration, in particular, is very explicit about the social objectives of degrowth, which include high quality of life, the fulfilment of basic human needs, equity, increased free time, conviviality, sense of community, individual and collective health, and participatory democracy.

Despite the longstanding critique of growth, the steady state alternative remains largely undeveloped. For this reason, I began working with a small team of volunteers to organise the first "Steady State Economy Conference", held in Leeds in 2010. The report of the conference, and other recent literature, suggest a number of policy reforms that would be needed to achieve a steady state economy. These include policies to limit resource use and waste production, stabilise population, reduce inequality, secure full employment, reform the monetary system, rethink business and investment, address global relationships, dismantle the culture of consumerism, and change the way we measure progress. The last of these policy reforms is the focus of the research conducted in this thesis.

3. How Should Progress Towards a Steady State Economy Be Measured? [9]

While you and I have lips and voices which
are for kissing and to sing with
who cares if some one-eyed son of a bitch
invents an instrument to measure Spring with?

— e.e. cummings

Within this chapter I explore how progress towards a socially sustainable steady state economy could be measured. After discussing the concept of indicators (Section 3.1), and why we might want to use them to measure progress towards a steady state economy (Section 3.2), I explore four different indicator approaches that could be applied (Section 3.3). These approaches include Gross Domestic Product, the Index of Sustainable Economic Welfare, separate biophysical and social indicators, and a composite indicator. Following this discussion, I recommend adopting separate biophysical and social indicators within a conceptual framework based on ends and means (Section 3.4). Finally, armed with an indicators approach and a conceptual framework, I provide an overview of the steps taken to generate a system of accounts for a steady state economy and the methods used to analyse the data within these accounts (Section 3.5).

3.1. *What Are Indicators?*

Central to the notion of measuring progress is the concept of indicators. An indicator is a small piece of information that reflects the status of a larger system. Indicators are not the real system, but a partial reflection of reality, based on uncertain and imperfect models (Meadows, 1998; Smolko et al., 2006). The power of indicators is that they allow us to summarise, focus, and condense the enormous complexity of the real world into a manageable amount of information (Singh et al., 2009).

We rely on indicators in our daily lives, often without even realising it—test scores indicate academic achievement, dark clouds signal rain, a heightened body temperature suggests infection. Without being able to translate the com-

[9] Much of the material in this chapter is published in O'Neill (in press).

plexity of the world around us into simple indicators that we are able to interpret, we would find it difficult to make decisions and plan our actions (Meadows, 1998). Such simplification is an accepted part of scientific research, but is associated with difficult choices about how much to simplify and how to do so without misrepresenting reality (Karlsson et al., 2007).

Indicators can take many forms, from numbers to signs, symbols, pictures, and colours (Meadows, 1998). Indicators are not the same thing as data. Rather, they transform data into meaningful information, often through the use of reference values such as benchmarks, thresholds, baselines, and targets (Moldan and Dahl, 2007).

Indicators may be either *objective* or *subjective*. Objective indicators are based on data independent of the observer. They may be verified by others, and can generally be expressed numerically (Meadows, 1998). Examples include CO_2 emissions, life expectancy, and income. Subjective indicators, on the other hand, are sensed internally, often by means which are difficult for the subject to explain or express quantitatively (ibid.). Examples include happiness, social cohesion, and creativity. While objective indicators have traditionally been considered more reliable and valuable, subjective indicators are also important as they may reveal trends and conditions that objective indicators cannot. An excellent example is happiness, which may be directly assessed by asking individuals for their subjective experience, but only indirectly assessed using objective measures (Abdallah et al., 2011). There is no such thing as a completely objective indicator since the calculation of any indicator involves subjective decisions about what data should be included, how these data should be aggregated, and so on (Meadows, 1998).

It is also worth distinguishing between indicators based on the method of aggregation used in their calculation. Following Moldan and Dahl (2007), we can distinguish between three indicator types:

- *Simple indicators*, which are calculated by processing and interpreting primary data. Examples include CO_2 emissions and the unemployment rate.
- *Aggregated indicators*, which are calculated by combining a number of simple indicators that are all measured in the same units. Examples include GDP and domestic material consumption.

- *Composite indicators* (or *indices*), which are calculated by combining indicators that do not share a common unit of measurement. The product is generally a single, dimensionless number. Examples include the Human Development Index (UNDP, 2010) and Environmental Performance Index (Esty et al., 2008).

A number of methodological issues must be confronted when designing an indicator system. These include data availability, the choice of spatial and temporal scale, the selection of the actual indicators, and the aggregation of these indicators (Parris and Kates, 2003). One of the most dangerous pitfalls of indicator design is *over-aggregation*: if too many things are combined together, the resulting number may be meaningless (Meadows, 1998).

It is often not possible to measure the indicators that we desire directly, perhaps because of data limitations or insufficient knowledge. For this reason, *proxy indicators* are often used in practice. Examples include bird counts as a proxy for biodiversity, and life expectancy as a proxy for health. Although most proxy indicators do not comprehensively account for the phenomenon they are supposed to measure, the hope is that they will change with that phenomenon and thus signal general trends (Moldan and Dahl, 2007).

Finally, indicator analyses are inherently limited by our imperfect understanding of reality, and even where reasonable understanding exists, analyses are constrained by what can be measured (i.e. data availability) and how it is measured (i.e. data quality). As Bauler et al. (2007) write, "the errors in developing indicators are inextricably linked to measuring the wrong issues perfectly or the correct issues inadequately".

3.2. *To Measure or Not to Measure?*

There are two reasons why we might consider *not* measuring progress in the degrowth transition to a steady state economy. The first of these is that the current state of global ecological overshoot was at least partially caused by our focus on, and attempt to maximise, a narrow set of economic indicators. It is arguable whether economic growth would have become such a high priority had indicators such as GDP not been invented. GDP has undermined the goal of economic welfare that it was supposed to support because people have ended up serving the abstract (but quantitative) indicator instead of the concrete (but qualitative) goal. We have fallen victim to what Alfred North Whitehead termed the "fallacy of misplaced concreteness" (Daly and Cobb, 1994)—the error of treating an abstraction as if it were reality. This might make advocates of a SSE—particularly those in the degrowth movement—wary of promoting new indicators, even if they represent a significant improvement on GDP, due to their potential to be misinterpreted or misused.

The second reason is that it may turn out to be impossible to measure some of the things that the degrowth movement is trying to achieve. Many of the characteristics of degrowth that are listed in the declaration from the Paris conference—items such as conviviality, sense of community, self-reflection, balance, creativity, flexibility, diversity, and good citizenship—are of a qualitative and subjective nature and do not lend themselves easily to measurement. There are other characteristics of degrowth from the declaration that are simpler to measure, such as reduced consumption of resources, an increase in free time, equity, and individual and collective health, but there is the danger that because these things are simpler to measure, too much attention could be focused on them. We may end up measuring, and therefore managing, what is easy, instead of what is important.

While the above are important concerns, I believe they can be addressed by choosing indicators carefully, and by keeping indicators in their rightful place as one tool in the decision-making process. Furthermore, the arguments against measurement are heavily outweighed by the arguments in favour of it.

The first of these arguments may be summed up by the popular phrase, "You can't manage what you don't measure." The call for degrowth in wealthy nations has largely arisen because a number of environmental indicators show that levels of resource use and waste production are too high globally. Large-scale studies such as the Millennium Ecosystem Assessment (2005) and the reports of the Intergovernmental Panel on Climate Change (e.g. IPCC, 2007) indicate that human beings have changed ecosystems and altered the global climate at a profound rate over the past half century. Ecological footprint studies suggest that many nations are currently using biotic resources faster than they can be regenerated, and producing CO_2 faster than it can be assimilated. The combined result is a state of global "ecological overshoot" (Wackernagel et al., 2002; Ewing et al., 2010a). Rockström et al. (2009b) estimate that humanity is transgressing three of nine "planetary boundaries" related to earth-system processes (climate change, biodiversity loss, and the nitrogen cycle). In short, measurement was necessary to demonstrate the need for a SSE, and it will be necessary to determine whether a SSE is being achieved. Reliable indicators give us the tools to determine whether we are making progress towards a more sustainable society, or are heading in the wrong direction—potentially being led astray by political rhetoric or greenwash.

The second reason is that "What gets measured tends to get done", and what is not measured tends to get ignored (by policymakers at least). At the moment, what is measured is GDP growth, and what is not given enough attention is the environment and issues of social equity. If the objective is to shift the agenda away from economic growth and towards a SSE, then creating and promoting indicators that measure what is meant by a SSE would be a very effective way of doing this. As Donella Meadows wrote:

> Indicators arise from values (we measure what we care about), and they create values (we care about what we measure)… [C]hanging indicators can be one of the most powerful and at the same time one of the easiest ways of making system changes—it does not require firing people, ripping up physical structures, inventing new technologies, or enforcing new regulations. It only requires delivering new information to new places. (Meadows, 1998, pp. viii, 5)

If, on the other hand, advocates of a SSE do not decide how to measure progress towards this goal, then there is the danger that this decision could be made by others (either implicitly or explicitly), potentially resulting in a false characterisation of a SSE.

Finally, indicators are a useful communications tool. The ecological footprint, for example, has been very effective at communicating the idea that wealthy nations are consuming resources unsustainably. Clear indicators would help to raise awareness about the need for a SSE, and with appropriate targets, could help to create a concrete and positive vision of what a SSE might look like.

3.3. Four Possible Approaches

With these considerations in mind, I discuss four approaches that could be taken to measure progress towards a socially sustainable steady state economy at the national level.

3.3.1. Gross Domestic Product

The first approach would be to continue using GDP. Since rising real GDP is the standard measure of economic growth, declining GDP could be interpreted as an indicator of degrowth, and stable GDP an indicator of the steady state. GDP is strongly correlated with the use of many natural resources (energy in particular), but not well-correlated with quality of life measures such as happiness beyond a basic level of income (around $20,000 a year according to Layard, 2005). Given these relationships, a potential target for a degrowth transition to a SSE in wealthy countries could be to reduce GDP by a certain amount each year (say 3%), until it reached this basic income level.

While straightforward, this approach is problematic because it relies on a very poor indicator of progress. There is a long-standing critique of GDP as a measure of economic welfare (see Cobb et al., 1995; van den Bergh, 2009), and this critique suggests a number of reasons why GDP would not be a useful indicator for measuring progress towards a SSE. First, GDP does not distinguish between costs and benefits. Instead, it adds together all money spent on final goods and services, counting economic activity that diminishes well-being in the same way as activity that enhances it. Second, GDP only tracks monetary *flows*. It does not account for changes in *stocks*, in particular the stock of natural capital, whose depletion may be counted as income in the GDP calculation. Third, GDP only counts activities where money changes hands. It neglects informal activities that have no market value (but large social value) such as household and volunteer work. And fourth, while GDP measures total income, and per capita GDP measures average income, neither of these indicators provide any information about how that income is actually distributed. An unequal distribution of income implies unequal opportunities for personal development and well-being.

Czech (2010) argues that while GDP may not be a good indicator of social welfare, it is an excellent indicator of aggregate environmental impact, and therefore what is needed is simply a different interpretation of GDP data. However, there are problems with this approach as well. Although GDP may be well correlated with many indicators of environmental impact, it can never provide information that is as accurate as actual environmental indicators. In part this is because GDP does not distinguish between increases in quantity (i.e. physical growth) and improvements in quality (i.e. development). These are critical distinctions for a steady state economy, where the goal is to stabilise resource use while still improving quality of life. Furthermore, while the rate of change of GDP may be a good proxy for the rate of change of resource use, it says nothing about whether the actual level of resource use accompanying a given GDP value is ecologically sustainable, or whether what is happening is socially sustainable. Zero GDP growth could still be accompanied by declining stocks of natural capital or increasing inequality, both of which would be counter to the objectives of a steady state economy.

The growing recognition that GDP is a poor indicator of progress has led to a number of major initiatives around the world that are investigating alternatives to GDP. These include the European Commission's Beyond GDP initiative (http://www.beyond-gdp.eu), the OECD's Better Life Initiative (http://www.oecd.org/betterlifeinitiative), and the Commission on the Measurement of Economic Performance and Social Progress launched by former French president Nicolas Sarkozy, which produced a detailed report (Stiglitz et al., 2009). It would be ironic if after finally having persuaded neoclassical economists and policy makers to reconsider using GDP as a measure of progress, ecological economists began promoting GDP as an indicator of degrowth towards a SSE, albeit with a different target (–3% per year instead of +3%, for example). I would argue that it is not enough to change the target on a bad indicator. The indicator itself needs to be changed.

Herman Daly has long argued against associating a steady state economy with any particular rate of GDP (or GNP) growth. He writes, "The concept of a SSE is independent of GNP, and what happens to GNP in the SSE simply does not matter. The best thing to do with GNP is to forget it." (Daly, 1993, p. 330). Recent writings in the degrowth literature also emphasise that the goal of degrowth is not a reduction in GDP. For instance, Schneider et al. (2010, p. 512) state that "what happens to GDP is of secondary importance; the goal is the pursuit of well-being, ecological sustainability and social equity." Van den Bergh carries the argument even further, claiming that we would be better off if we simply abolished GDP—even if we didn't replace it with another indicator—due to the huge information failure that would be removed by this action. In his view the current goal of unconditional GDP growth acts as a barrier to progress by preventing good policies in many areas. An unconditional requirement for GDP degrowth would be similarly flawed (van den Bergh, 2009; 2011).

3.3.2. The Index of Sustainable Economic Welfare

A second approach would be to use an improved indicator of economic welfare, such as the Index of Sustainable Economic Welfare (ISEW; Daly and Cobb, 1994) or the related Genuine Progress Indicator (GPI; Talberth et al., 2007). The ISEW and GPI are monetary indicators with a theoretical foundation based on Irving Fisher's definition of income and capital (Lawn, 2003b). They start with personal consumption expenditure as their base, but then make three main adjustments. First, personal consumption expenditure is weighted to account for inequality, based on the premise that a dollar of additional income brings less benefit to the rich than the poor. Second, additions are made to account for the value of non-market activity such as household and volunteer work, as well as the services provided by consumer durables and public infrastructure. Third, deductions are made to account for the costs of pollution, crime, automobile accidents, and other undesirable side-effects of economic growth, such as the depletion of natural capital (Talberth et al., 2007).[10]

The ISEW/GPI approach (hereafter ISEW for brevity) is a vast improvement on GDP as a measure of economic welfare because it separates costs and benefits, accounts for inequality, includes some forms of non-market activity, and counts the depletion of natural capital as a cost instead of a benefit. ISEW-like indicators have been calculated for a number of industrialised countries including Austria, Australia, Germany, the Netherlands, Sweden, the UK, and the U.S. These indicators generally show that while GDP per capita has increased steadily in recent decades, ISEW per capita stopped increasing sometime in the 1970s or 1980s (depending on the country), and in many cases has decreased since then (Lawn, 2007). The results of ISEW studies have contributed to the formulation of a "threshold hypothesis" (Max-Neef, 1995) which posits that there is a level of

[10] Interestingly, while the ISEW acknowledges that an unequal distribution of income detracts from welfare, it makes no adjustment for the declining marginal utility of *total* income. In other words, it equates higher personal consumption with higher welfare. This approach ignores the evidence from surveys of subjective well-being (e.g. Layard, 2005), which suggest that beyond a certain level, additional income does not make people any happier.

economic activity beyond which the costs of further economic growth exceed the benefits.

Of course, the ISEW is not without its critics (e.g. Neumayer, 1999; 2010). The main criticisms of the indicator are: (1) the differentiation between costs and benefits is rather subjective, (2) the weighting of personal consumption for inequality may hide implicit assumptions by the researcher, (3) non-renewable resource depletion is valued using a replacement cost method that assumes renewable substitutes become more expensive over time, and (4) the costs of long-term environmental damage (e.g. climate change) are allowed to accumulate, which may amount to double counting. These are, for the most part, criticisms of the specific valuation methods used in the calculation of the ISEW, not of the conceptual approach itself. Assuming that it is possible to reach a consensus on the best valuation methods to use, there is still the question of whether the indicator would be useful for measuring progress in the transition to a steady state economy.

Theoretically, the point at which to establish a steady state economy would be the threshold point, where the benefits of additional personal consumption are just matched by the costs associated with this consumption (i.e. where economic welfare peaks and then begins to decline). This is generally also the point where the trajectories of the GDP and ISEW for a country diverge. Upon reaching this point, a country might decide to establish a steady state economy. In fact, Lawn (2006) suggests that Australia should have done exactly this in the mid-1970s when Fisherian income (which is related to the ISEW) peaked and then began to decline. The problem, however, is what happens next. Although a decline in the ISEW may signal the need to establish a steady state economy, it does not tell us whether such an economy is being achieved. Other indicators would still be required to determine whether resource use was stable and within ecological limits, and quality of life was high. Moreover, for industrialised countries that have already passed the threshold point, degrowth would presumably be required to reach a steady state economy. It is not obvious what effect degrowth would have on the ISEW. Would the indicator go up or down? If personal consumption were reduced, the ISEW would probably go down, since costs associated with long-term environmental damage (e.g. climate change) would still remain—at least in the short-term. Thus the indicator could show the same behaviour in a degrowing economy as in a growing economy. It is therefore hard to see how the ISEW could be used on its own to manage the transition to a steady state economy.

An additional problem is that the ISEW is an indicator of *weak sustainability* (Neumayer, 1999; Daly and Cobb, 2007), while a steady state economy operationalises the concept of *strong sustainability*.[11] According to the strong sustainability view, natural capital and built capital are complements (as opposed to substitutes), and only by maintaining both stocks intact can long-term economic welfare be guaranteed (Neumayer, 2010). A steady state economy is an economy in which the stock of built capital is held constant, largely to preserve the stock of natural capital, which is assumed to be complementary (and necessary). Weak sustainability allows for natural resources to be depleted, so long as this depletion is offset by increases in the stocks of other forms of capital (ibid.). Since the ISEW translates the benefits and costs of economic activity into monetary values, its accounting framework allows reductions in natural capital to be offset by increases in personal consumption. As long as reductions in natural capital are smaller than gains in personal consumption, the ISEW indicates an increase in economic welfare.

The strong sustainability position is that an increase in personal consumption cannot compensate for a decrease in environmental quality, particularly when environmental degradation is imposed on future generations (Neumayer, 2010). As Barry (1991, p. 264) writes:

> We will all agree that doing harm is in general not cancelled out by doing good, and conversely that doing some good does not license one to do harm provided it does not exceed the amount of good. For example, if you paid for the realignments of a dangerous highway intersection and saved an average of two lives a year, that would not mean that you could shoot one motorist per year and simply reckon on coming out ahead.

In summary, the ISEW is a very useful indicator for exposing the flaws in GDP and showing where economic growth has become "uneconomic". However, it does not provide the biophysical data necessary to measure progress in the transition to a steady state economy. Nor, for that matter, does it provide the data on

[11] Neumayer (2010, p. 23) suggests that the publication of Daly's (1977) book *Steady-State Economics* may in fact mark the foundation of strong sustainability. Kerschner (2010) claims that a steady state economy and strong sustainability could be regarded as identical concepts.

human well-being that would be needed to tell whether such a transition was socially sustainable.

3.3.3. Biophysical and Social Indicators

A third approach would be to dispense with monetary indicators, and measure progress more directly, with biophysical and social indicators. Given the definitions of degrowth and a steady state economy (which focus on biophysical quantities and social goals), this is arguably the logical approach. It is also the approach advocated in an article on degrowth by Martínez-Alier (2009, p. 1099), which states, "Now… is the moment to substitute GDP by social and environmental indicators at the macro-level and to trace progress towards a socio-ecological transition by the behaviour of such indicators".

The question, of course, is which indicators to use. Material Flow Accounting (MFA) provides one potential approach for generating biophysical indicators. MFA is a standardised methodology (see Eurostat, 2001; 2007) for tracking the overall material inputs to national economies, the changes in the stock of materials within the economic system, and the material outputs to other economies (via trade) or back to the environment. Material inputs to the economy can be grouped into five basic categories—biomass, minerals, fossil fuels, water, and air—of which MFA studies track the first three.

The main criticism of the material flows approach is that, by summing together the weights of very different materials, it effectively adds up apples and oranges. Neumayer (2010), for example, argues that different forms of material throughput cannot be meaningfully added together because they have very different environmental impacts. Nevertheless, I would argue that there are three reasons to consider using a material flows approach to measure progress towards a steady state economy. First, today's most pressing environmental problems (e.g. climate change, biodiversity loss, groundwater depletion) are caused by the overall growth in throughput, not by specific harmful substances (Giljum et al., 2009; Krausmann et al., 2009). Although some resources may be more harmful than others, all resource use and dislocation has an environmental impact (Hinterberger et al., 1997). Second, material flow studies generally present results in a disaggregated form, distinguishing between biomass, metals, construction materials, and fossil fuels. Thus the "apples and oranges" critique is not entirely accurate with respect to current practice. And third, a steady state economy is defined as an economy with constant material and energy throughput (maintained within ecological limits). If one accepts the need for a steady state economy, then one also accepts the need to measure throughput.

The main problem with using material flows data to measure progress towards a steady state economy is determining sustainable levels for the flows. While targets such as a "factor four" or "factor ten" reduction in material use for industrial economies have been proposed (e.g. Hinterberger et al., 1997), these are somewhat arbitrary. The best attempt to date to construct an aggregate indicator that compares the size of resource flows with the capacity of ecosystems to accommodate these flows is probably the ecological footprint (Wackernagel and Rees, 1996). The footprint measures the area of biologically productive land that a country needs to produce the biotic resources it consumes, and assimilate the CO_2 it generates. Although it does not account for the flow of non-renewable resources such as minerals, it does include fossil fuels in terms of the CO_2 emissions that are produced during their combustion. These emissions are translated into the area of forested land necessary to sequester the CO_2. The ecological footprint may be compared to biocapacity (the supply of biologically productive land) to arrive at a ratio of the scale of economic activity in relation to what the environment can sustain (Ewing et al., 2010a).

Although widely used, the ecological footprint has also been widely criticised (e.g. van den Bergh and Verbruggen, 1999; Best et al., 2008; Fiala, 2008). A review of the footprint based on a survey of 34 internationally-recognised experts and an assessment of more than 150 papers concluded that the indicator is a strong communications tool, but that it has a limited role within a policy context (Wiedmann and Barrett, 2010). As an aggregated indicator of resource use with a single sustainability threshold, the footprint provides no information on when specific ecological limits relating to key ecosystem services might be reached (ibid.). The footprint has also been criticised for the method used to translate CO_2 emissions into land area. For example, Ayres (2000) claims that the forest-land method exaggerates the size of the footprint, as more land-efficient methods of sequestering CO_2 could be devised (e.g. pumping compressed CO_2 into empty oil and gas wells). In response, however, proponents of the ecological footprint argue that the method is valid because the footprint measures environmental impact under existing technology, and forests are the "best technology" currently available (and in use).

Other, arguably more scientific, measures of the scale of humanity's use of resources also exist, such as "human appropriation of net primary production" (HANPP; see Vitousek et al., 1986; Haberl et al., 2007; O'Neill et al., 2007). HANPP measures the amount of photosynthetically-captured energy (i.e. plant biomass) that human beings either (1) harvest, or (2) make unavailable through land cover change. Although HANPP provides a clear measure of the magnitude of human activity in a specific area with respect to available ecological energy flows, it currently lacks the clear sustainability threshold provided by the ecological footprint.

In addition to biophysical indicators, it seems very likely that social indicators will also be needed to measure progress in the degrowth transition to a steady state economy. The great challenge of degrowth is how to maintain (or even enhance) the well-being of the planet's citizens while global resource use and waste production are being reduced to within ecological limits. Social indicators are therefore needed to ensure that quality of life is maintained or improved by degrowth, and not diminished by it.

An important social indicator to consider using is subjective well-being (e.g. happiness). As Layard (2005, p. 13) remarks, "The most obvious way to find out whether people are happy in general is to survey individuals in a random sample of households and to ask them." Although economists have traditionally avoided such measures due to their subjective nature, there is strong evidence that what people say about their state of well-being reflects reality. For example, measures of subjective well-being are correlated with at least five other relevant sets of variables: the reports of friends, the plausible causes of well-being, some plausible effects of well-being, physical functioning (such as blood pressure and levels of cortisol), and measures of activity in different parts of the brain (Layard, 2010).

Another important social indicator to consider monitoring is income inequality. As Wilkinson and Pickett (2009) show in their book *The Spirit Level*, high levels of inequality are associated with a variety of health and social problems across society, including decreased trust, increased mental illness, and higher crime rates. Reducing inequality is therefore a key objective of both the degrowth and steady state movements.

Although I have described some of the indicators that could be used to measure progress towards a socially sustainable steady state economy, there are clearly other indicators that would also be useful (e.g. health, energy use, leisure time, the unemployment rate). In fact, the problem is that it is possible to imagine quite a few indicators that are relevant. There is the danger of having too many indictors, and not being able to understand the complex relationships and trade-offs between them. This is largely what has happened with sustainable development indicators. For example, the UK uses a set of 68 indicators to measure progress towards its Sustainable Development Strategy (Defra, 2010), while the EU uses an even larger set of over 100 indicators to measure progress towards the equivalent EU strategy (Eurostat, 2009).

Most countries that have developed sets of national sustainable development indicators have done so using a "theme-based" framework (United Nations, 2007). In such a framework, indicators are grouped according to the issue that they most closely relate to (e.g. health, governance, economic development). Theme-based frameworks are useful for monitoring performance on specific policy goals, but they provide no information on the relationship between indicators, or their relative importance. Without a unifying conceptual framework it is also difficult to know which indicators to include, and whether the collection of indicators is comprehensive. As Meadows (1998, p. ix) notes, "What is needed to inform sustainable development is not just indicators, but a coherent information system from which indicators can be derived."

3.3.4. A Composite Indicator

A fourth approach would be to combine a number of individual biophysical and social indicators to create a composite indicator (also known as an index). There are a number of reasons to consider this approach. First, a composite indicator allows a complex set of data to be compressed into a single indicator. Since a single indicator is easier to interpret than many separate indicators, an index facilitates communication, especially with policy makers and the general public. Second, an index allows countries to be directly compared against one another, and rankings to be constructed. This again can generate public interest, and draw attention to the issue that the index measures (OECD, 2008). An index showing how close various countries were to a steady state economy could be a useful tool to recognise those countries closest to this goal, and encourage better performance from those furthest away.

However, there are also some very serious reasons to question using a composite indicator. First, the aggregation of multiple indicators into a single number results in the loss of a tremendous amount of information. A single indicator may send misleading messages and invite overly simplistic policy conclusions. Second, composite indicators hide value judgements. In order to create a composite indicator, it is first necessary to normalise the data from the component indicators (to account for different measurement units), and then assign weights to the individual indicators so that they may be aggregated. A number of different weighting techniques exist, but regardless of which one is used, weights represent value judgements (OECD, 2008). These value judgements are often hidden by the quantitative and objective appearance of the index.

One of the best-known composite indicators is the Human Development Index (HDI). The HDI was created as an explicit alternative to monetary indicators like GDP, to show that development is about more than just increasing national income. The HDI, which was recently revised and updated for the 20th anniversary edition of the *Human Development Report* (UNDP, 2010), is calculated by taking the geometric mean of indicators of life expectancy, education, and standard of living. It is a strictly socio-economic indicator, and does not include environmental measures. As such, the HDI is arguably more informative (in its particular area of focus) than many other composite indicators that conflate social and environmental goals.

A key problem with many composite indicators is that they include both environmental and social indicators, and *add* the two together to form a single index. The Environmental Performance Index (Esty et al., 2008) and Sustainable Society Index (van de Kerk and Manuel, 2008) are good examples. By adding together scores on environmental and social indicators, these composite indicators make the implicit assumption that environmental and social objectives can be substituted for one another. They are, like the ISEW, weak sustainability indicators. To measure how close economies are to a steady state economy requires a strong sustainability approach which recognises that more society does not compensate for less environment, or vice versa. Each of these goals must be achieved on its own terms, and therefore measured on its own terms (and in its own units). The report of the Stiglitz Commission makes this point and provides a particularly good analogy:

> The assessment of sustainability is complementary to the question of current well-being or economic performance, and must be examined separately. This may sound trivial and yet it deserves emphasis, because some existing approaches fail to adopt this principle, leading to potentially confusing messages. For instance, confusion may arise when one tries to combine current well-being and sustainability into a single indicator. To take an analogy, when driving a car, a meter that added up in one single number the current speed of the vehicle and the remaining level of gasoline would not be of any help to the driver. Both pieces of information are critical and need to be displayed in distinct, clearly visible areas of the dashboard. (Stiglitz et al., 2009, p. 17)

This is not to say that there is no meaningful way to combine data on social and environmental performance. One aggregation procedure that may prove particularly useful is to take the *ratio* of social and environmental indicators. This ratio is a measure of the efficiency with which natural resources are translated into human well-being, and is the approach taken by the Happy Planet Index (Marks et al., 2006; Abdallah et al., 2009).

3.4. Recommended Approach

The approach that I propose for measuring progress towards a socially sustainable steady state economy, and that I adopt in this thesis, is to construct a set of biophysical and social indicators that are based directly on the definition of a steady state economy and the goals of the degrowth movement. Although a number of biophysical and social indicators were discussed in Section 3.3.3, it was not obvious from this discussion which indicators should be included, or how to relate them to one another.

To solve this problem, and generate a meaningful set of indicators, requires a unifying conceptual framework. This framework should acknowledge that the economy is a subsystem of the environment, and its scope should include the full range of relations between natural resources and human well-being. Herman Daly's "Ends–Means Spectrum" (Daly, 1977) provides such a framework, which Donella Meadows proposed using as the basis of an information system for sustainable development indicators (Meadows, 1998). The framework (Figure 3.1) organises items in a hierarchy from *ultimate means* (the natural resources that sustain life and all economic transactions) to *intermediate means* (the factories, machines, and skilled labour that transform natural resources into products and services) to *intermediate ends* (the goals that the economy is expected to deliver) to *ultimate ends* (those goals that are desired only for themselves, and are not the means to achieve any other end).

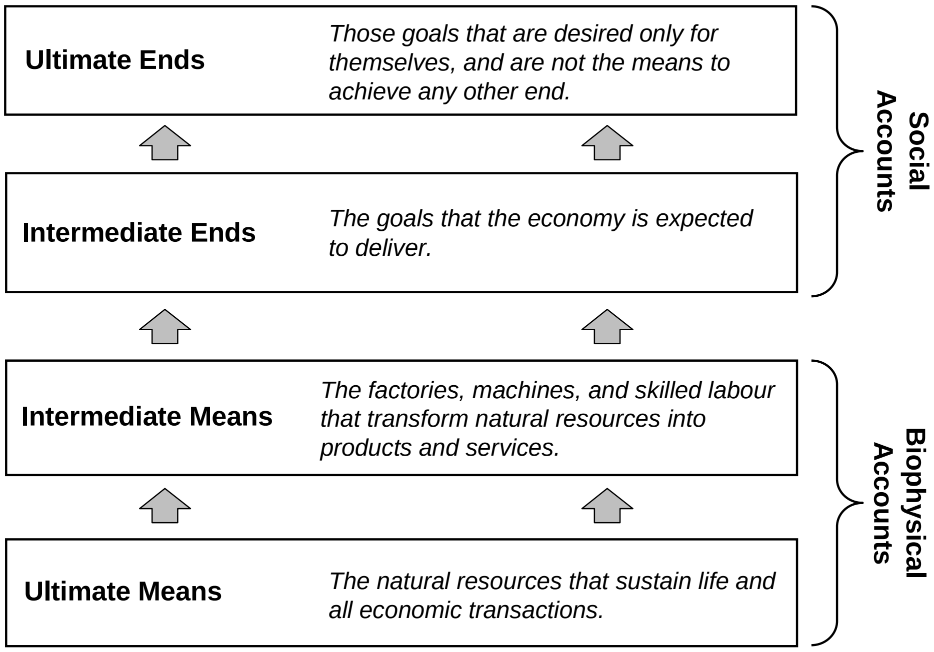

Figure 3.1: The conceptual framework for a set of indicators to measure progress towards a socially sustainable steady state economy. Source: based on Daly (1977) and Meadows (1998).

The Ends–Means framework effectively divides the indicators into two separate accounts: biophysical and social. The Biophysical Accounts measure the use of means, while the Social Accounts measure progress towards ends. The framework also separates natural capital (the ultimate means) from built capital (an intermediate means). By organising the indicators in this way, the framework helps to deliver a set of indicators that measures strong sustainability.

It is important to state that the framework should *not* be interpreted as suggesting that the only purpose of nature is to fulfil human needs. The framework simply indicates that to fulfil human needs first requires healthy, functioning ecosystems (Meadows, 1998). In this sense, the Ends–Means Spectrum is a framework for understanding and managing the economy, not a hierarchy of values.

3.5. Methodological Steps

The selection of an indicators approach (separate biophysical and social indicators) and a unifying conceptual framework (the Ends-Means Spectrum) brings us one step closer to answering the research questions investigated in this thesis. As described in Section 1.4, this thesis aims to answer two main questions:

1. How can progress towards a steady state economy be measured at the national level?
2. What is the relationship between a country's proximity to a steady state economy and its social performance?

In order to answer these questions, three further steps are required: (1) the identification of a set of biophysical indicators based on Daly's definition of a steady state economy, (2) the identification of a set of social indicators based on the stated goals of the degrowth movement, and (3) the application of these indicators to a large number of countries.

The first of these steps is the topic of the next two chapters (Chapters 4 and 5). I approach this topic by first dividing Daly's definition of a SSE into three separate components (stable stocks, stable flows, and sustainable scale). However, even following this relatively straightforward approach, a number of difficult conceptual issues arise when attempting to translate Daly's abstract definition into a concrete set of indicators. In Chapter 4, I explore these issues in depth and generate a list of criteria to guide the selection of biophysical indicators. Following this, in Chapter 5, I identify a list of "abstract indicators" to measure how close an economy is to a steady state economy. For each of these, I then select a measurable proxy (or proxies) based on the best data currently available for a large number of countries.

The second step of the analysis (the identification of social indicators) is the topic of Chapter 6. Based on the Paris Declaration and other relevant degrowth and steady state literature, I identify a number of intermediate ends to work towards in a SSE, and a single ultimate end to help prioritise these. For each intermediate end, I discuss how it is described in the literature, how it contributes to the ultimate end, how it relates to environmental resource use, and what indicators exist to measure progress towards it. As with the biophysical indicators, I then identify a measurable proxy for each social indicator based on the best data currently available for a large number of countries.

The third step of the analysis (the application of the indicators) is the topic of Chapter 7. This step may be further divided into three separate parts: (1) the assessment of how close national economies are to biophysical stability and sustainable scale, (2) the assessment of the social performance of national economies, and (3) the analysis of the relationship between a country's proximity to a SSE and its social performance.

To assess how close national economies are to biophysical stability, I employ two methods: (1) a multi-criteria approach that categorises countries based on their performance on seven rate-of-change indicators, and (2) an index that is calculated by averaging these indicators. To assess how close national economies are to sustainable scale, I employ a single method that categorises countries based on their performance on a hybrid sustainability indicator. Finally, to assess the overall social performance of countries, I construct a composite indicator based on the indicators in the Social Accounts.

Following these assessments, I analyse the relationship between a country's proximity to a SSE and its social performance. This analysis consists of two parts. First, I analyse the relationship between biophysical *stability* and social performance; second, I analyse the relationship between biophysical *scale* and social performance. In each sub-analysis, I use two methods to examine the relationship between biophysical and social variables: (1) a comparison of means, and (2) correlation analysis. Finally, I use multiple regression to evaluate to what degree both biophysical stability and biophysical scale are able to predict social performance.

3.6. Summary

As described at the beginning of this chapter, indicators are small pieces of information that reflect the status of a larger system. They are not the real system, but an imperfect representation of it. In fact, even when a reasonable understanding of the real system exists, indicator analyses are constrained by what can be measured (i.e. data availability) and how it is measured (i.e. data quality).

Nevertheless, indicators are a very useful tool as they condense the enormous complexity of the real world into a manageable amount of information. Moreover, there is a strong case to be made for using indicators to measure progress towards a steady state economy. Indicators can tell us whether countries are moving closer to, or further away from, such an economy. They are an important communications tool, and the publication of the right indicators could help shift the agenda away from economic growth and towards a SSE.

Within this chapter I have identified four possible indicator approaches that could be used to measure progress towards a socially sustainable steady state economy. These approaches include Gross Domestic Product, the Index of Sustainable Economic Welfare, biophysical and social indicators, and a composite indicator. I suggest that separate biophysical and social indicators represent the best approach, but that a unifying conceptual framework based on ends and means is needed to choose appropriate indicators and interpret the relationships between them.

Armed with an indicators approach and a unifying conceptual framework, the analysis conducted in this thesis proceeds in three main steps: (1) the identification of a set of biophysical indicators based on Daly's definition of a steady state economy, (2) the identification of a set of social indicators based on the stated goals of the degrowth movement, and (3) the application and empirical analysis of these indicators for a large number of countries.

4. Interpreting the Definition of a Steady State Economy

Everything should be as simple as possible, but not simpler.

— Albert Einstein

The definition of a steady state economy developed by Daly and presented in Chapter 2 provides the foundation for much of the work in this thesis. It is a definition that gives a high-level view of what would be held steady, and what would be allowed to change, in a SSE. But it is also a definition that leaves many questions unanswered. How should stocks and flows be aggregated? What is the role of international trade? And how should non-renewable resources be treated? In order to translate Daly's definition into a set of indicators to measure progress towards a SSE at the national level, it is necessary to address these questions.

Within this chapter I discuss a number of conceptual issues that arise when attempting to translate the abstract definition of a steady state economy into a set of biophysical indicators. First, I divide Daly's definition of a SSE into three separate components (stocks, flows, and scale), and argue that constant stocks are an important part of the definition that should not be neglected (Section 4.1). Following this, I investigate how to aggregate stocks and flows (Section 4.2), whether renewable and non-renewable resources should be treated differently (Section 4.3), the role of international trade (Section 4.4), the relevance of hidden resource flows (Section 4.5), and the role of the stock of natural capital (Section 4.6). Finally, in Section 4.7, I summarise the main arguments made in the chapter, and present a list of criteria that the indicators in the Biophysical Accounts should aim to satisfy.

4.1. *Stocks, Flows, and Scale* [12]

In general, Daly's definition of a steady state economy (see Section 2.1) contains three components: *stocks* (the physical size of the economy), *flows* (the throughput required to support the economy), and *scale* (the size of the economy in relation

[12] Much of the material in this section is published in O'Neill (in press).

to the environment). There are three stocks that are relevant to the definition: the stock of built capital (e.g. buildings, transportation infrastructure, cars, durable goods), the stock of people (i.e. the human population), and the stock of domesticated animals (i.e. livestock and aquaculture). There are three flows that are relevant: the flow of material inputs from the environment to the economy, the flow of material outputs from the economy back to the environment, and the energy used by the economy. And finally, there are two measures of scale that are relevant: the ratio of material inputs to the capacity of ecosystem sources to regenerate materials, and the ratio of material outflows to the capacity of ecosystem sinks to assimilate wastes. The diagram of the global economy embedded within the biosphere that was presented earlier (Figure 1.1) may be redrawn to include these quantities (Figure 4.1).

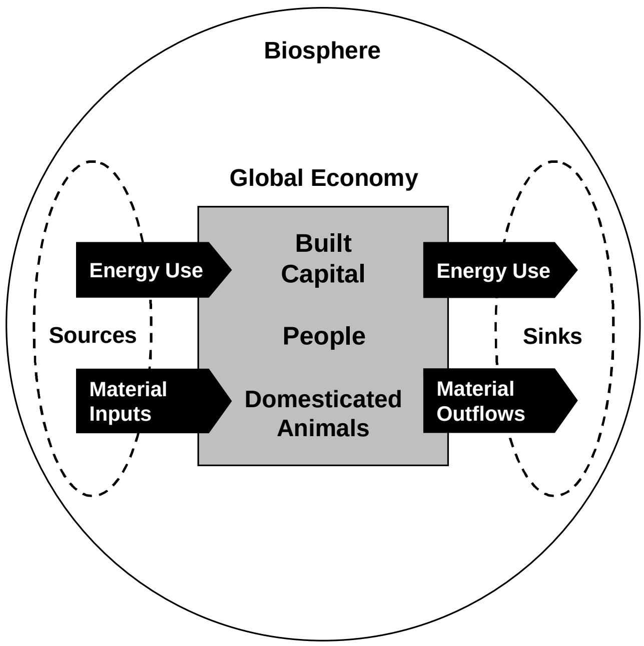

Figure 4.1: The stocks, flows, and scale quantities that relate to Daly's definition of a steady state economy. Stocks are shown within the grey box representing the economy, flows are shown as arrows, and scale may be visualised as the relationship between arrows and dashed ovals. Source: based on Goodland (1991, p. 17).

Based on the quantities in Figure 4.1, I make a number of definitional distinctions. If an economy manages to stabilise the stocks and flows pictured in Figure

4.1, then I refer to it as a "stable economy". If the economy also manages to maintain material flows within ecological limits, then I refer to it as a "steady state economy". If, in addition to these biophysical criteria, the economy achieves a high quality of life for its citizens, then I refer to it as a "socially sustainable steady state economy" (more on this later).

In practice, it is unlikely that a country would manage to stabilise all relevant stocks and flows concurrently. Boulding (1975, p. 92) writes that "All stocks… do not have to be stationary at the same time, and we can postulate a number of quasi-stationary states in which some elements of the system are stationary while others are not." Presumably, though, the more stocks and flows that were stabilised, the closer a given economy would be to a true steady state economy.

It is worth noting that Daly focuses less on constant stocks, and more on constant flows, in his definition of a steady state economy. In particular, he acknowledges the practical difficulties inherent in trying to measure the aggregate stock of built capital in the economy, and goes as far as to suggest that such an exercise may not actually be necessary:

> The capital stock is an aggregate of unlike things, and to speak of it as constant in the aggregate, yet variable in composition, implies some coefficients of equivalence among the various unlike things. This problem haunts standard economics as well. However… we do not really need an operational measure of the aggregate stock. We can control throughput and let the stock grow to whatever maximum size can be supported by the limited throughput. Control over aggregate throughput will result from controls (depletion quotas) on particular resources. If, thanks to technological progress, it becomes possible to support a larger stock with the same throughput, that is all to the good and should be allowed to happen. (Daly 1977, p. 17)

However, I would argue that it is necessary to have both constant stocks and constant flows in order to achieve a steady state economy. There are five reasons that constant stocks are also important:

1. If built capital and natural capital are complements (as strong sustainability suggests), then an increase in the stock of built capital would likely lead to a reduction in the stock of natural capital, contrary to the goal of a steady state economy. As cities expand, for example, they generally do so at the expense of the surrounding natural landscape, eroding natural capital. This can happen without any change in material flows.

2. If the goal in a steady state economy were simply to stabilise flows, and no effort were made to stabilise stocks as well, then it would be very difficult to actually stabilise the flows. The stocks determine the standing demand for matter and energy, and therefore an increase in stocks creates a very strong pressure to increase flows. An increase in human population or built capital, for example, would likely drive an increase in the flows needed to maintain these stocks, despite attempts to prevent this from happening.
3. In order for stocks to increase while flows remain constant, efficiency improvements must be made. The human population could increase, while the harvest of food remained constant, if less food were wasted. The number of buildings in a city could grow, while the mining of construction materials remained stable, if buildings were designed to last longer. However, these trends could not continue forever as this would require efficiency to increase indefinitely, in defiance of the Second Law of Thermodynamics. While it is possible to imagine some transitionary phase characterised by increasing stocks, the end state for a steady state economy must still include a constant population of people, domesticated animals, and built capital.
4. While population could be allowed to grow temporarily in a SSE provided that total resource use did not, the result would be declining per capita resource use, which could have negative social implications. Moreover, the average age in an economy with zero population growth would likely be higher than in an economy with a growing population. The social policies needed in the two economies would likely be very different (particularly with respect to resources dedicated to caring services, pensions, and so on). While the two economies might both be ecologically sustainable (assuming resource flows were constant and within ecological limits), they could be very different places to live. Thus it is questionable whether both should be referred to as steady state economies.
5. Very little work has been done to date to measure the stock of built capital in any kind of physical sense. The environmental pressure exerted by a growing stock of built capital may be adequately captured by flow indicators, but at the moment we don't have the necessary data on stocks to

test this hypothesis. An accounting system that tracked changes in stocks, as well as changes in flows, would allow a number of potential relationships to be investigated.

There are certain stocks that straddle the boundary between natural and built capital. These include livestock, aquaculture, plantation forests, and agricultural plants. Daly (1996, p. 80) refers to these stocks as "cultivated natural capital", and while he does not include any of these stocks in his definition of a steady state economy, I believe that domesticated animals (i.e. livestock and aquaculture) should be included as stocks within the economic system, while plantation forests and agricultural plants should be considered outside of the economic system. There are three reasons that I propose drawing the system boundary in this way.

First, livestock and aquaculture are highly "colonised" forms of cultivated natural capital (Eurostat, 2007). They have been significantly modified from their natural state by human actions, and their production and reproduction are largely controlled by society (more so than other forms of cultivated natural capital such as plantation forests and agricultural plants). Second, the stock of domesticated animals is substantial. Domesticated animals account for 69% of the global biomass of vertebrates, while humans account for 28%, and wild animals just 3% (Smil, 1991, p. 77). This stock requires a large flow of resources to sustain it: globally, close to 60% of all harvested plant biomass is used as food or bedding material for livestock (Krausmann et al., 2008a). And third, the inclusion of livestock and aquaculture as stocks within the economic system, and the exclusion of plantation forests and agricultural plants from it, follows the system boundaries used in Material Flow Accounting (e.g. Eurostat, 2001; 2007). As Eurostat note, there are practical reasons for not including cultivated plants as stocks within the economic system:

> Treating plants as part of the national economy would create the necessity to account for water, CO_2, and plant nutrients as the primary inputs from the environment. Effectively, this would mean that the system boundary between a national economy and its environment would have to be drawn at the inorganic level (i.e. plant nutrients, CO_2 and water). Statisticians would be forced to convert rather robust and valid data on annual agricultural and timber harvest to comparably weak estimates of the primary inputs needed to produce these plants. (Eurostat, 2007, p. 10)

4.2. The Issue of Aggregation

Daly (1996, p. 31) states that in a SSE "aggregate throughput is constant". However, he does not specify how this aggregation should be performed. In order to be able to measure progress towards a SSE, it is necessary to decide how to perform the aggregation—for both stocks and flows.

There are a number of possible ways that stocks and flows could be aggregated, such as by weight, volume, area (e.g. ecological footprint), energy content, or monetary value. Victor (2009) is critical of these simple aggregation methods, however, claiming that aggregation in monetary terms is not consistent with Daly's biophysical definition of a SSE, and that aggregation in physical terms overlooks important differences in the composition of stocks and the environmental impact of flows. He writes:

> Counting people is easy, we do it on a regular basis through the census and so we know what is happening to the stock of people… Counting artefacts is an altogether different matter. Statistical agencies do not keep systematic and complete inventories of artefacts and to the extent they do, they usually aggregate them in monetary terms using market prices. A constant stock of artefacts in value terms is at odds with Daly's insistence that [a] SSE is a physical concept. What does it mean to keep the stock of artefacts constant in physical terms? To simply add them up by weight or volume is not very meaningful and fails to allow for qualitative improvements in the stock and changes in its composition.
>
> Of course Daly realizes this… and offers an alternative, more operational, definition of a steady-state economy that focuses on flows rather than stocks… While it may be easier to obtain more comprehensive information on the physical magnitude of flows to and from an economy and the environment, the problem remains of determining whether physical inflows and outflows are rising, falling, or remaining constant unless we abstract completely from changes in their composition. To do so overlooks the dramatically different environmental impacts of flows of materials and energy of equal magnitude and again is unsatisfactory. (Victor, 2009)

Van den Bergh (2011) makes a similar objection against using simple aggregated indicators to measure degrowth. He writes:

> [O]ne should be careful with the precise definition of physical degrowth. We certainly do not want to focus on reducing some simplified, aggregate measure of total tons of materials and substances in the economy (whether stocks or flows). Not everyone agrees with this—witness the popular notions of factor X (X=4, 10, etc.), MIPS, ecological rucksack and TMR promoted by the Wuppertal Institute. Counting total material flows is a nice pastime activity, but we should instead be concerned with environmentally relevant substances/materials and assign these appropriate weights in any aggregation process. All in all, it is not clear what aggregate physical quantity should exactly degrow—there is a measurement or indicator problem here. (van den Bergh, 2011, p. 884)

These critiques raise an important question: what is the main objective of a steady state economy? Is it to reduce environmental *impact*, or environmental *pressure*? The distinction between these two concepts is made in the DPSIR indicator framework used by the European Environment Agency. DPSIR is a causal framework for describing the interactions between society and the environment, categorising these as Driving forces, Pressures, States, Impacts, and Responses. According to the DPSIR framework, social and economic developments exert pressure on the environment and, as a consequence, the state of the environment changes. This change leads to impacts that may (or may not) elicit a societal response. Pressures include the use of resources, the emission of wastes, and the use of land. Impacts refer to changes in the functioning of the environment, including changes to ecosystem health, resource availability, and biodiversity (EEA, 2003).

The implicit suggestion made by Victor (2009) and van den Bergh (2011) is that the focus of a steady state economy should be to reduce and stabilise environmental impact. However, I would argue that the goal of a steady state economy is to reduce and stabilise environmental pressure. Conventional environmental policy is failing to solve major environmental problems such as climate change and biodiversity loss because it does not address the driving forces and pressures that are causing these problems. A SSE attempts to reduce the pressure on the environment by limiting the aggregate quantity of material and energy throughput, thus making environmental policy objectives more achievable. As stated in Section 2.3, the objective of a SSE is not to solve problems related to the quality (or composition) of resource throughout. Issues relating to the substitution of specific materials for one another are the role of conventional environmental policy, which would still be needed in a SSE. The objective of a SSE is to address the overall scale of the production and consumption system—to hold *quantity* steady while allowing *quality* to improve—and for this purpose I believe that highly aggregated indicators that measure environmental pressure are appropriate.

The simplest interpretation of Daly's definition would therefore measure stocks and flows in terms of their basic physical magnitudes, i.e. mass and energy content. In fact, Neumayer (2010) claims that the concept of Material Flow Accounting, originally developed by Schmidt-Bleek (1993a; 1993b), was inspired by

Daly's definition of a steady state economy and his "emphasis on the growing scale or material throughput of the economy as the main cause of environmental degradation" (Neumayer 2010, p. 175). While not without limitations, aggregate material use is a well-established indicator of environmental pressure. As Krausmann et al. (2009) write:

> Clearly, the environmental pressures and sustainability problems associated with the extraction and use of materials are extremely heterogeneous. They differ largely by material and vary over time with technological change. Aggregate materials use indicators… cannot capture the full environmental effect of shifts in the composition of materials use or of technological fixes. But even though there is no simple one to one relation between aggregate materials use and environmental deterioration, the size and composition of materials use serves as a proxy for environmental pressures resulting from human activities. (Krausmann et al., 2009, p. 2703)

All else being equal, it is reasonable to assume that an increase in environmental pressure (as measured by aggregate resource flows) will result in an increase in environmental impact. As Matthews et al. (2000) write:

> Highly aggregated indicators of materials flow should not be interpreted as direct indicators of environmental impact. A ton of iron ore is not equivalent to a ton of mercury. Big flows are not automatically bad, and small flows are not automatically better. However, we believe that indicators are useful measures of potential environmental impact. All resource use involves environmental impacts of some kind at every stage of the material cycle from extraction or harvesting to final disposal. Unless technologies are changed dramatically, increases in resource throughput imply increases in environmental impacts. Therefore, indicators of materials flow that tell us whether overall resource throughput is rising or falling, and whether national economies are becoming more or less efficient in their use of resources, are valuable starting points for analysis. (Matthews et al., 2000, pp. 2-3)

Moreover, there is empirical evidence to support the notion that larger aggregate resource lead to greater environmental impacts. Environmentally-weighted Material Consumption (EMC) is an indicator that aims to measure the total environmental impact of material flows. To calculate this indicator, mass data from material flow accounts are multiplied by environmental impact data from life-cycle assessment studies. Based on an EMC study conducted in the Netherlands, van der Voet et al. (2004) find that while the mass flows of an *individual* material are not indicative of its environmental pressure, the same is not true when materials are aggregated. They write, "On a more aggregate level of groups of materials, mass-based and impact-based indicators appear to point in the same direction. At the least, therefore, the relevancy of the mass-based indicators cannot be dismissed easily" (van der Voet et al., 2004, p. 134).

Based on a larger study of 28 European countries, van der Voet et al. (2005, p. 69) conclude that there is a "rather high" degree of correlation between aggregate material flows (as measured by domestic material consumption [DMC]) and aggregate environmental impact (as measured by EMC). The correlation coefficient between the two quantities is 0.73, indicating that around 53% ($=0.73^2$) of the variation in EMC is explained by DMC, and vice versa. Therefore the use of environmental pressure indicators such as the total weight of material flows may also go some way towards satisfying the environmental impact agenda articulated by authors such as Victor (2009) and van den Bergh (2011). Such indicators also have the advantage of being more transparent than environmental impact indicators.

Although aggregation might seem to be less of an issue for energy flows than material flows, a number of methods for aggregating energy from different sources do exist. Since all forms of energy can be converted to heat, the simplest aggregation method involves adding up energy flows in terms of their heat content. The advantage of the heat content approach is that it uses a simple and well-defined accounting system based on the conservation of energy, and the heat contents of fuels are easily measured (Cleveland et al., 2000). The heat content approach does not, however, take into account qualitative differences between different energy carriers. The method implicitly assumes that "all Joules are equal", although from a socio-economic perspective they may not be. Electricity is a higher quality form of energy than coal, for example, because it performs many important tasks that coal cannot, or it performs them more effectively (Cleveland, 2010).

In order to account for differences in energy quality, alternative measures such as *exergy* and *emergy* have been devised. Exergy measures the maximum amount of useful work that could theoretically be performed by a given amount of energy. While energy is always conserved in any process (this is the First Law of Thermodynamics), the same is not true of exergy. Exergy is not conserved, but is partially "used up" in any transformation (Ayres and Warr, 2009). Emergy, on the other hand, is a measure of all the energy used in a process in units of one type of energy (usually solar). Energy sources of different types are aggregated based on their "transformities", which are calculated based on the amount of one type of energy required to produce a heat equivalent of another type of energy (Cleveland et al., 2000).

The main reason to consider using an approach that takes energy quality into account would be to link socio-economic performance to a physical measure of resource use. This was the objective of a study by Ayres and Warr (2009), for example, who were able to explain past U.S. economic growth using a production function that includes capital, labour, and exergy, and which does not require the exogenous technological progress factors used in conventional models. Although it is hoped that a better understanding of economic systems will be obtained by analysing the relationships between the biophysical and social indicators developed in this thesis, such an analysis is not the primary purpose of the indicators. The primary purpose of the indicators in the Biophysical Accounts is to determine how close national economies are to a SSE, based on their use of ultimate and intermediate means. In this context it is not important whether energy is being used to perform useful work, or squandered as waste heat, since both of these processes exert pressure on the environment. Thus, as with material flows, I would argue that energy flows should be aggregated in terms of quantity (i.e. heat content in Joules), as opposed to quality.

4.3. Renewable and Non-renewable Resources

A related issue that is worth considering is whether renewable and non-renewable resource flows should be treated differently in the definition of a SSE. Daly's three principles for sustainable resource use, which were introduced in Section 2.4.1, provide some guidance. These principles state:

1. Limit the use of all resources to rates that ultimately result in levels of waste that can be absorbed by the ecosystem.
2. Exploit renewable resources at rates that do not exceed the ability of the ecosystem to regenerate the resources.
3. Deplete non-renewable resources at rates that, as far as possible, do not exceed the rate of development of renewable substitutes. (Daly, 1990; 2005)

The principles imply that it is necessary to distinguish between renewable and non-renewable resources entering the economy, since the rules for their sustainable use are different. While a steady state economy implies a constant rate of total resource use, maintained within the regenerative capacity of ecosystems, it effectively implies a declining rate of non-renewable resource use if the economy is to be sustainable in the long run.

However, it is important not to confuse the stability of resource flows with their scale. I would characterise an economy with a constant level of total resource use (i.e. renewable plus non-renewable) as a "stable economy", and one worth being able to identify. In such an economy the resource flow available to meet society's needs would be constant, as would the level of pressure exerted by the economy on the environment (all else being equal). A stable economy would not necessarily be sustainable, however, unless the rate of renewable resource use was kept within the regenerative capacity of ecosystems, and the rate of non-renewable resource use decreased over time. Resource use in such an economy might resemble the scenario depicted in Figure 4.2.

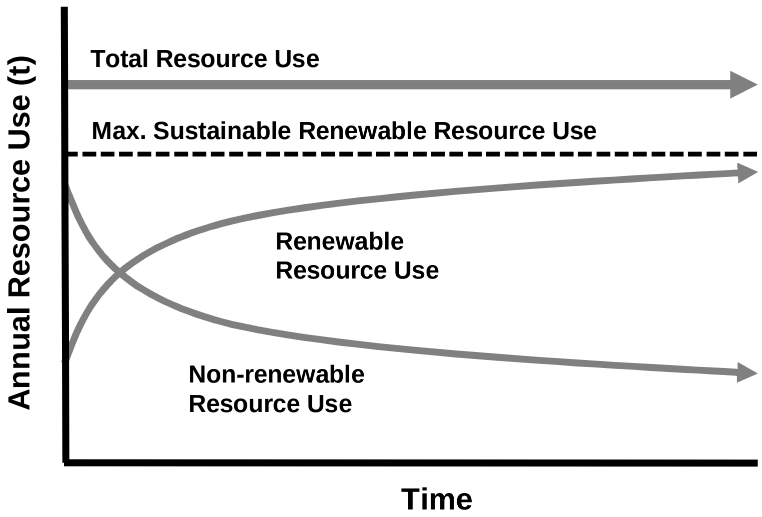

Figure 4.2: Resource use in an economy that satisfies both the stability and scale criteria (on the input side) for a steady state economy.

It is worth noting that if (a) total resource use is constant, and (b) non-renewable resource use is decreasing at a rate of X% per year, then renewable resource use must be increasing at X% per year. In other words, conditions (a) and (b) are effectively equivalent to Daly's third principle of not depleting non-renewable resources faster than renewable substitutes can be developed.[13] Perhaps more importantly, these two conditions are also easier to measure.

As Krausmann et al. (2009) show, global economic growth has been associated—not only with rising material use—but also with a shift from renewable to non-renewable resource use (see Figure 1.2). In a SSE this trend would need to be reversed. However, the substitution of non-renewable resources by renewable resources could cause renewable resource use to increase further beyond the regenerative capacity of ecosystems. Some authors, such as Haberl et al. (2007), already caution about the limited possibility of substituting renewable resources such as biomass for non-renewable resources such as fossil fuels. Thus, it seems likely that degrowth in total (i.e. renewable plus non-renewable) resource use will be needed in order to achieve a SSE that can be maintained over the long term.

On the outflow side it is not particularly important whether wastes come from a renewable or a non-renewable source. It is more important to distinguish where these materials are deposited (e.g. in land, water, or air). Like inflows, the stability of outflows remains an important criteria for ensuring that environmental pressure does not increase over time. However, the most important issue is for total outflows to remain within the assimilative capacity of ecosystems (Figure 4.3).

[13] There is still the danger, however, that the supply of non-renewable resources could run out before they are replaced by renewable substitutes (i.e. if X is too low).

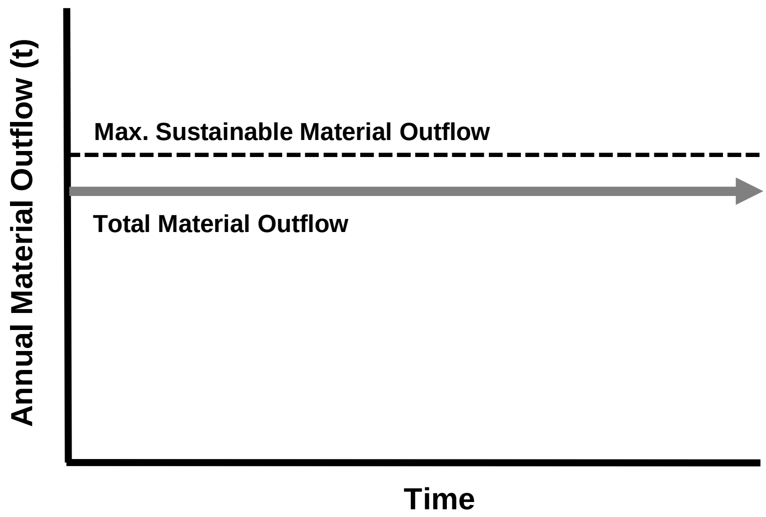

Figure 4.3: Total material outflow in an economy that satisfies both the stability and scale criteria (on the outflow side) for a steady state economy.

4.4. *The Issue of Trade*

In order to make the case for a SSE, Daly and others often use a figure showing the global economy embedded within the biosphere (see Figure 4.1). While this global picture is useful for describing the basic idea of a SSE, it is not sufficient for describing a SSE at the national level. A definition of a SSE at the national level is needed because economic policy is not managed globally, but nationally. Countries engage in international trade. Some of the resources that enter a country's economy are extracted within its borders, while others are imported. Furthermore, some of the products that are produced within a country are not consumed there but exported to other countries. A more complex picture that takes international trade into account is therefore needed in order to arrive at a working definition of a steady state economy at the national level.

The methods and terminology of Material and Energy Flow Accounting (MEFA) are particularly useful for exploring some of the different ways that a SSE could be defined at the national level. MEFA is a framework for analysing the flow of physical inputs into an economy, the accumulation of stocks within the economy, and the flow of physical outputs to other economies or back to nature (Haberl et al., 2004a). It is based on the concept of "social metabolism" (Ayres and Simonis, 1994; Fischer-Kowalski, 1998), which views an economy as a metaphorical organism that functions by appropriating materials and energy from the environment, and returning these back in an altered form. The MEFA framework includes established standards of Material Flow Accounting (MFA; Eurostat, 2001; 2007), and proposed methods of Energy Flow Accounting (EFA; Haberl, 2001).

Figure 4.4 shows the physical flows between a national economy, its environment (i.e. national territory), and the rest of the world. It introduces a number of quantities that are drawn from Material and Energy Flow Accounting, which I use to illustrate some of the general issues surrounding trade. With respect to materials, these quantities include:

- *Domestic material extraction* (DME) — The raw materials that are extracted from within a country's borders and used as material inputs to the national economy.
- *Material imports* (I_M) — Products at all stages of processing (from basic commodities to highly processed goods) that are imported and used in the national economy.
- *Direct material input* (DMI) — All materials, whether extracted in the national territory or imported, that enter the national economy for further use in production or consumption processes.
- *Domestic processed output* (DPO) — The outflow of waste materials that are released back into the national territory after having been used in the national economy.
- *Material exports* (X_M) — Products at all stages of processing that are exported from the national economy.
- *Direct material output* (DMO) — All materials, whether wastes or exports, that leave the national economy.

In general, for each of the above material flow quantities, there is a corresponding energy flow quantity drawn from Energy Flow Accounting. *Domestic energy extraction* (DEE) parallels domestic material extraction (DME), *energy imports* (I_E) parallel material exports (I_M), and so on. It is worth noting that there is some degree of overlap between the quantities considered in both MFA and EFA. For example, fossil fuels such as coal, oil, and natural gas are both a material and an energy source, and are therefore included in both accounting systems. Measuring both material and energy flows therefore has the potential to lead to double counting—a topic I return to in Chapter 5 when choosing specific indicators.

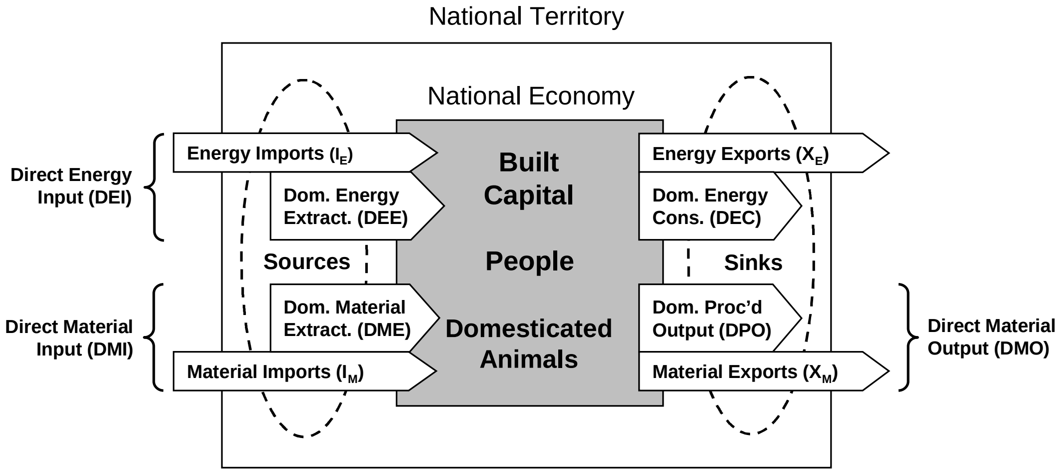

Figure 4.4: The stocks, flows, and scale relationships for a national economy, taking international trade into account.

Based on the discussion in Section 4.1, it seems reasonable that for a national economy to be called a SSE, the stock of built capital, people, and domesticated animals within its physical borders should be stable over time. However, exactly which flows should remain constant, and what sources and sinks they should be compared to, is not so clear. Below, I discuss four possible options for defining a national SSE, using terminology drawn from Material and Energy Flow Accounting. The first of these ignores trade, while the other three include it. The four options are: (1) stable domestic extraction and domestic outflows, (2) stable direct inputs and direct outputs, (3) stable consumption, and (4) stable throughput. Note that the important issue of whether to include hidden flows in the definition of a SSE is discussed separately in Section 4.5.

4.4.1. Stable Domestic Extraction and Domestic Outflows

The first option would be to define a SSE in terms of the material and energy extracted within a country's borders, and the wastes released within its borders. In other words, to define it based on stable domestic material extraction (DME), domestic energy extraction (DEE), and domestic processed output (DPO). Trade (i.e. imports and exports) would be completely ignored. There is a certain logic to this approach, as it only tracks flows between the economy in question and the environment. Flows between national economies (i.e. within the global economic system) are not considered.

In this approach, the scale of economic activity in relation to ecosystem capacity could be calculated on the input side by comparing domestic material extraction to sources within the country's borders. On the output side, scale could be calculated either by comparing domestic processed output to national sinks (e.g. for pollutants remaining within the country's borders), or by comparing it to some assigned share of global sinks (e.g. for pollutants crossing national borders, such as CO_2).

The main problem with the domestic extraction and outflows approach, however, is that a country could be importing a large and increasing volume of materials and energy, and still be considered a SSE if domestic extraction were not increasing. If the goods consumed in the country were produced abroad, then the waste outflows generated during their production would not be counted in the importing country's accounts either. Given the increasing shift of manufacturing from developed to developing countries, a national SSE definition based solely on domestic extraction and domestic outflows would favour developed countries, and seemingly allow them to skirt responsibility for the environmental impact of their resource consumption. It is debatable whether such an approach would really capture what is meant by a SSE.

4.4.2. Stable Direct Inputs and Direct Outputs

The second option would be to define a SSE in terms of all of the material and energy inputs entering the economy (whether extracted domestically or imported), and all of the material outputs leaving it (whether as wastes or as products for export). In other words, to define it based on stable direct material input (DMI), direct energy input (DEI), and direct material output (DMO). In general, the relationship between the quantities discussed so far (and shown in Figure 4.4) is:

$$\text{DMI} = \text{DME} + I_M \tag{4.1}$$

$$\text{DEI} = \text{DEE} + I_E \tag{4.2}$$

$$\text{DMO} = \text{DPO} + X_M \tag{4.3}$$

where I_M is material imports, I_E is energy imports, X_M is material exports, and X_E is energy exports.

What is accounted for in this approach is the total amount of material and energy entering the national economy (regardless of where it comes from), and the total amount of material leaving the economy (regardless of where it goes). With this approach, a country could reduce its domestic extraction, while increasing imports, and still remain a SSE. Similarly, it could emit less waste domestically, and export more products to other countries, and still remain a SSE.

A potential problem with the direct input/output approach, however, is that the resource flows accounted for may not necessarily benefit the people living in the country in question, and therefore it is debatable whether they should be held responsible for these flows. Resources could be extracted within a country's borders, but then exported (i.e. sold and consumed elsewhere). Or, resources could simply pass through the economy, first being imported and then re-exported (the so-called "Rotterdam effect"). Moreover, the approach results in double counting, as a raw material imported into Country A but exported to Country B as a finished product would be counted as an input to both economies. While DMI, DEI, and DMO could be used to assess the stability of total material and energy flows entering and leaving a particular economy, they could *not* be used to assess the scale of economic activity in relation to ecosystem capacity due to this double counting problem. Separate indicators (such as those described in the previous section) would still be needed to assess scale.

4.4.3. Stable Consumption

The third option would be to define a SSE using a consumption-based approach. If the economy is viewed as a system for translating natural resources into human well-being (as the Ends–Means Spectrum shown in Figure 3.1 suggests), then it may make more sense to account for resource use according to who benefits from the resources—in other words, by who consumes them. Following the standards of Material and Energy Flow Accounting, material and energy consumption indicators may be defined as follows:

$$\text{DMC} = \text{DME} + (I_M - X_M) = \text{DPO} + \text{NAS} \quad (4.4)$$

$$\text{DEC} = \text{DEE} + (I_E - X_E) \quad (4.5)$$

where DMC is *domestic material consumption*, DEC is *domestic energy consumption*, and NAS is *net additions to the stock of built capital*. DMC represents the flow of material inputs to a given economy that are either converted into wastes by the economy or accumulate as stocks within the economy. Since all stocks will eventually turn into emissions and wastes at some point in time, Weisz et al. (2006) note that DMC may also be interpreted as an indicator of the waste potential of a national economy.

It is worth noting that DMC and DEC are measures of "apparent consumption", as opposed to "total consumption". Although DMC and DEC account for trade, they only include trade in finished products, and do not include the upstream resource flows used to make these products. I use measures of apparent consumption within this section—not to suggest that upstream resource flows are not important—but because DMC and DEC are a bit simpler to interpret than their total consumption equivalents, and can be used to illustrate the same issues. Furthermore, while the methods of Energy Flow Accounting proposed by Haberl (2001) make provision for tracking energy stocks within the economy, I would argue that the energy consumption measure that is most relevant to a SSE is energy that is actually used. Therefore, I make a simplification and equate DEC to the energy that is degraded in quality and lost from the economic system.[14]

If the economy is viewed as an organism, then DMC represents the material used for both the organism's growth and maintenance, while DEC represents the energy needed for these processes. The health of an organism relates closely to what it ingests, i.e. consumes. Therefore I would expect that there would be a stronger relationship between consumption measures and social indicators than between extraction measures and social indicators.

In practice, material consumption indicators such as DMC are normally calculated in input units (i.e. as tonnes of biomass, minerals, and fossil fuels entering the economic system). These data could be compared to some assigned share of global sources to arrive at a measure of economic activity in relation to ecosystem capacity—on the input side at least. However, material consumption indicators such as DMC could not be meaningfully compared to national or global sinks since only part of what is counted as consumption enters the waste stream

[14] As described here, domestic energy consumption (DEC) represents the energy equivalent of domestic processed output (DPO).

in a given year (the rest accumulates as a stock). Therefore, a material outflow indicator (such as DPO) would still be needed to construct a measure of scale on the output side

Although a consumption-based approach might seem to be an improvement on the purely territorial approach discussed in Section 4.4.1, there are still some sticky issues. A country could have low and stable levels of consumption, but extract a high and increasing volume of resources. If these resources were exported, they would not be counted in the accounts of the extracting country. They would, instead, be counted in the accounts of the country where they were consumed. The intention of a consumption-based approach is to assign the responsibility for a given resource flow to the people who benefit from that flow. However, it could be argued that the extractors of a resource also benefit from the flow produced because they earn an income when they export it. It is therefore tempting to propose some form of shared responsibility between extractors and consumers (e.g. Lenzen et al., 2007). However, I would argue that the extractors do not actually benefit until they spend their income. Only then are they receiving goods and services in return for the resources that they have extracted.

4.4.4. Stable Throughput

The fourth, and final, option would be to define a SSE in terms of stable "throughput". Daly often uses this term when defining a SSE, which lends some weight to using a throughput measure. However, it is difficult to know whether Daly is using the term in the technical sense that is used in Material Flow Accounting, or as a shorthand for some other quantity.

From a Material Flow Accounting perspective, throughput is the flow of matter or energy that goes *through* the economy within a certain period of time—generally the accounting period of one year. Eurostat (2001) proposes two methods of defining and calculating material throughput (MT). The first method equates throughput to direct material input minus net additions to stock:

$$MT_1 = DMI - NAS = (DME + I_M) - NAS = DPO + X_M = DMO \quad (4.6)$$

The corresponding relationships for energy throughput (ET) would be:

$$ET_1 = DEI = DEE + I_E = DEC + X_E \quad (4.7)$$

These relationships are shown in Figure 4.5.

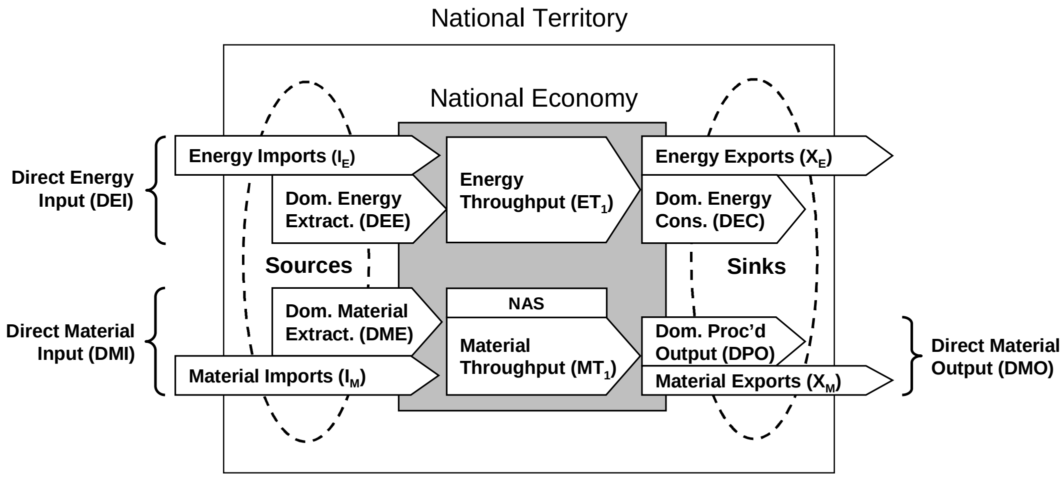

Figure 4.5: The first definition of material and energy throughput.

However, as Eurostat (2001) notes:

> It is not clear whether the term "throughput" is an appropriate term for these material flows. Throughput implies that material input is turned into material output during the accounting period. This is not the case when material output includes also wastes from the demolition of stocks and material input includes the materials that are added to stock (gross additions). In general, neither inputs nor outputs equal throughput defined as materials entering and leaving the economy in one accounting period (except for a flow equilibrium or steady state where stocks are constant).
>
> An alternative definition of throughput could be the input flows that become output to the environment (i.e. excluding exports) in one accounting period. This would correspond to inputs minus gross additions to stock which is equal to outputs minus outputs due to removals from stocks.

According to this second definition, material throughput would be defined as:

$$MT_2 = DMI - GAS - X_M = DPO - RFS = DMC - GAS \qquad (4.8)$$

where GAS is *gross additions to stock* and RFS is *removals from stock*. The corresponding relationships for energy throughput would be:

$$ET_2 = DEI - X_E = DEC \qquad (4.9)$$

These relationships are shown in Figure 4.6.

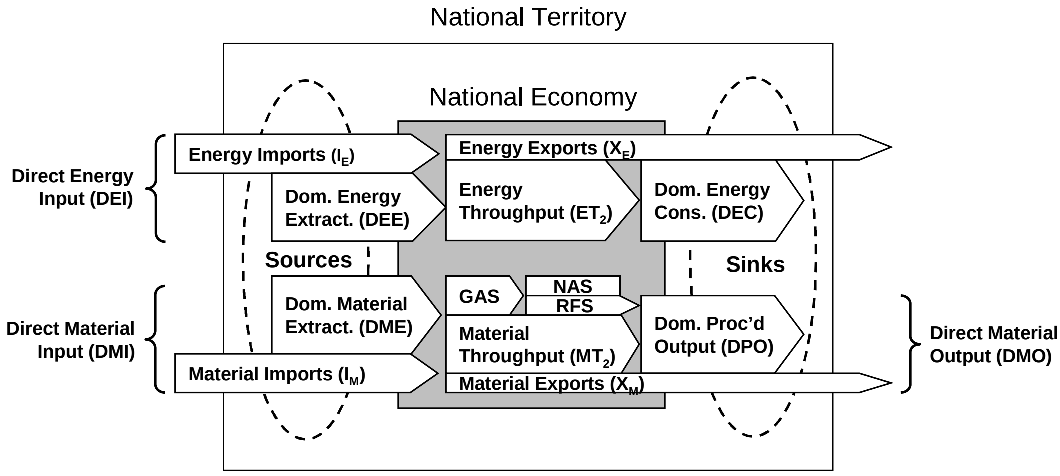

Figure 4.6: The second definition of material and energy throughput.

The two definitions of energy throughput both reduce to measures that have already been presented (i.e. DEI and DEC). Similarly, the first definition of material throughput is equivalent to domestic material output (DMO). The only new quantity is the second definition of material throughput, which is equivalent to the amount of *new* material that is discharged as waste by the economy.

Daly speaks of ensuring that throughput is "within the regenerative and assimilative capacities of the ecosystem" (Daly 2008, p. 3). However, regardless of which of the two definitions presented above is used, material throughput cannot be directly compared to the regenerative and assimilative capacities of ecosystem sources and sinks. Comparing the first definition of material throughput to either sources or sinks would result in double counting since exports are not subtracted from imports. Moreover, the first definition omits flows from nature that accumulate as stocks, making it incomparable with ecosystem sources. While using the second definition would avoid the double counting issue, this definition still omits flows from nature that accumulate as stocks (thus it cannot be compared to ecosystem sources), and it omits outflows associated with removals from stock (thus it cannot be compared to ecosystem sinks). In short, material throughput is not directly comparable to ecosystem sources and sinks because—by Eurostat's (2001) definitions at least—material throughput does not include all of the flows between the economy and the environment.

Daly appears to have a somewhat looser interpretation of the meaning of throughput than either of the above definitions. He writes:

> Throughput is the entropic physical flow of matter-energy from nature's sources, through the human economy and back to nature's sinks; it is necessary for maintenance and renewal of the constant stocks… But throughput it not itself capable of directly yielding service. It must first be accumulated into a stock of artifacts; it is the stock that directly yields service. Stocks may be thought of as throughput that has been accumulated and "frozen" in structured forms capable of satisfying human wants. (Daly, 1993, pp. 326-327)

This definition is closer to MT_1 than MT_2, although it is not identical to either. Daly appears to consider material throughput to be any material input that eventually becomes a material outflow, regardless of how long the material is captured as a stock in the economy. In the language of Material Flow Accounting, Daly's quantity is not really material throughput, but either direct material input (DMI) or domestic material consumption (DMC). Which one, of course, depends on how exports are treated in a SSE—a topic that Daly does not discuss.

4.4.5. Which Approach to Choose?

In the sections above I have discussed four possible options for defining a national SSE. I propose adopting a consumption-based approach, as described in Section 4.4.3, for three main reasons:

1. A consumption-based approach assigns responsibility for resource flows to those who benefit from using the resources.
2. A consumption-based approach helps to link together the indicators in the Ends–Means Spectrum. If there is any relationship between resource use and social performance, then a consumption-based approach would be the most likely approach to reveal it.
3. A consumption-based approach allows for greater consistency between the indicators that are used to measure the stability of flows and those that are used to measure the scale of economic activity in relation to the capacity of ecosystem sources and sinks.

That said, there is undoubtedly value in complementing consumption indicators with territorial measures (e.g. domestic extraction and domestic outflows) to ensure that countries are held accountable for the activities that take place within their own borders. While international demand may drive resource extraction in a country, it is still up to that country whether they choose to extract and sell their national resources.

4.5. *Hidden Flows*

The grey box shown in Figure 4.4 illustrates the system boundary between a national economy, its territory, and the rest of the world. The flows that enter the economy are referred to as *used extraction* in MEFA because they are used to produce the goods and services consumed, and they are ascribed economic value. However, materials and energy may also be extracted from the environment without ever entering the national economy. Examples include soil and rock that are excavated during construction, biomass that is killed but not harvested (e.g. discarded by-catch and wood harvesting losses), and overburden from mining and quarrying. These flows are referred to as *hidden flows* in MEFA, and fall into two categories: (1) resources that are extracted from within a nation's territory but not actually used by the national economy (so-called *domestic hidden flows*), and (2) the upstream resource requirements associated with imported products (so-called *foreign hidden flows*). The indicators discussed in Section 4.4 may be extended to include these hidden flows. For example, if domestic and foreign hidden flows are added to direct material input (DMI), the result is referred to as *total material requirement* (TMR). If domestic and foreign hidden flows are added to domestic material consumption (DMC), the result is referred to as *total material consumption* (TMC), and so on (Eurostat, 2001).

Empirical studies show that hidden flows can be very large. For example, Adriaanse et al. (1997) analysed the material requirements of four industrialised economies (Germany, Japan, the Netherlands, and the United States) and found that hidden flows accounted for 55–75% of the total material requirement of these economies. By comparison, data from the Global Material Flows Database (SERI, 2010) suggest that hidden flows account for about 40% of global material extraction.

An important issue to consider is whether or not hidden flows should be included in the definition of a SSE. On the one hand, it seems reasonable to draw a hard boundary between the economy and the environment and exclude hidden flows since they do not cross this boundary. If the economy is viewed as a system for translating natural resources into human well-being (as the Ends–Means Spectrum shown in Figure 3.1 suggests), then the Biophysical Accounts should include only those resources that actually enter the economic system. Flows that enter the economic system are transformed into goods and services and therefore have the potential to contribute to the intermediate and ultimate ends of the economy, whereas unused flows do not. In short, if the objective is to create a system of accounts that sheds light on the social implications of different patterns of resource use, then it would be more appropriate to measure used extraction than total extraction.

However, there is also a strong argument to be made for including hidden flows in the definition. Hidden flows are a by-product of economic activity, and they exert a pressure on the environment. Omitting hidden flows could result in an artificially low estimate of the scale of economic activity in relation to what ecosystems can support. For example, the used extraction of biomass (e.g. fish capture) might be lower than the maximum sustainable yield, but the total extraction of biomass (e.g. including by-catch as well) might be higher. Furthermore, data on foreign hidden flows may be necessary to determine whether a shift is occurring in resource-intensive production from developed to developing countries. In short, if the objective is to create a system of accounts that assesses environmental sustainability, then hidden flows should be included.

One problem with including hidden flows, however, is that the system boundary for their inclusion is difficult to define. Although several projects are currently developing and testing methodologies to account for hidden flows, a standard approach has yet to be adopted (Fischer-Kowalski et al., 2011).

Given that the primary objective of the Biophysical Accounts is to measure how close countries are to a SSE, and sustainable scale is a critical part of the definition of a SSE, I would argue that hidden flows should ideally be included in the accounting system. However, this does not necessarily imply that hidden flows should be included in all applications to which the accounting system is put. For example, when examining the relationship between resource use and social performance, it may be appropriate to exclude hidden flows.

4.6. Natural Capital

A SSE is defined as an economy in which the stocks of built capital, people, and domesticated animals—and the material and energy flows required to support them—are held constant, and where these flows are kept within ecological limits. But what is the role of the stock of natural capital in this definition?

Daly and Farley (2004, p. 17) define natural capital as "a stock that yields a flow of natural services and tangible natural resources. This includes solar energy, land, minerals and fossil fuels, water, living organisms, and the services provided by the interactions of all of these elements in ecological systems." Although the stock of natural capital generates a flow of natural resources that enter the economic system, I would argue that the stock of natural capital itself lies outside of the system boundaries of the economy. One of the main reasons for establishing a SSE is to preserve the stock of natural capital, which is seen as complementary to the stocks within the economic system (and necessary for their maintenance). The hope is that by stabilising the scale of the economic system, the stock of natural capital, and the services that it provides, can be maintained.

I would therefore argue that indicators relating to the stock of natural capital itself should not necessarily be included in an accounting system for a SSE, with the notable exception of indicators that measure the regenerative and assimilative capacities of ecosystems. These latter indicators are required to determine whether the scale of material flows between the environment and economy is sustainable—one of the main criteria for a SSE.

This is not to say that there is no value in developing an accounting system to monitor changes in the stock of natural capital and the services provided by it—clearly there is. Indicators that measure natural capital could, for example, be compared to biophysical indicators that measure the size of the economy to test whether an increase in the size of the economy results in a decrease in natural capital (as strong sustainability predicts). However, an accounting system for natural capital would be complementary to the one developed in this thesis, which focuses on the biophysical requirements and social performance of the economic system.

4.7. Summary

The definition of a steady state economy developed by Daly, and summarised in Chapter 2, provides a high-level description of what would be held steady in a SSE. However, it also leaves a number of questions unanswered. This chapter discussed some of the ways that specific aspects of the definition could be interpreted, with the eventual aim of developing a set of biophysical indicators capable of measuring what is meant by a steady state economy. Based on the discussion in this chapter, I suggest that a system of Biophysical Accounts designed to measure progress towards a national SSE should:

- Include indicators for the three main components of the definition (stocks, flows, and scale);
- Show how the stock and flow indicators are changing over time;
- Use aggregated indicators that measure the quantity of resource use, not its quality;
- Adopt a consumption-based approach, but also track territorial measures;
- Measure total (i.e. renewable plus non-renewable) resource use, and non-renewable resource use;
- Include hidden flows;
- Not include indicators that measure characteristics of the stock of natural capital, with the notable exception of indicators that measure the regenerative and assimilative capacities of ecosystems.

Moreover, I also propose three important definitional distinctions. If an economy manages to stabilise its biophysical stocks and flows, then I refer to it as a "stable economy". If the economy also manages to maintain material flows within ecological limits, then I refer to it as a "steady state economy". If, in addition to these biophysical criteria, the economy achieves a high quality of life for its citizens, then I refer to it as a "socially sustainable steady state economy".

There are undoubtedly other ways that the definition of SSE could be interpreted than what I have put forward. Other interpretations might draw the system boundary in a different way (for example attaching less importance to what is happening to the stock of built capital, and more importance to what is happening to the stock of natural capital). Nevertheless, I believe that my interpretation is a reasonable one that resolves a number of outstanding issues, and allows an operational set of indicators to be constructed.

5. The Biophysical Accounts

The Earth has no way of registering good intentions or future inventions or high hopes. It doesn't even pay attention to dollars, which are, from a planet's point of view, just a charming human invention. Planets measure only physical things – energy and materials and their flows into and out of changing populations of living creatures.

— Donella Meadows

In the previous chapter I discussed a number of the conceptual issues that arise when attempting to translate Daly's definition of a steady state economy into a concrete set of indicators. Within this chapter, I propose an operational set of indicators that reflect Daly's definition and these criteria. The primary purpose of these indicators is to measure how close national economies are to the biophysical stability and sustainable scale conditions of a steady state economy.

After proposing a set of "abstract" indicators based on Daly's definition (Section 5.1), I select a proxy to measure each of these, based on the best data currently available for a large number of countries. I choose three indicators to measure the rate of change of stocks (Sections 5.2 to 5.4), four indicators to measure the rate of change of flows (Sections 5.5 to 5.7), and a single indicator to measure the scale of economic activity in relation to the capacity of ecosystems to regenerate materials and assimilate wastes (Section 5.8). Finally, following the selection of these measurable proxies, I present a method for using the three types of indicators (change in stocks, change in flows, and scale) to determine how close different economies are to the idea of a steady state economy (Section 5.9).

5.1. What is Held Steady in a SSE?

As discussed in the previous chapter, a steady state economy may be defined as an economy where biophysical stocks and flows are stabilised, and where the scale of material flows is kept within ecological limits. With this stock–flow–scale categorisation in mind, it is possible to construct a set of "abstract" biophysical indicators to measure how close national economies are to a steady state economy. I use the term abstract indicators to refer to the general quantities that we would like to be able to measure, without specifying exactly how these quantities should be measured in practice. The abstract indicators are:

- Stocks
  - Human population growth rate
  - Domesticated animals growth rate
  - Built capital growth rate
- Flows
  - Material use growth rate
  - Material outflows growth rate
  - Energy use growth
- Scale
  - Ratio of material use to the capacity of ecosystem sources to regenerate materials
  - Ratio of material outflows to the capacity of ecosystem sinks to assimilate wastes

The first six indicators in the list (those related to stocks and flows) are growth rates, i.e. the rate of change of a variable over time. To calculate these indicators in practice would require time series data for a sufficiently long time period to observe trends (i.e. 5–10 years). The scale indicators, on the other hand, are ratios that could either be calculated as an average over this time period, or based on the final year in the period. The target for a steady state economy would be a growth rate of zero for the stock and flow indicators, and a ratio ≤ 1 for the scale indicators.

The objective of this thesis is not just to propose a set of abstract indicators that could be used to measure progress towards a steady state economy, but also to find measurable proxies for each of these and estimate how close current economies are to a SSE. I conduct this empirical analysis over a ten-year time period from 1997 to 2007. I selected this time period to be long enough to observe trends, but not so long as to introduce a serious restriction on the number of countries that could be analysed.

In the following sections I choose a proxy for each of the abstract indicators listed above, based on the best data currently available for a large number of countries over the analysis period. In practice this means that I only consider biophysical indicators that are available for at least ~150 countries, with data for each year in the 1997–2007 period.

5.2. *Human Population*

A constant population is one of the defining elements of a steady state economy. All else being equal, the total resource use of a country will increase when either the number of people living in the country increases, or the amount that each of these people consumes increases. To achieve a steady state economy, it is therefore necessary to stabilise—not just per capita resource use—but also population numbers.

Given the widespread availability of population data, this abstract indicator is easily translated into a measurable proxy. In order to calculate the annual rate of population growth, I use population data published by the United Nations Population Division (United Nations, 2009). These data provide annual population estimates for almost all countries, from 1950 to 2010.

5.3. *Domesticated Animals*

As discussed in Section 4.1, I consider domesticated animals (i.e. livestock and aquaculture) to be stocks within the economic system, but plantation forests and agricultural plants to be outside of the economic system. To construct a proxy for the rate of change of the stock of domesticated animals, I use livestock data obtained from the Food and Agriculture Organization (FAOSTAT, 2011a). These data tabulate the number of animals by species in different countries, over the period 1961–2009. In order to arrive at an aggregated total for the stock in each country, I convert the livestock population data to *livestock units*. A livestock unit is a standardised animal unit obtained by multiplying the number of animals by a conversion factor that takes into account the feed requirements of each type of animal. Conversion factors were obtained from Krausmann et al. (2008a, Table S7), and are based on FAO (2003).[15]

Unfortunately, I am unable to include aquaculture fish stocks in the domesticated animals indicator due to a lack of data. Aquaculture data, such as those provided by the Food and Agriculture Organization (FAO, 2011b), typically

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[15] It is worth noting that the conversion factors used in this analysis do not account for regional differences in livestock weight.

measure annual production (i.e. the quantity of fish harvested per year), and do not provide any information on the size of the actual fish stock. It is hard to know how significant the omission of aquaculture fish stocks is to the domesticated animals indicator, but some idea may be obtained by comparing aquaculture and livestock production data (recognising that production data represent flows, not stocks).

In 2007, world aquaculture production was roughly 50 million tonnes (FAO, 2011b), while world meat production was roughly 272 million tonnes (FAOSTAT, 2011b). If both stocks are equally proportional to their respective production flows (a somewhat tenuous assumption), then the global aquaculture fish stock would represent ~16% of the total stock of domesticated animals by weight. However, this figure probably overestimates the relative scale of aquaculture as there are large stocks of land animals that are not used to produce meat, and that are therefore not included in this simple calculation (e.g. dairy cows, egg-laying hens, and sheep raised for wool). Nevertheless, the omission of aquaculture data may result in a significant source of error in the domesticated animals indicator, particularly given the rapid growth that is occurring in the global aquaculture industry: between 1997 and 2007, global aquaculture production increased by 6.4% per year on average (FAO, 2011b), while global meat production increased by 2.2% per year (FAOSTAT, 2011b).

5.4. Built Capital

In his definition of a SSE, Daly refers to a constant stock of artefacts (i.e. built capital), which he defines as including both producer goods and the total inventory of consumer goods (Daly 1977, p. 16). Producer goods include the machines and other infrastructure like buildings, roads, and factories that contribute to the production process, but do not become embodied in its output. Consumer goods could theoretically include both durable goods (e.g. automobiles, furniture, and household appliances) and non-durable goods (e.g. food, beverages, clothing, and shoes). However, many non-durable goods move through the economy so quickly that it is probably more appropriate to think of them as a flow than as a stock. Following the standards used in Material Flow Accounting, I would suggest that any good that remains in the economy for less than a year should be considered a material flow as opposed to a net addition to the stock of built capital. This cut-off lends itself to an accounting system that allows flows to be compared to regeneration and assimilation rates in ecosystems (which also tend to be measured on an annual basis).

Theoretically, it is possible to calculate whether the stock of built capital is growing in mass terms using material flows data. If direct material inputs to the economy are larger than direct material outputs (i.e. if DMI > DMO), then the stock of built capital will increase.[16] If the two quantities are equal, the stock will not change. In general, net additions to stock (NAS) may be calculated as:

$$NAS = DMI - DMO = (DME + I_M) - (DPO + X_M) \quad (5.1)$$

Matthews et al. (2000) use material flow data to calculate net additions to stock in five industrial economies over the period 1975–1996. They find that between half and three quarters of direct material inputs pass through these economies and back to the environment within a year. The remainder is added to the stock, as construction materials in new buildings and other infrastructure, and materials incorporated into new durable goods such as cars, industrial machinery, and household appliances. Construction materials are by far the largest component of net additions to stock, greatly exceeding durable goods.[17]

With the exception of the above study, however, national material flow accounts are currently not comprehensive enough, particularly on the outflows side, to allow for the calculation of net additions to stock. Therefore it is necessary to consider other methods for calculating the change in the stock of built capital over time.

One approach would be to use traditional economic data on net investment (i.e. gross investment minus depreciation). The U.S. Bureau of Economic Analysis maintains a chain-type quantity index that measures the net change in the stock of fixed assets and consumer durable goods in the U.S. from 1925 to present (BEA, 2010). These monetary data correlate surprisingly well with the biophysical data produced by Matthews et al. (2000) for the period of overlap (Figure 5.1).

[16] Although not shown in the formula, balancing items (i.e. oxygen and water) must also be included in order to calculate net additions to stock.
[17] Eurostat (2001, p. 34) claims that infrastructure and buildings usually represent more than 90% of net additions to stock.

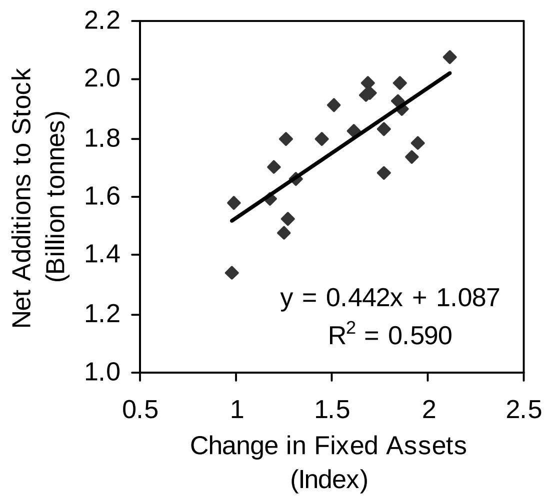

Figure 5.1: The correlation between change in fixed assets and net additions to stock (year on year) in the U.S. for the period 1975–1996. Source: own calculations, based on BEA (2010) and Matthews et al. (2000).

Unfortunately, similar data are not available for other countries. The closest data available for a wide number of countries are the World Bank's data on gross fixed capital formation (World Bank, 2009). However, there are two problems with using these data to measure change in the stock of built capital: (1) they measure the economic value of the stock, not its physical quantity, and (2) they do not account for depreciation. There is no significant correlation between the World Bank data and the biophysical data from the study by Matthews et al. (2000).

A second approach would be to use data on the change in urban land area. The largest component of the stock of built capital is buildings and other infrastructure, and as materials are added to this stock, it can expand either upwards or outwards. While upward expansion (i.e. urban infill, higher buildings) will not be captured by an urban land area indicator, I would argue that it is the outward expansion (urban sprawl) that has more serious environmental consequences because it directly displaces natural capital. Thus the physical land area occupied by the stock of built capital may be a more important measure than its actual quantity.

There are a number of global land cover datasets that include a measure of urban land area. Potere et al. (2009) identify eight global maps of urban area, and assess their accuracy. The problem with all of these maps, however, is that they provide a snapshot of urban area for one year only, generally around the year 2000. Moreover, due to the different sensors, resolutions, and land classification systems used, the different maps are not easily comparable to one another.

Another possible approach would be to estimate the change in built capital using night-time lights data. Nocturnal lighting is one of the hallmarks of humanity's presence on earth, and the density of lighting tends to match the density of infrastructure (Elvidge et al., 2011). The latest release of the Night-time Lights of the World dataset produced by the National Geophysical Data Center (NGDC, 2010) provides cloud-free night-time lights data for each year between 1992 and 2009. Unfortunately these data are not radiance-calibrated, making comparisons between years difficult. However, Elvidge et al. (2009) have developed an inter-calibration procedure based on the assumption that the brightness in certain reference areas has changed little over time. Using this procedure, Elvidge et al. (2011) have constructed a time series of stable lights data for 155 countries over the eighteen-year period from 1992 to 2009.

It is difficult to say whether these data adequately measure changes in the stock of artefacts as defined by Daly, or even changes in the largest component of this stock (i.e. buildings and other infrastructure). At present, there are simply not sufficient reference data to test whether this is the case. However, given the scarcity of data available to measure how the physical stock of built capital is changing over time, I use night-time lights data as a proxy. In order to calculate national trends, I use annual "sum-of-lights" data published by Elvidge et al. (2011). These data capture both changes in the intensity and area of nocturnal lighting. Change in night-time lighting is likely to be a very rough approximation of change in built capital, but one that is at least in keeping with the biophysical definition of a SSE.

5.5. Material Use

Material inputs to the economy may be grouped into five basic categories: biomass, minerals, fossil fuels, water, and air. Of these, biomass, water, and air are renewable resources, while minerals and fossil fuels are non-renewable resources. Based on the discussion in Chapter 4, I suggest that two aggregate material flow indicators are ideally needed to measure progress towards a SSE: one to measure overall (renewable plus non-renewable) material use, and one to measure non-renewable material use. Moreover, these indicators should measure resource *consumption*, include hidden flows, and be aggregated in physical units such as mass or volume. The goal in a SSE would be to stabilise overall material use, and reduce non-renewable material use.

The closest existing indicator approach to what I have suggested is probably *total material consumption* (TMC), as defined in Material Flow Accounting. TMC measures the total material use associated with domestic consumption, adding imports and their associated hidden flows, and subtracting exports and their associated hidden flows (Eurostat, 2001). Ideally, two TMC indicators would be used to measure progress towards a SSE. The first would measure the rate of change of overall material consumption (biomass, minerals, and fossil fuels), while the second would measure the rate of change of non-renewable material consumption (minerals and fossil fuels). Following the conventions of MFA, water consumption is probably best measured separately, while air may be excluded from the indicators altogether.[18]

Unfortunately, despite their conceptual appeal, TMC data are not yet widely available. Even domestic material consumption (DMC) data, which exclude hidden flows, are only available for selected countries and years. Eurostat (2011) have published annual DMC data for 30 European countries, for the period 2000–2007. Schandl and West (2010) have calculated annual DMC data for 59 countries in the Asia-Pacific region, for the period 1970–2005. Steinberger et al. (2010) have calculated DMC data for an impressive 175 countries, but only for the year 2000.

The result is that, at present, neither DMC nor TMC data are available for enough countries and over a long enough time period to create indicators that measure the rate of change of material consumption in the Biophysical Accounts. This situation will likely change within the next year or two, however, with time series data for both indicators becoming available for most countries. Dittrich and Bringezu (2010) have recently published an analysis of the physical dimensions of international trade which provides physical trade balances for seven re-

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[18] Water is excluded from MFA studies because water flows are generally an order of magnitude larger than all other flows combined, and their inclusion would obscure the meaning of the indicators (Matthews et al., 2000; Eurostat, 2001). Air is included as a balancing item in MFA studies, but excluded from the final indicators produced.

gions, spanning a roughly 40-year time period in five-year increments. The authors are working on a second paper which will combine national extraction data with both physical trade balance data and data on indirect flows to allow cross-national comparisons of both DMC and TMC. The authors intend to make these data publicly available via an online database (M. Dittrich, pers. comm., 2011).

The question then is which data that are currently available could be used as a proxy for DMC/TMC? There are two main candidates: (1) domestic material extraction (DME) and (2) the ecological footprint. Data for domestic material extraction are available from the Global Material Flows Database (SERI, 2010) for 215 countries, over the period 1980–2007. Ecological footprint data are available from the National Footprint Accounts (GFN, 2010) for 229 countries, over the period 1961–2007.

The main arguments in favour of using the ecological footprint are that it is an indicator of consumption that accounts for trade, and it may be compared to biocapacity to create a complementary indicator of scale. The footprint is more similar to DMC than TMC in that it measures apparent consumption as opposed to total consumption (i.e. it excludes foreign hidden flows). The main arguments against using the footprint are that it does not include all of the material flows accounted for with DMC (most notably minerals), and it uses a different aggregation scheme based on land area instead of mass.

The main argument in favour of using DME is that it includes the same materials, and is aggregated in the same way, as DMC. The main argument against using DME is that it does not account for trade. However, Steinberger et al. (2010, Table 7) show that there is a very strong correlation between DME and DMC ($R^2 = 0.85$) when national values are compared for a single year. This does not necessarily mean that the rate of change of these two variables over multiple years will be correlated, however.

As a compromise, I therefore include both indicators in the Biophysical Accounts. Neither of these indicators is ideal, but including the two of them has the advantage of providing both a territorial measure (DME) and a consumption-based measure (the ecological footprint). Domestic material extraction data are obtained from the Global Material Flows Database (SERI, 2010), while ecological footprint data are obtained from the National Footprint Accounts, 2010 edition (GFN, 2010). I do not calculate a separate measure of non-renewable resource use at this time due to issues of data availability and the extra complexity that this would add to the empirical analysis. Nevertheless, this remains an important quantity to consider including in future studies.

Although biomass, minerals, and fossil fuels are accounted for using DME and the ecological footprint, water is not, leaving the question of how to account for water use. The FAO's AQUASTAT database (FAO, 2011a) maintains data on total freshwater withdrawal for a number of countries. While data are available for most countries for the year 2000, there is very little data available for other years, making analysis of growth rates in water use across countries impossible using these data. The FAO data also represent water extraction, and do not account for water consumption.

The *water footprint* (Hoekstra and Hung, 2002; Hoekstra et al., 2011) provides an alternative indicator that could be used to measure the appropriation of freshwater resources from a consumption perspective. The water footprint is in many ways analogous to the ecological footprint; it measures the volume of water consumed (evaporated or incorporated into a product) or polluted per unit of time. Mekonnen and Hoekstra (2011, p. 11) provide a good description:

> A water footprint has three components: green, blue and grey. The blue water footprint refers to consumption of blue water resources (surface and ground water). The green water footprint is the volume of green water (rainwater) consumed, which is particularly relevant in crop production. The grey water footprint is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

Water footprint data are available from the National Water Footprint Accounts (Mekonnen and Hoekstra, 2011), which provide water footprint data for 174 countries. However, the data within the accounts represent average values over a ten-year period (1996–2005). Unfortunately, there is no time series of water footprint data currently available, and Mekonnen and Hoekstra (2011) note that calculating trends in water use over a short period (e.g. ten years) would be difficult because many of the required data are simply not available on an annual basis. Due to the current lack of availability of a water use time series, I am therefore forced to omit water from the material use indicators in the Biophysical Accounts at this time.

5.6. *Material Outflows*

Compared to material inputs, comprehensive assessments of material outflows have largely been neglected. One notable exception is a study for the World Resources Institute by Matthews et al. (2000) which documents the material outflows of five industrial economies (Germany, Japan, the Netherlands, the United States, and Austria) for the period 1975–1996. The authors calculate the domestic processed output (DPO) for these countries, which includes the following material outflows:

- Emissions to air from commercial energy combustion and other industrial processes;
- Industrial and household wastes deposited in landfills;
- Material loads in wastewater;
- Materials dispersed into the environment as a result of product use;
- Emissions from incineration plants.

The authors find that CO_2 emissions account for more than 80% of the material outflows by weight in the five countries studied, making the atmosphere the "largest dumping ground for industrial wastes" (Matthews et al., 2000, p. xii). As the authors explain, "Modern industrial economies, no matter how high-tech, are carbon-based economies, and their pre-dominant activity is burning material" (p. 23).[19] The single largest source of CO_2 emissions is the burning of fossil fuels, which accounts for three quarters of CO_2 emissions, and roughly 60% of all greenhouse gas emissions (WRI, 2009).

CO_2 emissions data are available from a number of sources. Terrestrial emissions data are available from the Carbon Dioxide Information Analysis Centre (CDIAC; Boden et al., 2010) for the period 1751–2007 and almost all countries; the Energy Information Administration (EIA, 2010) for 1980–2008 and almost all countries); the International Energy Agency (IEA, 2011) for 1971–2008 and 134 countries; and the United Nations Framework Convention on Climate Change (UNFCCC, 2011) for 1990–2008 and Annex I countries. In addition, consump-

[19] It is worth noting that the authors do not include water flows in their study, stating that they are so large that they would dominate all of the other material flows and obscure the meaning of the indicators. Oxygen, on the other hand, is included in emissions from industrial processes in the output indicators, which potentially inflates the relative magnitude of CO_2 emissions.

tion-based CO_2 emissions data are available from Peters et al. (2011) for the period 1990–2008 and 92 countries.

Given that CO_2 is such an important material outflow, and because CO_2 emissions data are readily available, I use CO_2 emissions as the indicator of material outflows in the Biophysical Accounts. Ideally, I would like to use consumption-based emissions data, but the small number of countries for which these data are available would restrict the scope of the analysis; therefore I use territorial emissions instead. The UNFCCC data are probably the most accurate of the territorial emissions data, followed by the IEA data (WRI, 2011). However, since these data are also only available for a limited number of countries, I use the CDIAC data. Specifically, I use total CO_2 emissions from fossil-fuel burning, cement production, and gas flaring, as published by Boden et al. (2010).

5.7. *Energy Use*

Physically speaking, energy is the ability to do work. Environmentally speaking, it has been called the "master resource" (Simon, 1996, p. 162). Our ability as a species to modify our environment is directly related to the amount of energy we have at our disposal. Although different sources of energy (e.g. coal, nuclear, hydro, and wind) have different environmental impacts, all else being equal as we use more energy we also use more materials, produce more wastes, and modify the landscape to a greater extent.[20] As Paul Ehrlich and colleagues put it:

> [N]o way of mobilizing energy is free of environmentally damaging side effects, and the uses to which energy from any source is put usually have negative environmental side effects as well. Bulldozers that ran on hydrogen generated by solar power could still destroy wetlands and old-growth forests (Ehrlich et al., 1997).

Daly argues both for the stabilisation of matter/energy throughput within ecological limits, and for the gradual replacement of non-renewable resources with renewable substitutes. He goes as far as to suggest that "solar energy would be the major source in the SSE" (Daly 1977, p. 146).

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[20] Common and Stagl (2005, p. 104) suggest that energy use may be interpreted as an approximate measure of environmental impact because "[i]f more energy is being 'used' by the economy, then more matter is being moved and transformed by the economy". Based on an analysis of global material and energy use for the period 1900–2005, Krausmann et al. (2009) find that material and energy use follow a very similar trajectory to one another.

Following the same approach that I propose for measuring material use, I suggest that two aggregate energy flow indicators are ideally needed to measure progress towards a SSE: one to measure overall (renewable plus non-renewable) energy use, and one to measure non-renewable energy use. The goal in a SSE would be to stabilise overall energy use, and reduce non-renewable energy use.

Standard energy use statistics, such as those published by the International Energy Agency (IEA) or U.S. Energy Information Administration (EIA), typically account for *technical* energy use. This is the energy used in technical devices to provide heat, light, mechanical work, and data processing (Haberl, 2001). It is, in other words, the flow of energy required to support the stock of built capital. As Haberl (2001) points out, however, these data neglect the nutritional energy flows required by the two other stocks within the economic system: people and domesticated animals. He suggests that an accounting system designed to measure the energetic metabolism of society should include the flows of nutritional energy as well.

Along these lines, Haberl (2001) proposes a system of Energy Flow Accounting with aggregate quantities that mirror those used in Material Flow Accounting. These include a measure of domestic energy consumption (DEC) that is analogous to domestic material consumption (DMC), and a measure of total energy consumption (TEC) that is analogous to total material consumption (TMC). From a strictly conceptual point of view, TEC would probably be the best indicator to use to measure energy use in the Biophysical Accounts, although DEC represents a more practical alternative due to the large uncertainties involved in measuring hidden flows.

However, if both DMC and DEC were included in the Biophysical Accounts, then a certain amount of double counting would occur since both measures include fossil fuels and biomass. It is tempting to want to exclude fossil fuels from the material consumption indicators since their primary use is the production of technical energy, not the creation of material artefacts. Following this logic, however, it would also be necessary to exclude the fraction of biomass used to produce technical energy, as well as the fraction used for the nutritional energy of people and domesticated animals. Such a decision would result in the exclusion of a large portion of overall material flows from the material consumption indicators, and could lead to a rather skewed view of the material requirements of modern economies.

I therefore argue in favour of following the standards used in Material and Energy Flow Accounting (Eurostat, 2001; Haberl, 2001; Eurostat, 2007), and including fossil fuel and biomass data in the calculation of both indicators. Although some of the underlying data used to calculate the two indicators are the same, DMC and DEC are aggregated in different units (mass units for DMC and energy units for DEC). Moreover, as Krausmann et al. (2009) note, there is no overlap between significant material flows (i.e. all non-energy-use materials) and energy flows (i.e. hydropower, nuclear power, geothermal energy) accounted for with the two indicators.

Unfortunately, DEC data calculated using the method proposed by Haberl (2001) are currently only available for selected countries and years (and TEC data are not yet available at all to my knowledge). Haberl et al. (2006) have calculated DEC for the EU-15 for the period 1970–2001, and for the United States for the period 1980–2000. Krausmann et al. (2008b) have calculated DEC for 175 countries, but only for the year 2000.

Given the shortage of DEC data, it is necessary to use a proxy for this indicator. The most obvious candidate is Total Primary Energy Supply (TPES), which measures the apparent consumption of technical energy. TPES is conceptually similar to DEC, but does not include the nutritional energy flows (i.e. biomass) consumed by people and domesticated animals. TPES data are available from the International Energy Agency (IEA, 2010) for the period 1971–2008 for ~135 countries, and from the U.S. Energy Information Administration (EIA, 2011) for the period 1980–2008 for ~215 countries.

Given the much larger number of countries covered by the EIA data, I use these data to measure the rate of change of energy use in the Biophysical Accounts. Unfortunately, the EIA data do not distinguish between renewable and non-renewable sources of energy, and therefore I do not include a separate measure of non-renewable energy use in the Biophysical Accounts at this time. Nevertheless, this remains an important indicator to consider including as data become available.

5.8. *Scale*

A steady state economy is not just an economy where stocks and flows remain stable over time. It is also an economy where the level of the flows is within the carrying capacity of ecosystems. Daly (2010) suggests that the maximum sustainable scale for the economy should be determined based on either the capacity of ecosystem sources to regenerate materials, or the capacity of ecosystem sinks to assimilate wastes—whichever limit is reached first. In this section I discuss three approaches that could be used to assess maximum sustainable scale. The first uses indicators on the source side, the second uses indicators on the sink side, and the third is a hybrid approach that includes both sources and sinks.

5.8.1. Ecosystem Sources

On the source side, only the flow of renewable materials (i.e. biomass and water) is relevant for assessing the scale of economic activity, as these are the only materials that ecosystems regenerate. The flow of non-renewable materials (i.e. minerals and fossil fuels) is largely irrelevant on the source side, since ecosystems do not regenerate these materials (except over geological time periods), and hence there is no ecosystem threshold to compare them to.

Human appropriation of net primary production (HANPP; Vitousek et al., 1986; Haberl et al., 2007; O'Neill et al., 2007) is an indicator that could be used to assess the scale of biomass use relative to ecosystem sources. HANPP measures the amount of biomass that human beings either (1) harvest, or (2) make unavailable through land cover change. It may be compared to the potential net primary production that would be available in the absence of human disturbance, to arrive at a measure of the magnitude of human activity with respect to available biomass flows. The most detailed HANPP study to date (Haberl et al., 2007) indicates that human beings currently appropriate about 24% of global potential net primary production.

Daly (1991, p. 245) suggests that HANPP is "[p]robably the best index of the scale of the human economy as a part of the biosphere". However, the problem with using HANPP as an indicator of scale is that HANPP does not provide a clear "sustainability threshold". Although 100% appropriation would clearly be destructive because it would leave no resources for other species, levels much lower than this may not be sustainable either (Haberl et al., 2004b). Based on the precautionary principle, Weterings and Opschoor (1992) argue that the level of HANPP should be "small" compared to natural processes, and propose 20% appropriation as a sustainability threshold. However, this number is not based on scientific criteria, and it is debatable how to set a meaningful lower threshold (Haberl et al., 2004b).

With respect to water, the blue water footprint (Hoekstra and Hung, 2002; Hoekstra et al., 2011), which measures the consumption of surface and ground water, is an indicator that could theoretically be used to assess the scale of water use. However, there is currently no complementary measure of national water availability/regeneration to compare the blue water footprint to. Rockström et al. (2009a) suggest that global blue water use should not exceed 4000 km^3 per year as surpassing this threshold could result in the collapse of terrestrial and aquatic ecosystems at the regional to continental scale. However, in order to construct meaningful national water budgets it would be necessary to have much more detailed information on national water resources than is currently available.

5.8.2. Ecosystem Sinks

While on the source side only the flow of renewable resources is relevant for assessing sustainability, the same is not true on the sink side. On the sink side, all outflows must be considered. Moreover, the media that outflows are deposited into (e.g. land, water, or air) is more important that whether they originate from renewable or non-renewable sources.

Modern industrial economies release a vast number of different materials into the environment as waste. Some of these materials are easily assimilated by ecosystem sinks (e.g. crop residues), while others cannot be broken down at all by biological processes (e.g. radioactive waste). Given the sheer number and wildly different characteristics of these materials, it might seem to be an almost impossible task to estimate whether material outflows are within the assimilative capacity of ecosystem sinks.

As was discussed in Section 5.6, however, the dominant material outflow from industrial economies is CO_2—a pollutant with a clear link to a global environmental problem, namely climate change. If greenhouse gases are weighted by their global warming potential, then CO_2 is the most important, accounting for

77% of all global anthropogenic greenhouse gas emissions (as of 2004), including those from land use change (IPCC, 2007).

There is a growing consensus that global warming must be limited to no more than 2 °C above pre-industrial levels if dangerous climate change is to be avoided. Based on a comprehensive probabilistic analysis, Meinshausen et al. (2009) conclude that if cumulative global CO_2 emissions are limited to 1,000 Gt over the period 2000–2050, the probability of exceeding 2 degrees of warming would be 25% (i.e. relatively low). Alternatively, if emissions were limited to 1,160 Gt, the probability would be 33%. These, or other similar data, could be used to construct national carbon budgets, acknowledging that there are many different ways that "carbon space" could be allocated among nations (Opschoor, 2010). National carbon budgets could be compared to national CO_2 emissions data to arrive at an indicator of the scale of waste outflows in comparison to ecosystem sinks. While such an approach would not account for all waste emissions from industrial economies, it would relate the largest of these to an established limit on the sink side.

5.8.3. A Hybrid Approach

If the separate source and sink indicators discussed above could be implemented, they would generate three indicators of scale—two on the source side (HANPP and the blue water footprint) and one on the sink side (CO_2 emissions). Following Daly's (2010) suggestion, maximum sustainable scale would be defined as the point where the first of these three indicators crossed its sustainability threshold.

While the separate indicators discussed above have a certain appeal, there are clear problems with implementing them in practice, particularly with regard to establishing sustainability thresholds for the source indicators. For the time being, I therefore propose using a hybrid indicator that combines information on both sources and sinks in order to measure maximum sustainable scale. The indicator I propose is the ecological footprint (Wackernagel and Rees, 1996). Although the methodology used to calculate the footprint has been criticised by a number of authors (see Section 3.3.3), it remains the only indicator of resource use and waste emissions that has a clear sustainability threshold.

The footprint measures the area of biologically productive land that a country needs to produce the biomass it consumes, and assimilate the CO_2 emissions it generates. The footprint does not include the flow of non-renewable materials such as minerals, but it does include fossil fuels in terms of the CO_2 emissions that are produced during their combustion. These emissions are translated into the area of forested land necessary to sequester the CO_2 emitted (Ewing et al., 2010b). Ecological footprint data are available from the National Footprint Accounts (GFN, 2010) for 229 countries, over the period 1961–2007.

The ecological footprint may be compared to biocapacity (the supply of biologically productive land) to arrive at a ratio of the scale of economic activity in relation to what the environment can sustain. At the national level, a country's footprint may either be compared to its national biocapacity (the area of biologically productive land within the country's borders), or to the concept of a "fair earthshare" (the area of biologically productive land that would be available to each person if global biocapacity were divided equally among all people).

There are arguments for and against each of these approaches. On the one hand it could be argued that comparisons should be made with respect to national biocapacity, since a country can only manage what happens within its own borders. Governments are elected nationally, the economy is managed nationally, and therefore a country's footprint should be compared to its national biocapacity. Each country has a certain endowment of biologically productive land and it should manage its activities so that it does not consume more than it can produce with this land.

While this approach is fair with respect to countries, it is not necessarily fair to the people living within them. It could be argued that existing borders propagate an artificial and unjust distribution of the Earth's resources, and that these resources should be shared much more equitably between global citizens. If global equity is the goal, then it would be more appropriate to compare the ecological footprint in each country to a fair earthshare.

From a technical perspective there is no right or wrong answer to which of these two approaches should be taken. Either approach, if adopted by all nations, would lead to ecological sustainability (assuming we accept the ecological footprint as a meaningful measure of sustainability). However, given the strong focus on equity in the degrowth movement, it is probably more appropriate to compare the ecological footprint to a fair earthshare. The Paris Declaration explicitly mentions the goal of "right-sizing" national economies, suggesting that "in countries where the per capita footprint is greater than the sustainable global level, right-sizing implies a reduction to this level within a reasonable time-frame" (Research & Degrowth, 2010, p. 524). I therefore use the ratio of per capita ecological footprint to a fair earthshare as the indicator of scale in the Biophysical Accounts.[21] I use data for the year 2007 (the final year in the analysis period). The data are obtained from the National Footprint Accounts, 2010 edition, and are calculated by the Global Footprint Network (GFN, 2010).

5.9. The Pathway to a Steady State Economy [22]

The previous sections of this chapter have identified a number of individual indicators that could be used to measure how close economies are to a steady state economy. These indicators belong to three broad groups: the rate of change of stocks, the rate of change of flows, and the scale of economic activity in relation to ecological limits. However, some method of conceptualising the relationship between these groups of indicators is still needed in order to tell how close a given country is to a SSE.

I suggest that the three different groups of indicators in the Biophysical Accounts may be thought of as orthogonal dimensions that form a three-dimensional space (Figure 5.2). A point for each country could be plotted in this space based on the values of its individual indicators. This approach would provide a clear visualisation of how close a given country was to a steady state economy, and which issues (e.g. population growth, resource use) needed to be addressed in order to move it closer to this goal. I refer to this approach as the "pathway approach".

[21] A "fair earthshare" is equal to 1.8 global hectares per person in the year 2007. This value is obtained by dividing global biocapacity by global population.
[22] The material in this section is published in O'Neill (in press).

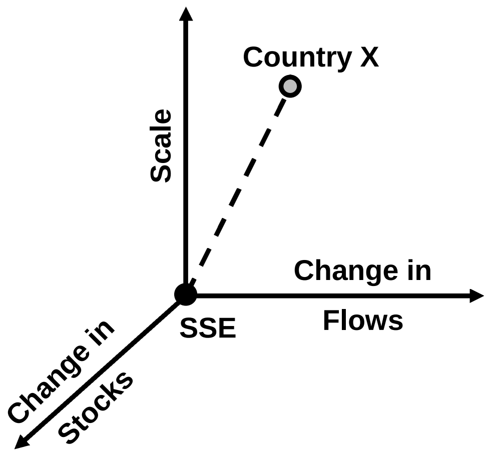

Figure 5.2: A three-dimensional visualisation of the distance between a given country and the goal of a steady state economy (SSE), based on the three indicator groups in the Biophysical Accounts.

In practice, the data would probably be easier to interpret if only two dimensions were considered at a time. If data were plotted for scale and change in flows, for example, then each country would fall into one of four quadrants, which I label desirable growth, undesirable growth, desirable degrowth, and undesirable degrowth. Using this approach, the pathway for a given country to reach a steady state economy could be plotted (Figure 5.3). For example, if an economy were experiencing *undesirable growth* (i.e. its resource use was too large and yet still increasing), then degrowth would be necessary before it could achieve a SSE. If an economy were experiencing *desirable degrowth* (i.e. its resource use was too large but decreasing) it would need to continue on this path until its resource use reached a sustainable level, at which point further degrowth would no longer be necessary, and it would have achieved a SSE. On the other hand, if an economy were experiencing *undesirable degrowth* (i.e. its resource use was below the optimal level and yet decreasing), then growth would be necessary before it could achieve a SSE. And finally, if an economy were experiencing *desirable growth* (i.e. its resource use was below the optimal level but increasing) it would need to continue on this path until its economy reached the optimal scale, at which point growth would no longer be necessary, and it would have achieved a SSE.

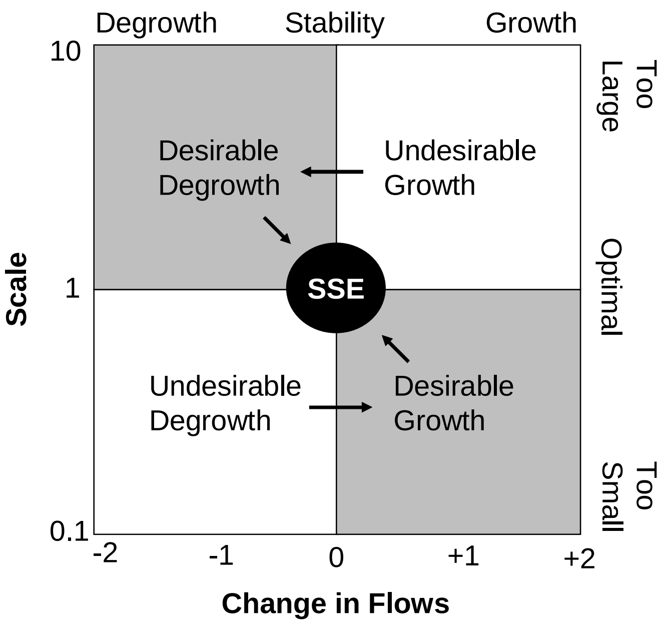

Figure 5.3: A two-dimensional visualisation (with scale and change in flows) showing the pathway to a steady state economy.

The concept of optimal scale is clearly important to define in such an analysis. The simplest option would be to define optimal scale as the maximum sustainable scale—in other words, to define it based solely on biophysical indicators related to the capacity of ecosystems to regenerate materials and assimilate wastes. This is the approach taken within this thesis. As described in Section 5.8, I use the ecological footprint as an indicator of scale, and define optimal scale as a "fair earthshare" (i.e. the biocapacity that would be available to each person if global biocapacity were equally divided among all people). A country that fell into either the desirable growth or desirable degrowth quadrant would be moving closer towards both its maximum sustainable scale and international equity (in terms of resource use).

There are other ways that optimal scale could be defined, however. Optimal scale could be defined somewhere below the maximum sustainable level to provide ecological space for other species. Or, alternatively, the indicators in the Social Accounts (next chapter) could even be used to help decide on the optimal scale of the economy. For example, if an economy achieved a certain *sufficient* score on the indicators in the Social Accounts, and its resource use was still below the maximum sustainable level, then this lower level might be considered the optimal scale for the economy. Or, following Lawn (2003a; 2006), a cost-benefit approach could be used to define optimal scale. Such an approach might use the ISEW in conjunction with biophysical indicators of scale, and define optimal scale as the level of resource use corresponding to the peak in the ISEW. Although one would hope that the optimal scale defined in this way would be less than the maximum sustainable scale, this might not happen in practice (e.g. due to the difficulties in accounting for environmental costs). This is one of the reasons that I adopt a simpler approach in my analysis, and equate optimal scale to maximum sustainable scale.

5.10. Summary

Based on Daly's definition of a steady state economy and the stock–flow–scale categorisation proposed in the previous chapter, it is possible to construct a set of "abstract" biophysical indicators to measure how close national economies are to a steady state economy. Some of these indicators, such as the population growth rate are simple measures where data are readily available. Others, such as the built capital growth rate and scale indicators, are fuzzier concepts that are much more difficult to quantify.

Therefore, for each of the abstract indicators in the Biophysical Accounts, I have chosen one or more measurable proxies based on the best data currently available for a large number of countries over the 1997–2007 analysis period. These indicators are summarised in Table 5.1.

Table 5.1: The indicators in the Biophysical Accounts.

Type	Abstract Indicator	Proxy / Proxies
Stock	Human population growth rate	Δ Human population
	Domesticated animals growth rate	Δ Livestock population
	Built capital growth rate	Δ Night-time lights
Flow	Material use growth rate	Δ Domestic material extraction †
		Δ Ecological footprint ‡
	Material outflows growth rate	Δ CO_2 emissions †
	Energy use growth rate	Δ Total primary energy supply ‡
Scale	Ratio of material flows to ecological limits	Ratio of per capita ecological footprint to a fair earthshare

Note: The Δ symbol signifies that an indicator is an annual rate of change, † signifies that it is a territorial measure, and ‡ signifies that it is a consumption-based measure.

The measurable proxies that I have chosen largely meet the criteria presented at the end of Chapter 4. Two notable exceptions are that I have not included hidden flows in any of the indicators due to a current lack of reliable data, and I have not included separate indicators that measure the rate of change of non-renewable resource use (again due to data limitations).

Finally, I have proposed a method for visualising how close economies are to a steady state economy. The method interprets the three broad groups of indicators in the Biophysical Accounts (i.e. change in stocks, change in flows, and scale) as orthogonal dimensions that form a three-dimensional space. A point for each country could be plotted in this space, based on the values of its individual indicators. If only two dimensions were plotted, then a country would be placed into one of four quadrants: desirable growth, undesirable growth, desirable degrowth, and undesirable degrowth. This approach would provide a clear visualisation of how close a given country was to a steady state economy.

6. The Social Accounts

Our refusal to reason about the Ultimate End merely assures the incoherence of our priorities, at both an individual and a social level. It leads to the tragedy of Captain Ahab, whose means were all rational, but whose purpose was insane. We cannot lend rationality to the pursuit of a white whale across the oceans merely by employing the most advanced techniques of whaling. To do more efficiently that which should not be done in the first place is no cause for rejoicing.

— Herman Daly [23]

The indicators proposed in the previous chapter measure the annual rate of change of certain biophysical stocks and flows, and the scale of these flows in relation to ecosystem sources and sinks. They are indicators that are designed to measure how close a national economy is to the biophysical concept of a steady state economy. While these indicators may tell us whether an economy is environmentally sustainable, they say nothing about whether it is socially sustainable. For this second purpose, additional indicators that measure progress towards the social goals that the economy is expected to deliver are required.

In Section 6.1, I discuss what would not be held steady in a SSE. Based largely on the Paris Declaration, I identify eight intermediate ends to work towards in a SSE, and a single ultimate end to be used to prioritise these. The ultimate end is human well-being, and the intermediate ends are health, equity, the elimination of poverty, increased social capital, participatory democracy, decreased working time, low unemployment, and stable prices.

In Section 6.2, I explore five different approaches to defining and measuring the ultimate end of human well-being. I propose that well-being should be measured using a small number of subjective indicators from three of these approaches. However, this proposal is hampered by a lack of internationally comparable data, and I therefore use a single life satisfaction indicator to measure well-being. The section concludes with a discussion of the known determinants of well-being, including the relationship between resource use and well-being.

In the remaining eight sections of the chapter (Sections 6.3 to 6.10) I discuss each of the intermediate ends in turn. For each intermediate end I discuss how it is described in the degrowth and steady state literature, how it contributes to the

[23] Daly (1977, p. 20)

ultimate end of human well-being, how it relates to environmental resource use, what indicators exist to measure progress towards it, and the proxy that I choose.

6.1. *What is Not Held Steady in a SSE?*

Until this point we have largely been concerned with what is held steady in a SSE. This topic is the focus of Daly's work and the steady state economics literature in general. An equally important topic, however, is what is *not* held steady in a SSE, but what is allowed—or even encouraged—to change and develop over time. In general, Daly says very little on this topic. Where he does touch on it, he writes:

> The culture, genetic inheritance, knowledge, goodness, ethical codes, and so forth embodied in human beings are not held constant. Likewise, the embodied technology, the design, and the product mix of the aggregate total stock of artifacts are not held constant. Nor is the current distribution of artifacts among the population taken as constant. Not only is quality free to evolve, but its development is positively encouraged in certain directions. (Daly, 1977, pp. 16-17)

Or, in another source, he writes:

> Knowledge and technology are not held constant. Neither is the distribution of income nor the allocation of resources. The SSE can develop qualitatively but does not grow in quantitative scale, just as the planet earth, of which the economy is a subsystem, develops without growing. (Daly, 1991, p. 182)

In discussing what is to be maximised in a SSE, Daly (1996, p. 32) suggests that "the maximand is life, measured in cumulative person-years ever to be lived at a standard of resource use sufficient for a good life". However, exactly what constitutes a "good life" is not something that Daly explores.

In general, social goals are discussed more actively by proponents of degrowth than by steady state economists. For example, the Paris Declaration states that degrowth is to be characterised by an emphasis on quality of life, the fulfilment of basic human needs, equity, increased free time, conviviality, sense of community, individual and collective health, participatory democracy, and a variety of other positive social outcomes (Research & Degrowth, 2010). The goal of increasing human well-being is often mentioned in the degrowth literature as well. For instance, Schneider et al. (2010, p. 512) define degrowth as "an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level, in the short and long term”. Similarly, Kallis (2011, p. 879) envisions “a society with a stable and leaner metabolism, where well-being stems from equality, relation and simplicity, and not material wealth”.

Given the greater focus on social goals in the degrowth literature, I have largely chosen the indicators in the Social Accounts based on the stated social goals of the degrowth movement, as articulated in the Paris Declaration (Research & Degrowth 2010). I identified 24 social goal statements within the text of the declaration, which I then grouped and reduced to seven general goals. These goals are human well-being, health, equity, the elimination of poverty, increased social capital, participatory democracy, and decreased working time. To the seven goals from the Paris Declaration, I have added two other intermediate ends which I think are important items to measure in the degrowth transition to a steady state economy. The first is low unemployment, and the second is stable prices.

Of these nine social goals, I have classified human well-being as the “ultimate end” of the economic system, and the others as intermediate ends in support of it. The identification of an ultimate end, and even intermediate ends, clearly invites debate. The goals that the economy is expected to deliver should be decided democratically, based on a participatory process, and not by one researcher’s particular interpretation of the literature. The list of ends that form the basis of the Social Accounts should therefore be viewed as a work-in-progress, to be refined over time as the social priorities of the degrowth and steady state movements on which they are based are also refined.

Although Daly stresses the importance of “reasoning about the Ultimate End”, he does not explore in any detail what this end should be. He simply writes, “The ultimate benefit or Ultimate End is less definable than the ultimate means. Perhaps, as a *minimum* definition, it could be considered as the survival and continuation of the evolving life process through which God has bestowed upon us the gift of conscious life” (Daly, 1977, p. 26; original emphasis).

From this brief definition one might conclude that Daly is proposing environmental sustainability as the ultimate end. As I see it, however, environmental sustainability is not the ultimate end of the economy, but a constraint on the ultimate end. The economy is a system that transforms natural resources into goods and services in order to satisfy human needs, and I therefore place human well-being at the top of the Ends–Means Spectrum.

The identification of human well-being as the ultimate end largely follows from the happiness literature. As Layard (2005, p. 113) writes, "[W]e naturally look for one ultimate goal that enables us to judge other goals by how they contribute to it. Happiness is that ultimate goal because, unlike all other goals, it is self-evidently good. If we are asked why happiness matters, we can give no further, external reason. It just obviously does matter." Happiness is, in other words, a goal desired only for itself. It is not the means to any other end, and therefore satisfies the definition of "ultimate end" provided in Section 3.4. Nevertheless, not everyone agrees that happiness should be considered the ultimate end. Some see it as just one element of a good life, and there are other competing views on what constitutes the ultimate end, such as justice, freedom, and human development (Frey and Stutzer, 2002a).

Moreover, the identification of human well-being as the ultimate end does not mean that I have forgotten about environmental sustainability, or that it is any less important. The pursuit of the ultimate end must still occur within the limits imposed by the ultimate means. Loosely speaking one might say that "sustainable human well-being" is the ultimate end, although to be consistent with the Ends–Means Spectrum it would be more appropriate to say that the ultimate end is human well-being, but that this end must be achieved within the constraints imposed by the ultimate means.

Although both Layard (2005) and Daly (1977) point to there being only one ultimate end, there could theoretically be more than one objective that is desired only for itself. Social equity is one possible candidate. While steady state economists are probably more likely to promote greater equality as a means to an end, the degrowth community may view greater equality as an end in itself, as evidenced by the expression "degrowth *for* social equity" (Schneider et al., 2010; my emphasis).

Both Layard (2005) and Daly (1977) also suggest that if a single ultimate end is adopted, then it may be used as an ordering principle to rank or prioritise the intermediate ends. Extending this idea, I would suggest that the intermediate ends that should be prioritised are those that contribute the most towards the ultimate end (i.e. human well-being) while using the least amount of the ultimate means (i.e. material and energy). These would be the most efficient intermediate ends to pursue in order to achieve a socially sustainable steady state economy.

Finally, one of the main research questions that I attempt to answer in this thesis is whether there is any relationship between biophysical growth rates and social performance. To answer this question it is necessary to look at the relationship between the rate of change of biophysical indicators and the absolute level of social indicators. Thus, within this chapter, the social indicators that I select are generally values for a single year, or averages over the 1997–2007 analysis period, as opposed to rates of change for this period.

6.2. *Human Well-being*

There are a number of different approaches to defining and measuring human well-being. The five most relevant approaches to the Social Accounts are probably (1) the *preference satisfaction approach*, which relates well-being to the satisfaction of wants and desires; (2) the *hedonic approach*, which relates well-being to the balance between positive and negative feelings;[24] (3) the *evaluative approach*, which relates well-being to an individual's subjective appraisal of how his or her life is going; (4) the *eudaimonic approach*, which relates well-being to positive psychological functioning (i.e. "living well") and the realisation of potential; and (5) the *capabilities approach*, which relates well-being to an individual's freedom to choose between different ways of living. Below I discuss each of these approaches in turn.

6.2.1. Preference Satisfaction Approach

The preference satisfaction approach equates well-being to the satisfaction of individual wants and desires. According to this view, preferences can best be satisfied when people have the freedom to act as they wish, and the resources to do so. Markets allow people to express their subjective preferences via their willingness to pay for various goods and services. The more income that people have at their disposal, the more wishes and desires they are able to satisfy, and thus the higher the level of their well-being (or so the theory goes). This approach to well-being has its origins in neoclassical economic theory, and it serves

[24] The hedonic approach to well-being, as described here, should not be confused with the hedonic pricing method used to value environmental amenities.

as the theoretical justification for using GDP as a measure of welfare (Dolan et al., 2006; Thompson and Marks, 2008). However, as was discussed in Section 3.3.1, there are a number of reasons why GDP would not be an appropriate indicator to use in a steady state economy. In fact, the purpose of the current chapter is largely to identify an alternative system to measure social progress. Nevertheless, the preference satisfaction approach is presented here for completeness.

6.2.2. Hedonic Approach

The hedonic approach equates well-being to the balance between positive and negative emotions. It is an approach to well-being that is partially derived from the philosophy of hedonism, which suggests that pleasure is the only thing that is good for us, and pain is the only thing that is bad (Bentham, 1789). The approach relies on subjective reports from individuals regarding the frequency and intensity of emotions felt over a recent time period (generally some time between the last day and the last month). The Day Reconstruction Method (DRM) is one approach used to measure hedonic well-being (Kahneman et al., 2004). With the DRM, individuals are asked to list all of the activities that they engaged in during the previous day, and rate these activities according to the positive and negative emotions that accompanied them. It is worth noting that achieving high hedonic well-being does not mean eliminating *all* negative emotions, but achieving an optimal balance between positive and negative emotions (Thompson and Marks, 2008).

6.2.3. Evaluative Approach

The evaluative approach equates well-being to an individual's subjective assessment of how his or her life is going. Evaluative measures may range from a single question about life satisfaction, to multiple questions about different aspects of a person's life. In contrast to the hedonic approach which attempts to capture feelings, the evaluative approach attempts to capture "judgements about feelings" (Thompson and Marks, 2008).

While it is not unreasonable to expect a link between positive feelings and positive evaluations, the link is not always straightforward. If a person acquires the things in life that he or she desires, and achieves his or her goals, then this could be expected to lead to both positive emotional experiences and a positive sense of life satisfaction. However, some positive feelings may be caused by factors other than the realisation of goals. For instance, people may take drugs that directly alter the neurological processes in the brain in order to produce pleasant experiences. Such actions may lead to positive hedonic well-being without contributing to greater life satisfaction (Diener et al., 2009).

Evaluative measures based on variations of the question "How satisfied are you with your life as a whole?" are probably the most widely used measures of well-being (Forgeard et al., 2011). According to Forgeard et al. (2011), the biggest problem with the evaluative approach is that life satisfaction is too often equated to overall well-being, leading researchers to ignore other facets. As Michaelson et al. (2009, p. 56) remark, "It is all very well knowing that someone is satisfied with their life, but the interesting question is *why*?"

6.2.4. Eudaimonic Approach

The eudaimonic approach to well-being focuses on the *content* of an individual's life, and the *processes* involved in living well (Ryan et al., 2008). It stands in contrast to the hedonic and evaluative approaches which both focus on achieving a specific *outcome* (net positive affect in the hedonic approach, and positive life satisfaction in the evaluative approach). It is rooted in Aristotle's eudaimonic philosophy of happiness, which distinguishes between happiness as experiencing pleasure (i.e. hedonia) and happiness as living well (i.e. eudaimonia, often translated as "flourishing"). Ryan et al. (2008, p. 145) summarise Aristotle's philosophy of eudaimonia as "being actively engaged in excellent activity, reflectively making decisions, and behaving voluntarily toward ends that represent the realization of our highest human natures."

Modern conceptions of eudaimonia relate well-being to important aspects of positive psychological functioning. For example, Ryff and Keyes (1995) have developed a model of well-being that includes six components of positive psychological functioning: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance. Ryan et al. (2008), on the other hand, propose a model of eudaimonic well-being based on self-determination theory, in which well-being is achieved by behaving in a way that satisfies the basic psychological needs of autonomy, competence, and relatedness. The need for autonomy refers to a feeling of choice and authenticity in the regulation of behaviour, the need for competence refers to a sense of efficacy and self esteem, and the need for relatedness refers to the importance of feeling cared for and closely connected to others. Whereas Ryff and Keyes (1995) *define* well-being from a psychological perspective, Ryan et al. (2008) identify the basic psychological needs whose satisfaction *predicts* well-being (Forgeard et al., 2011).

6.2.5. Capabilities Approach

The capabilities approach equates well-being to an individual's freedom to choose between different ways of living. It is an approach that was developed in somewhat different ways by Amartya Sen in economics, and Martha Nussbaum in philosophy (Sen, 1990; 1993; 1999; Nussbaum, 2006). Like the eudaimonic approach, the capabilities approach is inspired by Aristotle's conception of what it means to live well, but the indicators that it advocates are generally objective rather than subjective. There are two important concepts in the approach: *functionings* and *capabilities*. According to Sen:

> *Functionings* represent parts of the state of a person—in particular the various things that he or she manages to do or be in leading a life. The *capability* of a person reflects the alternative combinations of functionings the person can achieve, and from which he or she can choose one collection. The approach is based on a view of living as a combination of various "doings and beings", with quality of life assessed in terms of the capability to achieve valuable functionings. Some functionings are very elementary, such as being adequately nourished, being in good health, etc., and these may be strongly valued by all, for obvious reasons. Others may be more complex, but still widely valued, such as achieving self-respect or being socially integrated. (Sen, 1993, p. 31)

It is worth stressing that it is an individual's capability to achieve valuable functionings, more than actually achieving these functionings, that is considered important. Capabilities are thus opportunities, not realisations or outcomes. It is up to individuals which functionings they choose to realise, and which they leave unused. Nevertheless, as Robeyns and van der Veen (2007) emphasise, any attempt to operationalise the capabilities approach needs to specify what the valuable functionings are.

While Sen has shied away from proposing a comprehensive list of capabilities (preferring instead to leave the creation of such a list to democratic processes), Martha Nussbaum has spent more than a decade developing a list of central human capabilities. Sen focuses on the socio-economic aspects of well-being, whereas Nussbaum stresses the psychological, emotional, and aesthetic aspects of well-being (Robeyns and van der Veen, 2007). Her list of ten central human capabilities includes items such as being able to live to the end of a human life of normal length, being able to have attachments to things and people outside ourselves, and being able to participate effectively in political choices that govern one's life (see Nussbaum, 2006, pp. 76-78 for the full list). Nussbaum (2006) argues that all of the capabilities in the list are of equal importance, and that a minimum threshold for each should be provided to all people. In this sense the capabilities approach is a human rights approach.

As mentioned above, the capabilities approach is also an objective approach to well-being, in contrast to the subjective approaches discussed in the previous three sections. Perhaps the strongest criticism of the capabilities approach is that it is not based on a formal theory of well-being, but instead equates well-being to an *ad hoc* list of capabilities (Dolan et al., 2006). Moreover, while it may be possible to assess the capabilities using objective indicators, the selection of which capabilities to include in the list remains inherently subjective (Forgeard et al., 2011). As yet, there is no consensus on which capabilities should be included, or even how they should be selected (Robeyns and van der Veen, 2007).

The best-known empirical application of the capabilities approach is probably the Human Development Index (HDI), which is calculated by taking the geometric mean of indicators of life expectancy, education, and standard of living (UNDP, 2010). Although widely used, the HDI considers only a very limited number of functionings. In a detailed report to the Netherlands Environmental Assessment Agency, Robeyns and van der Veen (2007) explore the idea of creating a more comprehensive index of well-being based on the capabilities approach. Their proposal includes 13 domains: physical health, mental health, knowledge and intellectual development, labour, care, social relations, recreation, shelter, living environment, mobility, security, non-discrimination and respect for diversity, and political participation. The empirical development of this index is still at an early stage, however.

6.2.6. Which Approach to Choose?

With such a wide range of interpretations and potential measures of human well-being, it is difficult to know which to use in the Social Accounts. Some authors, such as Layard (2009), advocate using a single over-arching indicator to measure well-being. Layard claims that a single indicator is necessary in order to be able to evaluate policy options against one another. In his words, "It is not enough simply to list the impact of a policy on each 'capability', as Sen argues. There must be a way of aggregating these impacts, otherwise we shall rarely be able to rank one policy over another" (p. 2). He suggests that the single indicator should be a measure of happiness, and provides two reasons for this choice: (1) because happiness is self-evidently good (a philosophical reason), and (2) because when people are asked what they want most in life the majority reply "to be happy" (an empirical reason). Of the various measures of happiness that are available he suggests using life satisfaction because it has been the most intensively studied, its determinants are relatively well known, and these determinants correspond to established policy areas.

Jackson (2009a), on the other hand, is critical of subjective approaches to measuring well-being, in particular the hedonic approach. He writes:

> [T]here are as many reasons for not equating prosperity with happiness as there are for not equating prosperity with exchange values. For one thing, the overriding pursuit of pleasure is a very good recipe for things not going well in the future… More fundamentally, to equate prosperity with happiness goes against our experience of what it means to live well. People can be unhappy for all sorts of reasons, some of them genetic, even when things do go well. Equally, they may be undernourished, poorly housed, with no prospect of improvement and yet declare themselves (some might say foolishly) completely content with their lot. (Jackson, 2009a, p. 43)

Jackson (2009a, p. 45) suggests that the capabilities approach provides a better starting point than subjective well-being for defining what it means for human beings to prosper. He argues for an approach to well-being based on "bounded capabilities", stressing that capabilities should not be thought of as a set of "disembodied freedoms", but must respect the biophysical limits of the planet.

Other authors, such as Michaelson et al. (2009), advocate using a collection of indicators from multiple approaches in a system of national accounts. The *National Accounts of Well-being* developed by these authors includes hedonic, evaluative, and eudaimonic indicators, as well as indicators that measure psychological resources and social well-being (all of these are subjective measures). In defence of the multiple indicators approach, the authors argue that there is increasing consensus within the field of well-being research about the importance of measuring both whether people are "feeling good" and "doing well". Moreover, they argue that using a single question to measure well-being results in a high risk of errors.

The report of the *Commission on the Measurement of Economic Performance and Social Progress* (Stiglitz et al., 2009) recommends that national statistical offices should use both subjective and objective indicators of well-being in order to measure social progress. The authors recommend using (subjective) indicators from the hedonic and evaluative approaches, as well as (objective) indicators from the capabilities approach. With respect to objective indicators, they suggest focusing on health, education, personal activities, political voice, social connections, environmental conditions, and insecurity. The authors also note that, "While assessing quality-of-life requires a plurality of indicators, there are strong demands to develop a single scalar measure… The search for a scalar measure of quality of life is often perceived as the single most important challenge faced by quality-of-life research" (Stiglitz et al., 2009, pp. 56, 59).

Forgeard et al. (2011) also argue in favour of using both objective and subjective measures of well-being "in order to provide the full picture of human flourishing" (p. 98). However, they question whether combining several measures of well-being into a composite indicator is really a useful project, and instead argue in favour of a "dashboard" approach to well-being measurement. They write:

> Being able to say that one country has the highest level of well-being in the world does make for an appealing headline, but it also provides a poor description of the nature of this country's flourishing… Thus, we recommend that future measures of well-being present their results in a way that takes advantage of the variety of constructs that are measured. (Forgeard et al., 2011, p. 97)

In an attempt to bring together the competing approaches to well-being that have been discussed, Thompson and Marks (2008) have proposed a conceptual model that interprets well-being as a *dynamic process* in which the various approaches represent different aspects or stages (Figure 6.1). The model describes how an individual's external conditions (e.g. income, employment status, social context) act together with their personal resources (e.g. physical health, self-esteem, resilience) to allow them to function well in their interactions with the world (i.e. satisfy basic needs for autonomy, competence, and relatedness) and therefore experience positive emotions and a sense of life satisfaction. The model resolves the conflict between the hedonic/evaluative approach and the eudaimonic approach by showing how having good overall feelings and a positive evaluation of life is *dependent* on functioning well. Moreover, by accounting for external conditions (i.e. the social and material conditions of people's lives), the model includes objective factors associated with the capabilities approach. And finally, by including personal resources, the model also recognises that people are not all the same, but differ from each other in numerous ways such as personality, outlook, intelligence, and physical abilities (Thompson and Marks, 2008; Abdallah et al., 2011).

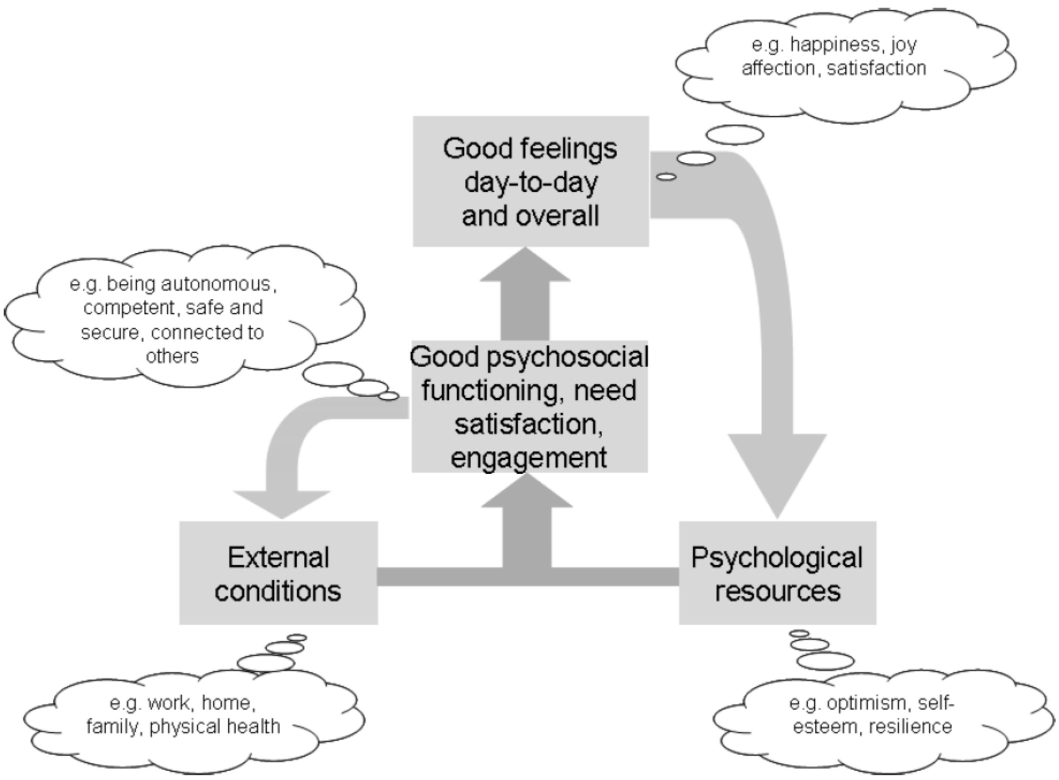

Figure 6.1: A dynamic model of well-being. Source: Thompson and Marks (2008, p. 12).

In a report that makes recommendations to the UK Office for National Statistics, Abdallah et al. (2011) suggest that indicators from all four of the boxes depicted in Figure 6.1 are required in order to understand human well-being fully. They define well-being in terms of "flourishing"—an interpretation that is strongly influenced by the eudaimonic approach:

> [P]eople are "flourishing" when they are functioning well in their interactions with the world and experience positive feelings as a result. A flourishing life involves

> good relationships, autonomy, competence and a sense of purpose, as well as feelings of happiness and satisfaction. Measures of well-being should focus on flourishing, and this is best measured subjectively—by asking people about their experiences (their feelings and their interactions with the world) and about their judgements of those experiences. (Abdallah et al., 2011, p. 2)

The authors recommend developing an index of human well-being based on subjective measures (to be reported as the "percentage of people who are flourishing"), as well as a separate set of objective indicators that measure the "drivers of well-being" (Abdallah et al., 2011, p. 32). They also stress the importance of monitoring the distribution of well-being (an area that has received little attention).

The approach that I would ideally like to use in the Social Accounts largely follows from the recommendations made by Abdallah et al. (2011). I suggest that the ultimate end of human well-being should be measured using a single index that combines a small number of subjective measures from the hedonic, evaluative, and eudaimonic approaches to well-being. There are three reasons that I suggest this approach:

1. I subscribe to Layard (2005) and Daly's (1977) view that the primary role of the ultimate end is as an ordering principle to rank or prioritise the intermediate ends. For this to work in practice, however, there can only be *one* ultimate end, and thus one indicator. That said, the selection of human well-being as the ultimate end does not necessarily mean that it should be measured using a single survey question. In fact, in order to minimise the risk of error, it is probably advisable to use a composite indicator that combines results from more than one question.
2. There is clearly a role for objective indicators in any system of well-being accounts. However, following the dynamic model of well-being proposed by Thompson and Marks (2008), I would argue that the social and material conditions of people's lives are best viewed as drivers (or determinants) of well-being, rather than as constituents of well-being. Objective indicators of health, political voice, social connectedness, and so on, are worth monitoring and pursuing—but these should be viewed (and accounted for) as intermediate ends, not the ultimate end.
3. Even when human well-being is reduced to a purely subjective concept, it still retains multiple facets. To capture whether people are both "feeling

good" and "doing well", a combination of hedonic, evaluative, and eudaimonic indicators is required.

Data from the European Social Survey have been used to create two well-being indices that roughly match the above proposal. The first is an index of personal well-being developed by Michaelson et al. (2009) as part of the *National Accounts of Well-being*, which is based on 15 separate indicators. The second is as index developed by Huppert and So (2009) that reports the percentage of people who are flourishing, based on data from six eudaimonic indicators and one hedonic indicator. However, both indices are only calculated and reported for a small number of countries. To my knowledge, no one has yet developed an index for a large number of countries that includes indicators from the evaluative, hedonic, and eudaimonic approaches. It is an approach to measuring well-being that remains largely untested, and it is questionable whether the necessary data are available.

In the interests of pragmatism, I therefore choose to measure the ultimate end of human well-being using a single evaluative (i.e. life satisfaction) indicator. Life satisfaction has been more intensively studied than other subjective well-being measures, and data for it are widely available. Moreover, the dynamic model of well-being proposed by Thompson and Marks (2008) suggests that a high level of eudaimonic and hedonic well-being could be expected to lead to a high level of life satisfaction. This does not mean that high life satisfaction should be interpreted as the ultimate end, but if the ultimate end of high human well-being is being achieved, then the outcome should be high life satisfaction. Indeed, as Dolan et al. (2006) note in their detailed analysis of subjective well-being (SWB) indicators:

> [D]espite many caveats and uncertainties about how to interpret some of the existing evidence, it would seem that most measures of SWB would produce similar results to one another. Therefore, for those interested in the subjective assessment of an individual's life, it might not matter too much which measure of SWB is used to assess the well-being of different population groups. (Dolan et al., 2006, p. 11)[25]

[25] The claim made by Dolan et al. (2006) largely refers to hedonic and evaluative well-being indicators, which were the focus of their survey. The eudaimonic measure of well-being developed by Huppert and So (2009) correlated only modestly with life satisfaction (r = 0.32), suggesting that the eudaimonic approach may capture different facets of well-being than the evaluative approach.

The life satisfaction data that I use are from the World Database of Happiness (Veenhoven, 2011). For most countries, these data are based on responses to the question "All things considered, how satisfied are you with your life as a whole these days?"[26] Respondents were asked to give their answer on a numerical scale from 0 to 10, where 0 is dissatisfied and 10 is satisfied. (In some cases the scale used was 1 to 10, but all results are standardised to a 0 to 10 scale.) Data are average values for surveys conducted over the period 2000–2009, and are available for 149 countries.

6.2.7. The Determinants of Well-being

There is a strong argument to be made that the intermediate ends that are measured in the Social Accounts should directly contribute to the ultimate end of subjective well-being. If this is not the case, then it is questionable why these ends would be pursued in a steady state economy. Nevertheless, I would argue that there may be a place for intermediate ends that do not directly contribute to the ultimate end, if they are goals that are deemed to be particularly important by the degrowth or steady state community. Equity is one such goal. As we shall see in Section 6.4, greater equity does not appear to contribute significantly to subjective well-being, but it is nevertheless one of the central objectives of degrowth.

There have been numerous studies conducted that attempt to identify the (usually objective) factors that contribute to subjective well-being. In an attempt to summarise the current state of knowledge, Dolan et al. (2006) reviewed 153 papers in the economics and psychology literature. The authors considered all of the potential influences on subjective well-being that were identified in the literature, which they categorised under seven broad headings: income, personal characteristics, socially developed characteristics, how we spend our time, attitudes and beliefs, relationships, and the wider economic, social, political, and natural environment. The majority of papers that they reviewed used hedonic and evaluative indicators. Based on their review, Dolan et al. (2006) conclude that subjective well-being is positively related to a number of factors including income (albeit with diminishing returns), physical and psychological health, being in an intimate relationship, seeing family and friends, religious practice and be-

[26] Most questions are of type O-SLW/c/sq/n/10/a (used in the World Values Survey) and O-SLW/c/sq/n/11/a (used in the Gallup World Poll).

liefs, having trust in others, and community involvement/volunteering. They also conclude that well-being is negatively related to factors such as unemployment, commuting, providing long-term informal care for others, and living in an unsafe area. Finally, they report a U-shaped relationship between age and subjective well-being, in which well-being is lowest for people aged 35–50.

More recently, Helliwell et al. (2009) have used data from the Gallup World Poll, which surveyed between 50,000 and 140,000 respondents in 125 countries, to investigate the determinants of well-being. They derive equations to predict subjective well-being based on variables including gender, age, marital status, household income, unmet food needs, social connectedness, freedom of choice, perception of corruption, pro-social behaviour, religious attachment, and health. They find that the combined effects of a few social and institutional measures are as large as those of income in explaining differences in life satisfaction both between, and within, countries. Moreover, they show that the same basic equation and parameters can be used to predict life satisfaction in all countries analysed, suggesting that international differences in subjective well-being are not due to different interpretations of the meaning of "a good life", but are instead due to the different social, institutional, and economic conditions that exist in countries (Helliwell et al., 2009). The message that the meaning and causes of a good life are largely the same across cultures is echoed by Veenhoven (2010), who concludes that well-being depends on similar conditions across the globe.

One of the questions that this thesis tries to answer is whether degrowing and steady state economies are likely to be better or worse places to live than growing economies. To date, there has been very little research that relates environmental factors to subjective well-being. The small number of studies that have been conducted fall into three groups: (1) the relationship between environmental pollution and well-being, (2) the relationship between the stock of natural capital and well-being, and (3) the relationship between resource consumption (i.e. the flow of natural resources) and well-being. Given their limited relevance to my research, I do not discuss the first group of studies here (but see Dolan et al., 2006, p. 61, for a brief summary of findings). However, the second and third group are worth discussing in some detail.

An example of a study from the second group is Vemuri and Costanza (2006), who attempt to measure the degree to which human, built, social, and natural capital determine life satisfaction across 57 countries. As a proxy for built and human capital, they use the Human Development Index; as a proxy for social capital they use a measure of freedom of the press; and as a proxy for natural capital they use an index of the monetary value of ecosystem services per square kilometre. The authors find that the human/built and natural capital indicators explain 72% of the variation in life satisfaction across countries, while social capital is not significant to the model. Although this is an interesting finding, I seriously question whether the proxies chosen are appropriate measures of human, built, social, and natural capital.

In a more robust analysis, Engelbrecht (2009) tests whether there is a correlation between natural capital and subjective well-being in a sample of 58 countries, using per capita natural capital data from the World Bank's Millennium Capital Assessment. He finds that there is a correlation between natural capital and well-being, and that this correlation remains even after other known macro-level determinants of well-being are included in the regression (i.e. income, trust, inequality, unemployment, and inflation). Based on his findings, Engelbrecht argues that "natural capital provides immaterial and often intangible functions that are nevertheless important for the quality of human life" (p. 387).

This may well be true, but the Ends–Means Spectrum that is used to organise indicators in this thesis suggests that there is a much more tangible link between natural capital and human well-being: all material and energy resources that contribute to human well-being originate from the environment. Without the stock of natural capital, there would be no flow of natural resources, and therefore no humans—let alone human well-being! The consideration of flows of natural resources (and not just stocks) brings us to the third group of studies, which is probably the most limited, but also the most relevant to my work.

In a recent study, Steinberger and Roberts (2010) investigate the relationship between four objective indicators of well-being derived from the capabilities approach (life expectancy, literacy, income, and the HDI) and two resource flow indicators (energy consumption and CO_2 emissions). Based on an analysis of 80–93 countries over a 30-year time period, they find that there is a threshold beyond which additional energy use or CO_2 emissions do not result in higher human well-being, and that this threshold is decreasing over time. The authors conclude that achieving well-being is becoming more environmentally efficient over time, and that the total amount of primary energy currently consumed is more than sufficient to deliver a high level of human development for all.

The Happy Planet Index (HPI), which was first developed by Marks et al. (2006) and updated by Abdallah et al. (2009), explicitly acknowledges the dependence of human well-being on the flow of natural resources between the environment and the economy. The HPI is calculated by dividing the product of life satisfaction and life expectancy by per capita ecological footprint. It measures how efficiently ultimate means (i.e. natural resources) are translated into the ultimate end (i.e. human well-being), while treating what happens in the middle as something of a black box. In general, the highest HPI scores are achieved by Latin American and Caribbean nations (Costa Rica tops the list), while the lowest are experienced by sub-Saharan African nations (Zimbabwe finishes last). Rich developed nations fall somewhere in the middle. The authors find that no single country successfully achieves the three goals of high life satisfaction, high life expectancy, and an ecological footprint within a fair earthshare (Abdallah et al., 2009).

Following a similar approach to the HPI, Dietz et al. (2009) introduce the concept of "environmentally efficient well-being" (EWEB) as a new definition of sustainability. They propose that sustainability should be defined based on how efficient a nation is at producing human well-being through the use of natural, built, and human capital. They model this relationship using life expectancy as a proxy for human well-being, GDP per capita as a proxy for the flow of built capital, the ecological footprint as a proxy for the flow of natural capital, and the UN's education index as a proxy for the stock of human capital. Using data for 135 nations, they find that human and built capital are statistically significant predictors of well-being, but that natural capital is not. This leads the authors to conclude that "improvements in well-being may be obtainable without adverse effects on the environment" (p. 114). I seriously question this interpretation of the results, however. Although life expectancy may be more strongly correlated with GDP than the ecological footprint, this in no way implies that GDP is decoupled from resource use. The study fails to account for the possibility that there may be a hierarchical relationship between the determinants of well-being (as suggested by the Ends–Means Spectrum).

Finally, Knight and Rosa (2011) construct a new measure of EWEB using average life satisfaction data and per capita ecological footprint data. The measure is conceptually very similar to the Happy Planet Index, although it is calculated using regression residuals and not as a ratio. The authors investigate the relationship between EWEB and a number of its possible determinants including income, social capital, democracy, inequality, climate, and world region. Using full information maximum-likelihood estimation, the authors analyse a sparse dataset that contains 50–105 country data points for each independent variable. Their main findings are that inequality has a negative effect on EWEB, social capital has a positive effect, and income has a negative quadratic effect. This last finding suggests that the environmental efficiency with which well-being is produced increases at low to moderate levels of affluence, but then decreases at high levels.

While the above studies consider the relationship between the absolute level of resource use and well-being, they do not consider the effect of the rate of change of resource use on human well-being, or the implication of a maximum sustainable threshold for resource use. One of the questions that this thesis tries to answer is how stabilising or decreasing the flow of resources between the environment and the economy would impact human well-being. To my knowledge, this question has yet to be addressed in the literature.

6.3. Health

Although the Paris Declaration states that degrowth should be characterised by "an increase in… individual and collective health" (Research & Degrowth, p. 524), this goal is rarely mentioned in the wider degrowth and steady state literature. Nevertheless, there are two good reasons to include this objective in the Social Accounts. First, when people are asked to identify what matters most to them in life, being in good health often tops the list (Frey and Stutzer, 2002a, p. 56; Veenhoven, 2010, p. 342). Second, there is strong evidence of a positive relationship between health and subjective well-being. The relationship holds for both physical and psychological health, although it appears to be stronger for the latter. Although causality could go both ways, the evidence suggests that health has more of an impact on subjective well-being than subjective well-being does on health (Dolan et al., 2006; Deaton, 2008; Graham, 2008).

Health affects both the length and quality of people's lives. Accordingly, Stiglitz et al. (2009) suggest that assessing health requires good measures of both how long people live and the condition of their health. But as the authors note, "although several combined indices of people's health exist, none currently commands universal agreement" (p. 46). Below I discuss three alternatives that could be used to measure health in the Social Accounts:

- *Life expectancy at birth* — This is probably the most widely-used measure of health. It measures the average number of years than a newborn could expect to live, if he or she were to pass through life exposed to the mortality rates prevailing at the time of his or her birth. Since mortality rates have tended to fall over time, this measure likely underestimates how long someone born today can expect to live. Life expectancy estimates are published by the United Nations in five-year averages from the period 1950–1955 to the period 2005–2010, and are available for over 190 countries (United Nations, 2011).
- *Healthy life expectancy at birth* — This is an alternative indicator that measures the average number of years that a newborn could expect to live in full health, taking into account time lived in less than full health due to disease and/or injury. The measures of health status used in the calculation generally come from questions about physical and mental functioning drawn from health surveys. Since healthy life expectancy captures both fatal and non-fatal health outcomes, it provides a more complete picture of health than life expectancy alone. The World Health Organization (WHO, 2004) has calculated healthy life expectancy for over 190 countries in the year 2002. Moreover, an updated version of these data for the year 2007 is available from the United Nations (2010)
- *Self-reported health* — This is an umbrella term for subjective indicators that capture an individual's assessment of his or her overall health using survey questions such as "How is your health in general?" According to Stiglitz et al. (2009), the responses to such questions predict subsequent mortality and correlate with a wide range of diseases and conditions in the population. However, measures of self-reported health have largely remained stable over time, despite large reductions in mortality. This leads Stiglitz et al. (2009) to

question the suitability of self-reported health as a measure of health quality, as people may adapt to changing health standards.

Given that it explicitly combines information about both the length and quality of people's lives (unlike the other two indicators discussed above), I use healthy life expectancy at birth as the indicator of health in the Social Accounts. I use data for the year 2007, as published by the United Nations (2010).

6.4. *Equity*

Greater social equity is a key objective of both the degrowth and steady state movements. There are two types of equity that are important to discuss. The first, which is emphasised in the Paris Declaration, is equity *between* nations, largely in terms of levels of resource use. The Declaration refers to "right-sizing" national economies, and suggests that for wealthy nations this implies reducing per capita ecological footprint to the sustainable global level, while for poorer nations this implies increasing consumption to a "level adequate for a decent life" (Research & Degrowth, p. 524). I would argue that this type of international "resource access" equity does not need to be accounted for in the Social Accounts, however, because it has already been accounted for by the scale indicator in the Biophysical Accounts (see Section 5.8.3).

The second type of equity, which is emphasised more by Daly (1977; 2008) and advocates of a steady state economy, is equity *within* nations. I would argue that it is this type of equity that should be accounted for in the Social Accounts. Indicators of equity generally measure the opposite of equity (i.e. inequity), and the strongest arguments relating to a SSE have been made with respect to *income inequality*. Daly argues that without growth, the only way to alleviate poverty is through redistribution, and that it is therefore necessary to limit the range of income inequality within society. Wilkinson and Pickett (2009) make even stronger arguments for reducing income inequality. In their book *The Spirit Level*, they show that societies with higher income inequality tend to have more health and social problems, including higher crime rates, increased mental illness, and decrease trust. Furthermore, they suggest that high levels of income inequality lead to unhealthy status competition, resulting in higher levels of material consumption than are necessary to meet people's needs.

If, as Wilkinson and Pickett (2009) claim, higher income inequality leads to more health and social problems, then one would also expect it to result in lower subjective well-being. Interestingly, this is not a relationship that Wilkinson and Pickett explore in their book, perhaps because the empirical evidence is mixed. Some studies show a positive relationship between inequality and happiness (e.g. Bjørnskov, 2003; Clark, 2003), while others show a negative relationship (e.g. Alesina et al., 2004; Oishi et al., 2011), and still other studies show no statistically significant relationship at all (e.g. Helliwell, 2003). Dolan et al. (2006) suggest that the inclusion (or non-inclusion) of particular countries may influence the results and thus lead to the conflicting findings. They note that the relatively happy Latin American countries tend to have fairly unequal income distributions, while the relatively unhappy former-Communist countries tend to have fairly equal income distributions.

In a recent paper, Verme (2011) attempts to empirically determine the cause of the heterogeneous results. Using a very large sample of world citizens, and a "standard" model that combines cross-country and longitudinal data, he tests some of the possible causes. He finds that income inequality has a negative effect on life satisfaction, and that this result is robust to the addition of different regressors, and holds across different income groups and different types of countries. However, he finds that the relation is easily obscured or reversed if country and year fixed effects are removed from the model.[27]

Although social equity could theoretically be measured using other variables besides income (e.g. gender, education, or happiness), I choose to use income inequality in the Social Accounts because low income inequality is an established goal for a SSE, and data for this indicator are widely available. There are two commonly used measures of income inequality: (1) the Gini coefficient, and (2) the ratio of the income of the richest to poorest members of society. Wilkinson and Pickett (2009, p. 18) note that the choice of which of these two measures is used rarely has a significant effect on the results. I use the Gini coefficient as it is the preferred measure in studies of income inequality (among economists at least). The Gini coefficient measures the extent to which the distribution of

[27] Fixed effects refer to dummy variables for countries in a cross-country study, or dummy variables for years in a longitudinal study. These dummies are used to account for unobserved country differences and time dependence and are routinely included in empirical models.

income among individuals or households within an economy deviates from a perfectly equal distribution. A coefficient of 0 represents perfect equality, while a coefficient of 100 implies perfect inequality. I use the Gini coefficient of net income, which measures inequality in household disposable income (i.e. income after taxes and transfers). The data used are from Solt's (2009) Standardized World Income Inequality Database (SWIID). The SWIID standardises data from the UN University's World Income Inequality Database, using data from the Luxembourg Income Study and a custom algorithm. It provides the largest set of intercomparable data available, between countries and over time. For the period considered in my analysis (1997–2007), Gini coefficient data are available for 161 countries.

6.5. Elimination of Poverty

The Paris Declaration describes degrowth as a process that will involve "the fulfilment of basic needs for all" and "the reduction and ultimate eradication of absolute poverty" (Research & Degrowth 2010, p. 524). The wider degrowth literature does not make such explicit claims, although alleviating poverty is certainly discussed (e.g. Latouche, 2009; Martínez-Alier, 2009). Although Daly (2008; 2010) does not describe the elimination of poverty as an explicit goal for a SSE, he is quick to point out the mechanism by which it could be achieved. He emphasises that without economic growth, the only way to cure poverty is through redistribution of income and wealth.

Conceptually, poverty is a difficult concept to define. Kingdon and Knight (2006) claim that "[a]ny attempt to define poverty involves a value judgement as to what constitutes a good quality of life or a bad one." The conventional view of poverty equates it to a lack of command over commodities. In this view, the poor are those who do not have enough income to put them above some minimum threshold. A broader view of poverty may be found in the capabilities approach (see Section 6.2.5). According to this approach, the poor are those who lack key capabilities needed to function in society. For example, they may have inadequate income or education, be in poor health, feel powerless, or lack political freedoms (Haughton and Khandker, 2009).

In practice, poverty may be measured in absolute or relative terms. The absolute approach defines poverty based on the minimum resources necessary for long-term physical well-being. It equates being poor to not being able to satisfy certain basic needs such as food, water, shelter, and clothing. The "poverty line" is defined as the amount of income required to satisfy these needs. By contrast, relative approaches do not claim to represent minimum physiological needs but instead estimate the level of financial resources below which people have substantially less than what is considered normal in a society. Relative poverty lines are generally set as a constant percentage (e.g. 40–60%) of mean or median income (Ravallion, 2010; Notten and de Neubourg, 2011). With the relative approach, if incomes rise but the distribution remains unchanged, then there is no reduction in poverty. In this sense, relative measures of poverty are more like indicators of inequality than sufficiency (Victor, 2008).

The main argument in favour of using a relative approach is to account for the role of social exclusion. It is often argued that poverty is about more than a person's absolute command over resources—that it is also about one's ability to participate actively in the life of society (Ravallion, 2010). The income needed to purchase the commodities needed to participate in society varies between countries and over time. Adam Smith famously pointed out the importance of owning a linen shirt for social inclusion in eighteenth century Europe. More recently, a commentator on Japan's poverty line (of around $15 per day) argued that, "Poverty in a prosperous society usually does not mean living in rags on a dirt floor. These are people with cellphones and cars, but they are cut off from the rest of society" (the commentator was Masami Iwata, as cited by Ravallion, 2010, p. 16). Interestingly, there is little research on the relationship between conventional measures of poverty and subjective well-being (Kingdon and Knight, 2006).

While measures of relative poverty clearly have value, I would argue in favour of using a measure of absolute poverty within the Social Accounts. There are two reasons for this: (1) the Paris Declaration explicitly states that the goal of degrowth is to eliminate *absolute* poverty, and (2) as Victor (2008) points out, measures of relative poverty are essentially measures of inequality. Since income inequality is already measured in the Social Accounts, an indicator of relative poverty would largely be redundant. Below, I discuss a few poverty indicators that could potentially be used in the Social Accounts:

- *Proportion of population living on less than $X per day* — This approach to measuring poverty, which was developed by the World Bank, provides a uniform measure of absolute poverty for developing countries. The World Bank calculates two related indicators. The first measures the percentage of the population living on less than $1.25 per day (at 2005 international prices), and the second measures the percentage living on less than $2 per day. Data are based on primary household survey data obtained from government agencies and World Bank country departments. While widely used, these indicators have also been criticised for using a poverty line that is rather arbitrary (i.e. not based on basic needs), for being overly sensitive to purchasing-power-parity exchange rates, and for not accounting for data uncertainties in India and China, where half the population of the developing world lives (Haughton and Khandker, 2009). The data are included in the World Bank's (2011a) *World Development Indicators*, and are available for 112 countries for the period considered in my analysis (1997–2007).
- *Human Poverty Index* — This measure of poverty was reported by the United Nations in its Human Development Reports between 1997 and 2009. It consists of two separate measures: HPI-1 (an index of poverty for developing countries) and HPI-2 (an index of poverty for OECD countries). HPI-1 is a composite indicator that measures deprivations in three areas: health, education, and living standards. It is calculated by averaging four indicators: the probability at birth of not surviving to age 40, the adult illiteracy rate, the percentage of the population not using an improved water source, and the percentage of children under-weight for their age. HPI-2 measure deprivations in the same three areas as HPI-1, as well as social exclusion. It is calculated by averaging a different set of four indicators: the probability of not surviving to age 60, the percentage of adults lacking functional literacy skills, the percentage of the population living below the income poverty line (defined as 50% of median household income), and the rate of long-term unemployment. HPI-1 data are available for 135 countries, and are calculated using data for the period 1999–2007. HPI-2 data are available for 25 countries, and are calculated using data for the period 1994–2007 (UNDP, 2009). The two indices are not directly comparable to each other given the different data used in their calculation.

- *Multidimensional Poverty Index (MPI)* — This is a relatively new measure of poverty that was created by the Oxford Poverty & Human Development Initiative for the 20th anniversary edition of the *Human Development Report* (UNDP, 2010). It replaces the Human Poverty Index. The MPI measures deprivations in the same three basic areas as HPI-1 (i.e. health, education, and living standards), but also identifies when people are facing *multiple* deprivations. It is calculated using 10 indicators that largely reflect the Millennium Development Goals and thus international standards of poverty. A person is identified as "multidimensionally poor" if they experience deprivation in at least a third of the weighted indicators. The MPI captures both the incidence of deprivation, and its intensity (how many deprivations people experience at the same time). The data are available for 109 countries, with years ranging from 2000 to 2010 (Alkire et al., 2011).

The problem with measuring poverty is that it is very difficult to compare poverty levels between developed and developing countries. In general, absolute poverty lines are used to measure poverty in developing countries, while relative poverty lines tend to dominate in developed countries (Ravallion, 2010). Three of the four poverty indicators described above provide data for developing countries, while the fourth provides data for developed countries. While not ideal, I would argue that the goal of eliminating absolute poverty (as specified in the Paris Declaration) is largely targeted at developing countries, and thus it is better to use a poverty indicator that is only available for developing countries than one that is only available for developed countries.

The choice is really between HPI-1 and the MPI, which are both inspired by the capabilities approach, giving them a stronger theoretical foundation than the World Bank indicators. I choose to use HPI-1 to measure poverty in the Social Accounts, largely because it is available for more countries than the MPI. As MPI data become available for more countries, however, it may be worth revisiting this decision.

6.6. Increased Social Capital

The Paris Declaration calls for an increase in sense of community, respect for cultural differences, and the encouragement of diversity, good citizenship, and generosity (Research & Degrowth, 2010, p. 524). Latouche (2009) suggests that "altruism should replace egoism, and unbridled consumerism should give way to cooperation… The importance of social life should take precedence over endless consumerism" (p. 34). He further writes that to make the transition to a degrowth society it would be necessary to "encourage the 'production' of relational goods, such as friendship and neighbourliness" (p. 70). Similar statements exist in the steady state literature. Daly and Cobb (1994, p. 164) call for a rethinking of economics based on the concept of *Homo economicus* as "person-in-community". Jackson associates prosperity with strengthening feelings of trust, belonging, and participation in society. He writes:

> To do well is in part about the ability to give and receive love, to enjoy the respect of your peers, to contribute useful work, and to have a sense of belonging and trust in the community. In short, an important component of prosperity is the ability to participate meaningfully in the life of society. (Jackson, 2009b, p. 7)

Although they are not specified as such in the literature, I would argue that the above objectives can be described as increasing *social capital*, and that this overarching concept should be measured in the Social Accounts. Social capital is a wide term, and there are a variety of related definitions. The OECD provides a particularly clear one:

> Social capital embodies the idea that social connections—friendship, family and other relationships—generate benefits above and beyond the intrinsic pleasure that comes from them. While definitions of social capital vary, most agree that social capital constitutes both social networks and the shared values, norms and understanding they generate, such as trust, tolerance of diversity, civic-mindedness, reciprocity, and mutual support. (OECD, 2011, p. 171)

Michaelson et al. (2009, p. 19) cite evidence that "feeling close to, and valued by, other people is a fundamental human need and one that contributes to functioning well in the world". They therefore stress the importance of measuring the social dimension of well-being, in addition to its personal dimension, in any system of national accounts. The OECD (2011) notes that social capital has been shown to influence a range of outcomes in society including democratic participation, governance, economic growth, labour market performance, crime rates, and health.

It is not surprising then that multiple studies have found that there is a very strong link between social capital and subjective well-being (e.g. Bjørnskov, 2003; Helliwell and Putnam, 2004; Dolan et al., 2006; Helliwell, 2006; Elgar et al., 2011). Helliwell and Putnam (2004) find that marriage and family, civic engagement, general levels of trust, and ties to friends, neighbours and work colleagues are all independently and strongly related to happiness and life satisfaction. Stiglitz et al. (2009, p. 184) make the bold claim that "[f]or no other class of variables (including strictly economic variables) is the evidence for the causal effects on subjective well-being probably as strong as it is for social connections".

Social capital is also theorised to be one of the factors that contributes to economic growth. The theory posits that in societies with higher levels of trust, less time is spent verifying that others do not cheat or behave opportunistically. These reduced "transaction costs" are thought to stimulate investment, production and trade, which in turn lead to economic growth (Berggren et al., 2008). The hypothesised link between social capital and economic growth is supported by the findings of a number of empirical studies (e.g. Whiteley, 2000; Pan and He, 2010), although the robustness of the link has been called into question by others (e.g. Schneider et al., 2000; Berggren et al., 2008).

Although potentially of concern to proponents of degrowth, the positive association between social capital and economic growth may turn out to be unimportant. If society's objective is economic growth, then countries with higher social capital could be expected to work more effectively towards this goal. However, if society's goal changes to something else (such as improving well-being), then the benefits of higher social capital could be applied towards this end instead. In fact, Helliwell and Putnam (2004, p. 1444) suggest that increasing social capital is a much better strategy for improving human well-being than increasing incomes because "the 'externalities' of social capital on subjective well-being (the effects of my social ties on your happiness) are neutral to positive, whereas the 'externalities' of material advantage (the effects of my income on your happiness) are negative".

Despite its importance, social capital is an area where robust, comparable data are particularly lacking (OECD, 2011). Below, I discuss four possible approaches that could be used in the Social Accounts:

- *Social trust* — Social trust refers to the belief that other people can be trusted. It is generally measured by the percentage of the population who answer affirmatively to the question, "Generally speaking, would you say that most people can be trusted, or that you need to be very careful in dealing with people?" Although Helliwell and Putnam (2004) do not include social trust within their core definition of social capital, they state that reciprocity and trustworthiness are nearly universal consequences of dense social networks. For this reason, they claim that social trust is a strong empirical index of social capital. Halpern (2005), in fact, identifies social trust as the best single proxy measure available.

- *Informal support* — Informal support refers to the social and material support provided by close personal relationships, which strengthen people's ability to deal with difficult times in their lives. It is generally measured by the percentage of the population who answer positively to a question of the form, "If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?" Answers to this question are found to correlate strongly with subjective well-being, but have little discriminatory power as almost all respondents answer affirmatively when surveyed (Stiglitz et al., 2009; OECD, 2011).
- *Civic participation* — Another proxy that is often used to measure social capital is the number of civic or religious organisations to which people belong. This measure has been criticised, however, as the existence of an organisation does not necessarily imply active social networks among its members (Stiglitz et al., 2009). A related approach involves measuring the amount of time that people spend doing activities that are assumed to be the result of social connections, such as volunteering. Such data may be obtained from national time use surveys, although definitions of these activities may vary significantly between countries (OECD, 2011).
- *Indices of Social Development (ISD)* — The Institute of Social Studies at Erasmus University has recently created a set of five composite indicators that measure different aspects of social development. These are: (1) civic activism, (2) clubs and associations, (3) intergroup cohesion, (4) gender equality, and (5) interpersonal safety and trust. Of these five, *Interpersonal Safety and Trust* probably relates most closely to the concept of social capital discussed in this section. This index synthesises data from 42 indicators, including measures of social trust from surveys, reported levels of crime victimisation, survey responses

on feelings of safety and security, data on the incidence of homicide, and risk reports on the likelihood of physical attack, extortion, or robbery (ISS, 2011).

Based on the strong support for it in the literature (e.g. Helliwell and Putnam, 2004; Halpern, 2005), I would like to use social trust as the indicator of social capital. Unfortunately, however, social trust data are only available for a limited number of countries. The fifth wave of the World Values Survey (WVS, 2011) included the social trust question quoted in the first bullet point above, but these data are only available for 57 countries (with survey years ranging from 2004 to 2008).

Due to the lack of social trust data, I therefore use the Index of Interpersonal Safety and Trust published by the Institute of Social Studies (ISS, 2011). Although not ideal, this index includes social trust data, and there is a moderate correlation (r = .566, p < .001) between it and the WVS data where the two sources overlap. The data that I use are for the year 2005, and are available for 151 countries.

6.7. *Participatory Democracy*

A deepening of democracy is a key goal of the degrowth movement. The Paris Declaration calls for the observation of the principles of participatory democracy, the encouragement of good citizenship, and respect for human rights (Research & Degrowth, 2010). Various degrowth scholars make the point that the transition to a more ecologically sustainable society and the transition to a more participatory and democratic society are mutually supportive goals that must be achieved together. As Schneider et al. (2010, p. 513) state, "Decentralizing and deepening democratic institutions and repoliticizing the economy are prime objectives of the degrowth movement, alongside the reduction of consumption and production; one cannot be considered without the other." Cattaneo and Gavaldà (2010) argue that degrowth must be the outcome of a general transition towards a more democratic and autonomous society—the result of a collective decision for a better life. They stress that degrowth most not be an externally-imposed imperative, otherwise it could lead to some form of eco-dictatorship.

References to the role of democracy in achieving a steady state economy are much harder to find. It is a topic that Daly does not really discuss, and where it is mentioned by other authors the focus is often on whether a democratic system could lead to a SSE. As Victor (2008, p. 193) writes, “The dilemma for policy makers is that the scope of change required for managing without growth is so great that no democratically elected government could implement the requisite policies without the broad-based consent of the electorate. Even talking about them could make a politician unelectable”. Nevertheless, Lawn (2005b) argues against critics who suggest that a SSE could only be accomplished under an authoritarian regime. He claims that a government wishing to make the transition to a SSE would be democratically electable provided that people can be convinced of the severity of the ecological crisis, the desirability of a SSE, and that their current freedoms would be preserved.

Some steady state economists do call for greater democracy as a way to achieve a SSE, but their proposals generally relate to the democratisation of specific organisations (Booth, 1994; O'Neill et al., 2010). For example, O’Neill et al. (2010) call for the democratisation of the places where people work in order to reduce inequality and lessen the growth imperative. They also call for the democratisation of powerful international organisations like the UN, World Bank, IMF, and WTO to allow wealthy countries and poor countries to develop in a fair and mutually supportive manner.

From a conceptual point of view, it is hard to question the importance of democratic rights to human well-being. As Stiglitz et al. (2009, p. 50) write, “Political voice is an integral dimension of the quality of life. Intrinsically, the ability to participate as full citizens, to have a say in the framing of policies, to dissent without fear and to speak up against what one perceives to be wrong are essential freedoms”. Empirically, there is also strong evidence that people who live in more democratic societies are happier (Frey and Stutzer, 2002b; Dolan et al., 2006; Helliwell and Huang, 2008; Inglehart et al., 2008; Inglehart, 2010). In fact, Helliwell and Huang (2008) find that life satisfaction is more closely linked to measures of the quality of government than it is to per capita income. As an explanation for these findings, Frey and Stutzer (2002b) suggest that people who live in constitutional democracies are happier because the politicians in these countries are motivated to rule according to their interests. Inglehart et al. (2008; 2010) propose a different theory, namely that democracy increases the amount of free choice that people have, which in turn increases subjective well-being. They note that while increases in income can improve well-being, rising social tolerance and political freedom are more important drivers.

At first glance, there might seem to be little connection between how democratic a society is and its resource use or environmental impact. Nevertheless, there is an extensive literature that investigates the relationship between democracy and economic growth. Based on an analysis of 65 countries over a 20-year period, Tavares & Wacziarg (2001) find that democracy fosters growth by improving the accumulation of human capital and by lowering income inequality, but hinders growth by reducing the rate of physical capital accumulation and by raising the ratio of government consumption to GDP. Overall, they conclude that the net effect of democracy on economic growth is "moderately negative" (p. 1341). While degrowth scholars might interpret these findings as reason to strengthen democratic institutions, the authors of the study instead suggest redesigning democratic institutions to "maximize the benefits of democracy [presumably for economic growth] while minimizing its costs" (p. 1372).

Despite numerous other studies, no firm conclusions have been reached on the impact of democracy on economic growth. In an attempt to resolve the debate, Doucouliagos and Ulubaşoğlu (2008) have performed a meta-regression analysis using 483 estimates from 84 studies. They conclude that democracy has no *direct* impact on economic growth. However, when taking indirect effects associated with democracy into account (e.g. economic freedom, political stability, government size) they come to the rather hesitant conclusion that "democracy's net effect on the economy does not seem to be detrimental" (p. 61).

In order to measure where a country stands in terms of democratic freedoms, Stiglitz et al. (2009) suggest that indicators in three areas are needed: (1) political voice and governance, (2) legislative guarantees, and (3) the rule of law. They go on to write:

> Despite the importance of political voice for [quality of life]… reliable measures remain limited… The information collection methodology typically involves drawing on expert opinions about how countries are performing in terms of democracy, corruption and freedoms… While experts' assessments are useful in some fields, such as concerning the existence of particular institutions of governance or legislative guarantees, they are also clearly inadequate for assessing how adequately or fairly such institutions function, or how people perceive them. To measure these aspects requires population surveys that provide information on citizens' perceptions of the functioning of these institutions. Such surveys are rare. (Stiglitz et al. 2009, pp. 180-181)

Below I discuss three alternatives that could be used to measure participatory democracy in the Social Accounts. The first two of these are based on expert opinions, while the third combines expert opinions with survey data:

- *Freedom in the World* — This indicator, published by Freedom House (2011b), measures freedom according to two broad categories: political rights and civil liberties. Each country is assigned a rating from 1 to 7 for both political rights and civil liberties, with 1 representing the most free and 7 the least free. The ratings are determined by the number of points that each country receives on 10 political rights questions and 15 civil liberties questions. An example of a question from the political rights component is "Are the national legislative representatives elected through free and fair elections?" Countries receive between 0 and 4 points on each question based on expert opinions. The overall freedom indicator is calculated by taking the average of the political rights and civil liberties components. Freedom House (2011a, p. 30) claim that their definition of freedom is culturally independent, and is "grounded in basic standards of political rights and civil liberties, derived in large measure from relevant portions of the Universal Declaration of Human Rights". The data are available from 1972 to 2011, and cover 194 countries in recent years.
- *Polity score* — This indicator, produced by the Polity IV Project (2011) , measures the "degree of democracy" in nations on a scale from -10 (hereditary monarchy) to +10 (consolidated democracy). The indicator is calculated from two sub-indicators, the first measuring elements of democracy, and the second elements of autocracy. The overall "polity score" is calculated by subtracting the autocracy score from the democracy score. The indicator is calculated based on expert opinions of the quality of executive recruitment, constraints on executive authority, and political competition. If focuses on the governing authority of the regime, and does not include data on civil liberties (Marshall et al., 2010). The data are available in a very long time series from 1800 to 2010, and cover 164 countries in recent years.
- *Worldwide Governance Indicators* — These data, published by the World Bank (2011b), include six composite indicators relating to governance: (1) voice and accountability, (2) political stability and absence of violence, (3) government effectiveness, (4) regulatory quality, (5) rule of law, and (6) control of corrup-

> tion. The indicators are based on a definition of governance as "the traditions and institutions by which authority in a country is exercised. This includes (a) the process by which governments are selected, monitored and replaced; (b) the capacity of the government to effectively formulate and implement sound policies; and (c) the respect of citizens and the state for the institutions that govern economic and social interactions among them" (Kaufmann et al., 2010, p. 4). The indicators compile and summarise information from 31 different data sources including surveys of households and firms as well as expert opinions from commercial business information providers, non-governmental organisations, and multilateral development agencies. Each of the six indicators is constructed by normalising and averaging together data from the sources that correspond to the concept of governance being measured. The aggregate indicators generated are in units of a standard normal distribution and range from approximately -2.5 to 2.5 (where a higher value corresponds to better governance). They are available from 1996 to 2010, and cover over 200 countries.

It is questionable whether any of the three indicators discussed above would adequately capture the "deepening of democratic institutions" that is advocated by proponents of degrowth. The Freedom in the World indicator is probably the closest from a conceptual point of view. However, both it, and the polity score, assign the highest ranking on their scale to a large number of countries. These indicators show no difference between countries that already have strong democracies, and would not capture any improvement in democratic institutions within these countries. The World Governance Indicators, while potentially biased towards a more "free enterprise oriented" version of democracy than the other two, have the advantage of using a cardinal scale that provides finer resolution and allows space for the top performers to improve.

Of the six World Governance Indicators, *voice and accountability* is probably the most relevant to the Social Accounts. According to the creators of the indicator, it captures "perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media" (Kaufmann et al., 2010, p. 4). Interestingly, there is a very strong correlation between the voice and accountability indicator and the Freedom in the World indicator (see Figure 6.2), so in practice it may not matter that much which one of the two is used. However, given that it is able to resolve much finer differences between countries, and also because it includes survey data as well as expert opinions, I use voice and accountability as the measure of democracy in the Social Accounts.

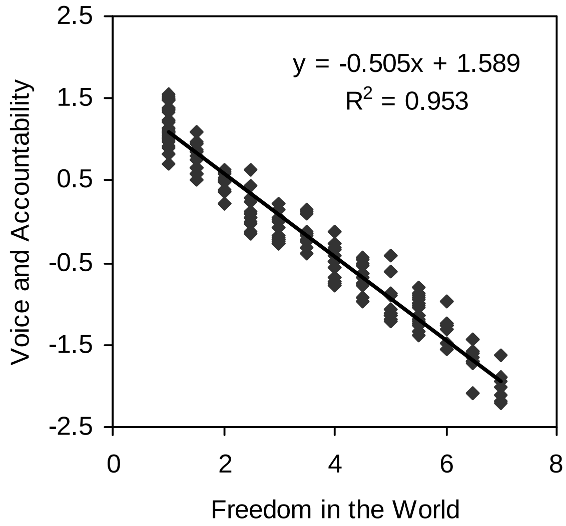

Figure 6.2: The correlation between the ordinal *Freedom in the World* indicator published by Freedom House (2011b) and the cardinal *voice and accountability* indicator published by the World Bank (2011b). Data are for the year 2007.

6.8. Decreased Working Time

A decrease in working time, and a corresponding increase in free time, is an objective mentioned in both the degrowth and steady state literature (e.g. Latouche, 2009). The Paris Declaration states that degrowth is to be characterised by "substantially reduced dependence on economic activity, and an increase in free time" (Research & Degrowth, 2010, p. 524). The report of the Steady Economy Conference identifies three benefits of working time reduction: (1) a reduction in working time allows available employment to be shared more equally among the work force, reducing unemployment; (2) a reduction in working time is likely to improve well-being by giving people more time to spend with friends and family, participate in the community, engage in creative activities, volunteer, and pursue personal and spiritual development; and (3) a reduction in working time has the potential to stabilise (or even reduce) resource use and waste emissions by stabilising (or reducing) the volume of production and consumption in the economy (see O'Neill et al., 2010, pp. 80-83).

In general, it would seem that using the benefits of technological progress to gradually reduce working time, rather than increase production, is an objective that would appeal to many people. Survey data suggest that—given the choice—the majority of people would rather work less than earn more money. In a U.S. Department of Labor study, 84% of respondents said that they would like to trade some or all of their future income for additional free time (Schor, 1993, p. 129). Moreover, survey data also suggest that a large number of people would like to reduce their current working time, even if doing so meant a reduction in pay. A survey conducted in 15 OECD countries found that 41% of people would prefer to spend less time at work, compared to 10% who would prefer to spend more time (Clark, 2010, p. 449).

According to Sanne (2010), labour productivity increases by about 2% each year in western economies. He claims that if this gain were applied to reducing working hours instead of increasing production, western economies could achieve a 4-day work week in 12 years, a 3-day work weeks in 25 years, and so on. But how much should working hours be reduced? As the next section discusses, having a job contributes strongly to subjective well-being, and not just because of the income it provides. The objective should therefore not be to reduce working time to zero, but to a level that permits a high well-being outcome for society.[28] In an essay contemplating the economic possibilities for his grandchildren, John Maynard Keynes (1963 [1930]) suggested that a 15-hour work week would accomplish this. In a recent report, the New Economics Foundation proposes that the standard work week should be reduced to 21 hours. As a rationale for this target, the authors state:

> 21 hours is very close to the average time that men and women of working age actually spend in paid employment each week. And it is just a few minutes more than the average time per week they spend in unpaid work at home. So we are suggesting a closer match between these averages and what is regarded as the "norm" for paid employment. Of course, such averages mask the way paid and unpaid hours of work are unevenly distributed, especially between women and men but also between rich and poor. Our proposal seeks to address these inequalities by redistributing working hours. (Coote et al., 2010, p. 7)

[28] It is worth pointing out that working time reduction can never be a permanent solution to unemployment, for the same reason that economic growth cannot be. Neither phenomenon can continue indefinitely.

Given that people report being less happy when working than when doing almost any other activity (with the notable exception of commuting; see Kahneman et al., 2004), one might expect there to be a strong negative correlation between working time and subjective well-being. However, based on their review of the factors that contribute to well-being, Dolan et al. (2006) conclude that the relationship is not straightforward, with studies showing conflicting results. For example, based on a panel data study for Germany, Pouwels et al. (2008) find that the logarithm of working hours is negatively correlated with life satisfaction (although the result is only statistically significant for men). Using additional panel data for Germany, and accounting for fixed effects, Knabe and Rätzel (2010) find that the impact of working hours on life satisfaction exhibits an inverse-U shape, and is rather small. Finally, based on a panel data study for Australia, Wooden et al. (2009) conclude that it is not the number of hours worked that is important for subjective well-being, but how closely these hours match an individual's preferences. As Dolan et al. (2006) conclude, further research is required to determine what relationship—if any—exists between working time and well-being.

There has also been relatively little research done on the relationship between working time and environmental impact. One exception is an empirical study of 45 countries by Hayden and Shandra (2009), who find that longer working hours are associated with higher environmental impact (as measured using the ecological footprint). The authors find two mechanisms at play in this relationship. First, longer working hours increase the ecological footprint via their contribution to higher GDP. Second, longer working hours lead to a more environmentally damaging mix of consumption and lifestyle practices, potentially due to a time-scarcity effect. They conclude that "shorter hours of work not only represent a form of sufficiency, the evidence here suggests they are also associated with greater ecological efficiency" (p. 591).

Unfortunately for the Social Accounts, data on average working time are not available for a large number of countries. The best available dataset is probably contained in the *Key Indicators of the Labour Market* database published by the International Labour Organization (ILO, 2011a). In order to measure annual working hours, I use data from "Table 7b: Annual hours actually worked per person" of this database. These data measure the total number of hours actually worked during a year per employed person. The data incorporate variations in part-time and part-year employment, in annual leave, paid sick leave and other types of leave, as well as in flexible daily and weekly working schedules. The data are available for 56 countries, spanning the period 1980–2010.

6.9. Low Unemployment

Although not mentioned in the Paris Declaration, I would argue that low unemployment is an important goal to include in the Social Accounts. Despite the popular characterisation of work as a "necessary evil", there is strong evidence that having a job contributes positively to a person's well-being. Besides providing income, work allows people to socialise, participate in collective activities, and develop a sense of belonging. It also contributes to identity, provides a sense of purpose in life, confers social status, and introduces structure to our lives (Lintott, 2004; Stiglitz et al., 2009; Theodoropoulou and Zuleeg, 2009).

The opposite of having a job—being unemployed—has been shown to be highly detrimental to well-being. As E.F. Schumacher (1974, p. 46) wrote, "If a man has no chance of obtaining work he is in a desperate position, not simply because he lacks an income but because he lacks this nourishing and enlivening factor of disciplined work which nothing can replace." Empirical studies consistently show that being unemployed has a large negative effect on well-being, with unemployed individuals reporting well-being scores that are 5–15% lower than those who are employed (Dolan et al., 2006). Such studies also confirm Schumacher's claim that the negative impact of unemployment on well-being is greater than what would be expected from lost income alone (Frey and Stutzer, 2002b). Based on an analysis of employed and unemployed workers in Britain, Clark and Oswald (1994, p. 655) conclude that "joblessness depresses well-being more than any other single characteristic, including important ones such as divorce and separation". Moreover, the negative effect of unemployment on well-being tends to persist even after a person finds a new job (Dolan et al., 2006).

A further reason to include a measure of unemployment in the Social Accounts is to address the criticism that degrowth will result in job losses. Jackson (2009a) describes the "dilemma of growth" in terms of two propositions: (1) growth is unsustainable due to rising resource use and environmental damage, and (2) degrowth is unstable, under present economic arrangements at least, because falling consumer demand leads to rising unemployment. While proposals such as working time reduction and a job guarantee have been put forward to maintain full employment in a steady state economy (see Section 2.4.4), and have even been simulated using a low-growth model (Victor, 2008), the availability of work remains a critical indicator to monitor in any transition.

Although providing employment to those seeking it would seem to be a reasonable goal in steady state economy, it is questionable whether "full employment" as currently defined should be the goal. Lintott (2004) argues that full employment would need to be redefined in a SSE to imply progressively shorter working hours, an objective that is in line with the intermediate end discussed in the previous section. Lintott goes on to suggest that the psychological benefits of employment would remain even if working hours were substantially reduced. He also suggests that the relationship between employment and well-being could be much weaker in a society where having a job was not considered as important, and where people were socialised differently.

Nevertheless, I suggest that an indicator that measures the percentage of the working population who are currently seeking employment should be included in the Social Accounts. As part of their *World Development Indicators*, the World Bank (2011a) maintains unemployment rate data that span the period 1980–2009. These data measure the share of the total labour force that is without work but available for (and seeking) employment. As the Bank notes, however, definitions of labour force and unemployment differ from country to country, which may affect the accuracy of international comparisons made using these data. Although the International Labour Organization (ILO, 2011b) has published a set of internationally comparable unemployment statistics, these data are only available for ~30 countries, and the series ends in 2005. Therefore I use the World Bank unemployment rate data in the Social Accounts. These data are available for ~100 countries for the period considered in my analysis (1997–2007).

6.10. Stable Prices

Price stability (i.e. low inflation) is the other goal that is not mentioned in the Paris Declaration, but which I believe is an important objective to include in the Social Accounts. From a conventional economic perspective, high inflation is problematic for a number of reasons. Even if wages increase in line with prices, inflation can be costly due to the inconvenience it causes (e.g. frequent price updates), and its ability to erode people's savings. Moreover, if the rate of inflation varies unpredictably, it can result in economic uncertainty and significant redistributions of wealth within the economy (Goodwin et al., 2009). According to Frey and Stutzer (2002b, p. 429), the "common opinion" of academic economists is that "rampant inflation is very dangerous for the economy, while a constant, and hence predictable, but low inflation (say 1–5 percent per year) is not taken to cause any major problems".

Economists and the general public seem to have rather different perspectives on the issue of inflation, however. An extensive survey by Shiller (1996) found that people are concerned with different issues than economists. The largest concern voiced in the survey is that inflation lowers people's standard of living. (Since wages tend to rise with prices, this is probably not the case in general, but the perception remains.) Other concerns that were voiced include that inflation may allow opportunists to take advantage of others, that the social atmosphere created by inflation is harmful to morale, that high inflation can cause political instability, and that inflation and currency depreciation damage national prestige.

Moreover, studies of the factors that contribute to subjective well-being suggest that high inflation has a negative effect on life satisfaction. These include studies that use only aggregate macro-economic data (e.g. Di Tella et al., 2001; Bjørnskov, 2003; Wolfers, 2003), as well as studies that control for individual personal characteristics (e.g. Alesina et al., 2004). Interestingly, the loss in well-being associated with a 1% increase in the unemployment rate versus a 1% increase in the inflation rate has been estimated in some studies. The general finding is that a percentage increase in unemployment is much more damaging to subjective well-being than a percentage increase in inflation. For example, Di Tella et al. (2001) find that people would trade a 1.7% increase in inflation for a 1% increase in unemployment, while Wolfers (2003) arrives at a ratio close to 5:1.

However, it may be worth interpreting these studies with some caution. In their review of the factors that contribute to well-being, Dolan et al. (2006) note that the studies that show a connection between inflation and well-being tend to contain a rather limited number of macro-economic variables. They therefore question whether the statistically significant correlation between inflation and well-being would remain if other variables were considered as well.

Nevertheless, based on the importance ascribed to low inflation by both mainstream economists and the general public (albeit for different reasons), and the potential link between inflation and subjective well-being, I would argue that an indicator of price stability should be included in the Social Accounts. It is probably also worth including such an indicator to respond to those critics who suggest that the sort of monetary system proposed for a steady state economy (i.e. a full-reserve banking system; see Section 2.4.5) would result in high inflation—perhaps even hyperinflation. Although proponents of a full-reserve system (e.g. Dyson et al., 2010) argue that 100% reserves would permit more direct control of the money supply than the current system (and hence better inflation targeting), the inflation rate is clearly an important quantity to monitor during the transition to a different model of money creation.

As the measure of price stability in the Social Accounts, I use inflation data published by the World Bank (2011a), which span the period 1961–2010. These data measure inflation using the consumer price index, and reflect the annual percentage change in the cost to the average consumer of acquiring a specific basket of goods and services (the basket may be fixed or change at specified intervals). The data are available for ~170 countries for the period considered in my analysis (1997–2007).

6.11. Summary

The definition of a steady state economy developed by Daly is largely biophysical in nature. It describes what would be held steady in a SSE, but not what would be allowed—or even encouraged—to change. Degrowth scholars have explored the topic of social goals a bit more than steady state economists, although their treatment of it is far from comprehensive.

Based in part on the Paris Declaration, and in part on my own survey of the literature, I identify eight intermediates ends to work towards in a SSE, and a single ultimate end to be used to prioritise these. The ultimate end is human well-being, and the intermediate ends are health, equity, the elimination of poverty, increased social capital, participatory democracy, decreased working time, low unemployment, and stable prices.

The choice of human well-being as the “ultimate end” for the economy, and even the choice of the intermediate ends in service of it, clearly invites debate. The list of abstract indicators that form the basis of the Social Accounts should therefore be viewed as a work-in-progress, to be refined over time as the social priorities of the degrowth and steady state movements are developed further.

A variety of different approaches exist to defining and measuring human well-being. I suggest that the concept should ideally be measured using a single index that combines a small number of measures from three of these approaches (the hedonic approach, evaluative approach, and eudaimonic approach). Such an index would capture whether people are both “feeling good” and “doing well”.

Unfortunately, limited data availability prevents me from using this idealised approach to measuring human well-being, and also constrains the measurability of the intermediate ends. For each of the abstract indicators in the Social Accounts I have therefore chosen a measurable proxy based on the best data currently available for a large number of countries. These indicators are summarised in Table 6.1.

Table 6.1: The indicators in the Social Accounts.

Type	Abstract Indicator	Proxy
Ultimate End	Human well-being	Life satisfaction
Intermediate Ends	Health	Healthy life expectancy at birth
	Equity	Gini coefficient
	Elimination of poverty	Human Poverty Index (HPI-1)
	Increased social capital	Interpersonal safety and trust
	Participatory democracy	Voice and accountability
	Decreased working time	Annual working hours
	Low unemployment	Unemployment rate
	Stable prices	Inflation rate

Seven of the nine indicators in the Social Accounts are available for a large number of countries over the 1997–2007 analysis period, while the other two (the Human Poverty Index and annual working hours) are only available for a relatively small number of countries. In general, there is a gap between what I would like to be able to measure for each of the abstract biophysical and social indicators, and what can actually be measured at present. This gap should be born in mind as these indicators are used to explore the relationship between resource use and social performance in the next chapter.

7. Empirical Analysis

However beautiful the strategy, you should occasionally look at the results.

— Winston Churchill

The previous two chapters have proposed a set of indicators to measure how close national economies are to the concept of a socially sustainable steady state economy. The indicators are divided into two separate accounts (biophysical and social), and organised using Daly's Ends–Means Spectrum. The complete set of indicators is shown in Figure 7.1.

In this chapter I proceed to analyse the indicator data. The empirical analysis serves two purposes. The first is to illustrate the system of accounts that I have developed, while the second is to contribute to a better understanding of complex economic systems. The analysis should be interpreted as a "first pass"—an attempt to survey a large number of countries to see (a) which are closest to the biophysical definition of a steady state economy, and (b) what relationship exists between a country's proximity to a steady state economy and its social performance.

The chapter continues as follows. In Section 7.1, I calculate and present the data in the Biophysical Accounts. These consist of seven indicators that measure the stability of stocks and flows, and a single indicator that measures the overall scale of flows in relation to ecological limits. I employ two separate methods to assess how close countries are to biophysical stability: the first is a multi-criteria approach that categorises countries based on their performance on the seven rate-of-change indicators, while the second is an index that is calculated by averaging these indicators. I plot how close countries are to a steady state economy using the pathway approach proposed at the end of Chapter 5, and investigate the degree of correlation between the biophysical indicators.

In Section 7.2, I calculate and present the data in the Social Accounts. These consist of eight indicators that measure progress towards intermediate ends, and a single indicator that measures progress towards the ultimate end of human well-being. In order to help assess the relative social performance of different countries, I normalise and aggregate some of the social indicators into an index of social performance. As with the biophysical indicators, I investigate the degree of correlation between the individual social indicators, and also use multiple regression to test which of the intermediate ends are the primary determinants of well-being.

In Section 7.3, I investigate the relationship between resource use and social performance. I test whether there is any relationship between biophysical stability and performance on each of the social indicators, as well as biophysical scale and performance on each of the social indicators. I also investigate what level of resource use is necessary to achieve a certain "sufficient" score on each social indicator. Finally, I use multiple regression to assess whether the stability findings are robust to the inclusion of scale, and retest the determinants of well-being in the presence of the biophysical indicators.

ULTIMATE END

- Human well-being
  Life satisfaction

INTERMEDIATE ENDS

- Health
  Healthy life expectancy
- Equity
  Gini coefficient
- Increased social capital
  Interpersonal safety and trust
- Participatory democracy
  Voice and accountability
- Low unemployment
  Unemployment rate
- Stable prices
  Inflation rate
- Elimination of poverty
  Human Poverty Index (HPI-1)
- Decreased working time
  Annual working hours

SOCIAL ACCOUNTS

INTERMEDIATE MEANS

- People (Stock)
  Δ *Human population*
- Domesticated animals *(Stock)*
  Δ *Livestock population*
- Built capital (Stock)
  Δ *Night-time lights*

ULTIMATE MEANS

- Material use (Flow)
  Δ *Domestic material extraction* †
  Δ *Ecological footprint* ‡
- Material outflows (Flow)
  Δ *CO_2 emissions* †
- Energy use (Flow)
  Δ *Total primary energy supply* ‡
- Scale
  Ratio of per capita EF to fair earthshare

BIOPHYSICAL ACCOUNTS

Figure 7.1: The complete set of indicators used to measure progress towards a socially sustainable steady state economy. The indicators are divided into two accounts (social and biophysical) and are classified according to Daly's Ends–Means Spectrum. Each of the accounts consists of a set of abstract indicators (underlined), and a set of corresponding proxies based on the best data that are currently available for a large number of countries (*italics*). The Δ symbol signifies that an indicator is an annual rate of change, † signifies that it is a territorial measure, and ‡ signifies that it is a consumption-based measure.

7.1. The Biophysical Accounts

There are three types of indicators in the Biophysical Accounts: (1) indicators that measure the rate of change of stocks, (2) indicators that measure the rate of change of flows, and (3) indicators that measure the scale of the economy in relation to the capacity of ecosystems. The objective of the first two types of indicators is to measure the short-term *stability* of the economy, while the objective of the third type is to measure the long-term *sustainability* of the economy. A steady state economy is an economy that is both biophysically stable and biophysically sustainable.

7.1.1. Rate-of-Change Indicators

Calculating Rates of Change

There are seven rate-of-change indicators in the Biophysical Accounts: human population, livestock population, night-time lights, domestic material extraction, total primary energy supply, CO_2 emissions, and ecological footprint. Although it is not one of the indicators included in the Biophysical Accounts, I also calculate the rate of change of GDP in order to investigate the relationship between this quantity and the other indicators. The GDP data are obtained from the World Bank's (2011a) *World Development Indicators*, and are expressed in 2005 purchasing power parity (PPP) dollars. Depending on the indicator, rate-of-change values are calculated for between 152 and 181 countries (Table 7.1). The original units vary from indicator to indicator, but the quantity of interest is the annual percentage rate of change of each indicator.

Table 7.1: Data availability for the rate-of-change indicators in the Biophysical Accounts (as well as GDP).

Indicator	Original Units	Number of Countries
Δ Human population	Number of people	181 (181)
Δ Livestock population	Livestock units	181 (181)
Δ Night-time lights	Sum of lights	152 (149)
Δ Domestic material extraction	Tonnes	180 (178)
Δ Total primary energy supply	Joules	180 (179)
Δ CO_2 emissions	Tonnes	180 (179)
Δ Ecological footprint	Global hectares	180 (167)
Δ GDP	2005 PPP dollars	172 (169)

Note: Values in parentheses indicate the number of countries where the standard error of the rate of change is less than 2% (explained below).

I estimate rates of change for all indicators over the ten-year analysis period (1997–2007) using log-linear regression, following a method suggested by Gujarati (1995, pp. 169–171). The method uses all data points in the period to calculate the compound annual rate of change, and is therefore superior to simpler approaches that use only the endpoints. The compound annual rate of change r is calculated as:

$$r = [\exp(m) - 1] \times 100 \tag{7.1}$$

where m is the slope of the best-fit line generated using ordinary least squares (OLS) regression, after log-transforming the data.

An example helps to illustrate the method used. Figure 7.2a shows energy use in Vietnam for the ten-year analysis period. The energy data are transformed to a logarithmic scale (Figure 7.2b), and a trend-line is fitted using OLS regression. The slope of this line is 0.0915, and the compound annual rate of change of energy use is therefore 9.58% per year (as calculated using Equation 7.1).

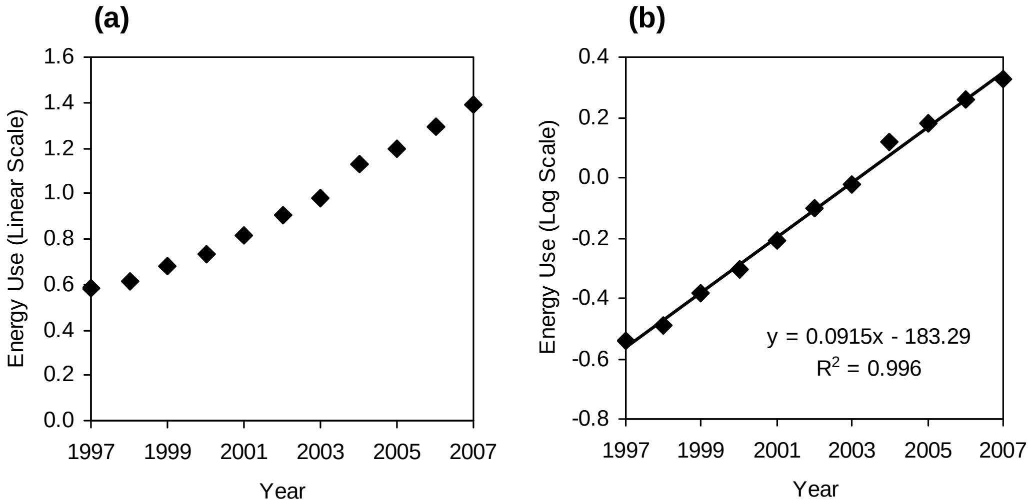

Figure 7.2: Energy use in Vietnam for the period 1997–2007. Panel (a) shows energy use on a linear scale, while panel (b) shows it on a logarithmic scale. The rate of change of energy use is calculated using ordinary least squares regression with the logarithmic data in panel (b).

There is clearly value in having some measure of the level of uncertainty in the trend. The standard measure of goodness-of-fit for a regression (R^2) is of little use in this case, however, because R^2 is zero whenever the rate of change is zero (the desired state in a SSE). I therefore use the standard error of the slope as a measure of the uncertainty in the trend. For energy use in Vietnam, the trend is very consistent and the standard error of the slope is low (0.20%). This is not the case for all countries and indicators, however. For example, the ecological footprint in Georgia decreased by close to a factor of ten between 1997 and 1999, suggesting some underlying anomaly in the data (Figure 7.3). The log-linear regression method produces a very high rate of change in this case (-15.1% per year) and a high standard error in the slope (6.2%).

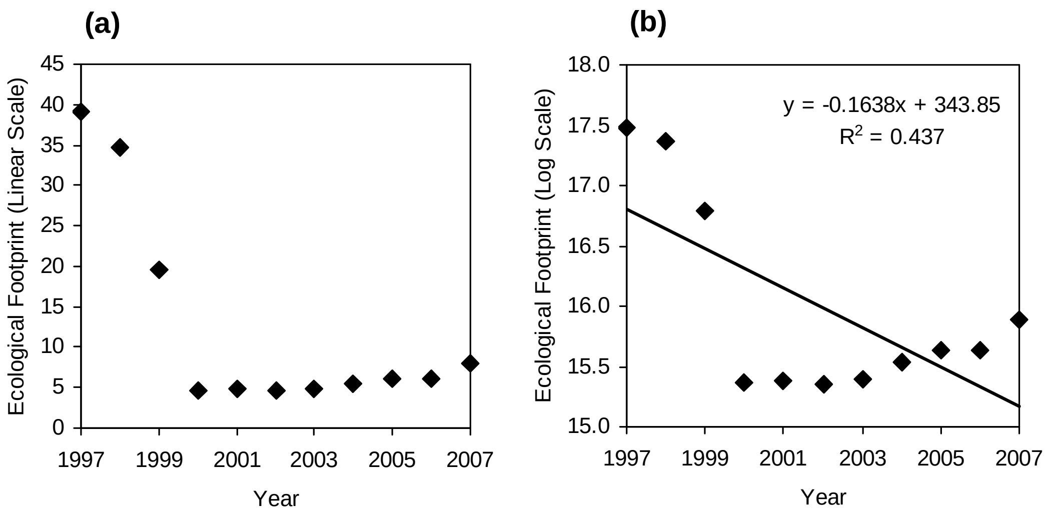

Figure 7.3: Ecological footprint in Georgia for the period 1997–2007. Panel (a) shows the footprint on a linear scale, while panel (b) shows it on a logarithmic scale.

A high standard error in the slope could either indicate some form of discontinuity in the data, or simply the absence of a consistent trend. Either way I would argue that rates of change with a high standard error should be excluded from the analysis of how close countries are to biophysical stability. As a cut-off, I therefore exclude all data points with a standard error that is greater than 2%.[29] For the "cleanest" of the indicators (population) no data points are excluded using this threshold, whereas for the "noisiest" of the indicators (the ecological footprint), 13 data points are removed (see Table 7.1).

After having calculated the rate-of-change indicators, I use two methods to assess how close countries are to biophysical stability: (1) a multi-criteria classification system, and (2) an index of average values. I apply two different methods as a type of sensitivity analysis to see how important the method of classification is to the identification of biophysically stable economies. The two different ways of classifying the biophysical data also lend themselves to two different methods of analysing the relationship between biophysical stability and social performance (to be discussed in Section 7.3.1).

[29] The 2% cut-off is somewhat arbitrary, but matches the size of the groups that are used to categorise economies, and serves to remove any extreme outliers.

Multi-criteria Approach

In the first method (which I refer to as the "multi-criteria approach"), I classify a country's performance on each of the seven indicators as either "degrowth", "stable", or "growth" depending on the value of the indicator. In general, a rate of change is classified as degrowth if it is less than −1% per year, stable if it is between −1% and +1%, and growth if is greater than +1% per year. The one exception is the rate of change of population where I use thresholds of −0.5% and +0.5%, due to the lower range and lower standard error for this indicator.[30]

Each country is then placed into one of five categories based on which of these three classifications dominates (Table 7.2). In general, if four or more of the classifications are of one type (e.g. "stable") then the economy is categorised as that type (i.e. "stable"). Two shoulder categories ("partial degrowth" and "partial growth") are used to capture economies that fall between types. A total of 174 countries are classified into these five groups, while the remaining seven countries are classified as "mixed". In general, the "mixed" countries are missing data for one or more of the indicators, making it difficult to categorise them.

Table 7.2: The rate-of-change criteria used to categorise economies.

Category	Criteria	Number of Countries	% of People
Degrowth	≥ 4 degrowth classifications	4	1.5
Partial Degrowth	≥ 5 stable or degrowth classifications	5	1.9
Stable	≥ 4 stable classifications	22	11.8
Partial Growth	≥ 5 stable or growth classifications	19	3.9
Growth	≥ 4 growth classifications	124	80.2
Mixed	All others	7	0.7

Table 7.3 presents the rate-of-change data and categorisations for the 181 countries in the Biophysical Accounts (the full data set with standard errors is provided in Table A.1 of the Appendix.) There are 22 countries that have relatively stable stocks and flows, and another 24 close to this situation (i.e. countries categorised as either "partial degrowth" or "partial growth"). The majority of the countries that are classified as "stable" are located in Europe, although a handful of Latin American countries also make the list.

[30] The choice of a lower threshold for the rate of change of population is largely statistical (i.e. better data). Changing this threshold to ±1% to match the other indicators would have little effect on the overall results.

There is only one country in the world (Japan) that achieves relative stability in all seven of the stocks and flows, while five countries (Denmark, France, Poland, Romania, and the U.S.) achieve stability in six out of the seven. Interestingly, the one indicator that does not meet the stability criteria in the U.S. is population, which is growing at 1.1% per year.

There are four countries in the world (Germany, Guyana, Moldova, and Zimbabwe) which achieve degrowth in the majority of the indicators, and another five countries that straddle the boundary between degrowth and stable (Lithuania, Slovakia, Sweden, the Ukraine, and the UK). There are a total of seven countries in the world that are either degrowing or stable in all indicators (Belgium, Denmark, Germany, Japan, Moldova, Romania, and Zimbabwe).

The UK performs well in general, achieving degrowth or stability in six out of the seven indicators. The one indicator that is increasing in the UK is the ecological footprint, which is growing at 1.2% per year. Since the ecological footprint is a consumption-based indicator, while all of the others except energy use are purely territorial, these results may indicate that the UK is shifting its environmental impact to other countries, as opposed to stabilising or reducing it. This interpretation of the results is supported by other studies (e.g. Barrett et al., 2011; Peters et al., 2011) which have found that UK greenhouse gas emissions are increasing when accounted for using a consumption-based approach.

In general, however, the consumption-based indicators are not noticeably higher than the other rate-of-change indicators for countries categorised as stable. This result reinforces the finding that some countries have indeed stabilised their resource use, regardless of the accounting perspective.

Nevertheless, the vast majority of countries in the world are biophysical growth economies. These countries account for roughly 80% of global population. Moreover, there are 32 countries (accounting for 12% of global population) where all seven biophysical indicators are increasing. The world as a whole is also a growth economy, with high rates of growth in five of the seven indicators.

Interestingly, despite its commitment to increasing gross national happiness (instead of gross national product), Bhutan shows growth in five of the six indicators that are available for it. This trajectory may be appropriate for Bhutan, however, as it is a relatively poor country where greater resource use may indeed contribute to greater happiness.

Table 7.3: The Biophysical Accounts: rate-of-change indicators and stability classifications.

		Change in Stocks (% per year)			Change in Flows (% per year)			
	Country	Pop.	Live.	Lights	Mat.	Energy	CO_2	EF
Deg.	Germany	0.06	-1.11	-1.74	-2.38	0.14	-1.02	0.03
	Guyana	0.11	3.12	-1.98	-4.27	2.07	-1.06	-1.29
	Moldova	-1.58	-3.29	-2.94	-0.65	0.37	-0.26	-1.50
	Zimbabwe	0.22	-1.03	-3.88	-2.01	-1.96	-4.69	-0.87
Partial Deg.	Lithuania	-0.58	-1.61	-0.55	3.46	0.77	-0.08	1.99
	Slovakia	0.04	-3.94	-3.78	1.81	0.49	-0.89	2.08
	Sweden	0.37	-1.44	-3.24	3.58	-0.56	-0.62	1.46
	Ukraine	-0.83	-6.14	-2.49	2.53	0.76	0.15	0.87
	United Kingdom	0.43	-1.81	-1.44	-2.37	-0.05	-0.09	1.22
Stable	Belgium	0.40	-2.10	-2.00	0.05	0.45	-1.22	0.93
	Colombia	1.62	0.52	-1.48	2.03	0.79	-0.35	0.62
	Cuba	0.20	-0.99	2.38	-1.50	-1.70	0.56	0.88
	Denmark	0.32	0.08	-1.76	0.82	-0.60	-0.76	0.01
	France	0.58	-0.87	-0.13	0.31	0.85	-0.08	0.53
	Hungary	-0.26	-0.92	-1.43	1.81	0.99	-0.70	0.03
	Italy	0.42	-1.14	0.62	0.07	1.08	0.74	1.12
	Japan	0.11	-0.72	-0.96	-0.03	0.49	0.15	-0.26
	Kyrgyzstan	1.18	1.49	-0.96	0.78	-0.92	1.27	0.18
	Macedonia	0.27	-2.64	0.16	-1.22	-0.64	-0.57	5.69
	Malta	0.63	0.07	..	1.67	0.44	0.69	-0.37
	Nauru	0.10	0.15	..	..	0.88	0.48	-0.54
	New Zealand	1.12	-0.05	-0.64	1.02	1.02	0.78	-0.19
	Norway	0.67	-0.42	-0.05	0.71	0.49	3.05	2.19
	Paraguay	2.01	0.24	-0.41	0.97	0.37	-0.70	-1.48
	Poland	-0.12	-0.21	1.10	0.59	-0.40	-0.64	0.50
	Romania	-0.46	-1.05	0.53	0.39	-0.55	-0.85	0.57
	Slovenia	0.17	-0.50	-0.46	6.28	1.01	-0.17	2.88
	South Africa	1.39	-0.26	0.90	0.99	2.27	1.53	-0.36
	Switzerland	0.61	-0.15	-0.11	0.40	0.09	-0.36	1.39
	United States	1.06	0.15	-0.95	0.51	0.64	0.64	0.98
	Uruguay	0.15	0.91	-2.51	2.64	0.06	0.96	-0.21
Partial Growth	Bahamas	1.36	-0.30	..	0.84	3.43	2.30	..
	Belarus	-0.48	-1.90	-2.36	2.94	1.61	1.33	-0.51
	Bulgaria	-0.70	-2.61	1.81	1.23	0.42	0.13	2.23
	Congo (Dem. Rep.)	2.89	-2.05	1.79	2.23	0.86	0.17	0.72
	Czech Republic	-0.05	-3.23	-1.47	1.15	1.49	-0.20	1.50
	Djibouti	2.24	0.53	..	0.94	-0.13	1.56	3.69
	Dominica	-0.20	0.04	..	0.07	3.66	4.47	-1.17
	Fiji	0.68	-0.56	..	-1.00	9.91	9.82	-0.37
	Gabon	2.17	0.16	2.06	-0.68	-0.36	-2.27	..
	Georgia	-1.21	0.97	9.01	6.60	-0.51	1.78	..
	Grenada	0.22	0.78	..	2.49	4.16	2.09	0.65
	Iceland	1.12	-0.79	..	1.34	5.69	0.97	..
	Lebanon	1.46	1.53	-1.15	1.06	-1.57	-0.49	0.26
	Netherlands	0.51	-1.92	-1.79	0.24	1.51	-0.08	1.14
	Russia	-0.44	-3.46	-1.43	3.43	1.60	0.78	1.12
	St. Lucia	1.07	0.55	..	0.83	7.46	1.93	0.99
	Samoa	0.38	1.83	..	0.87	2.47	2.15	0.53
	Tonga	0.56	0.44	..	0.35	2.52	5.42	-0.54
	Vanuatu	2.50	0.82	..	0.60	5.42	1.33	-12.22
Growth	Albania	0.18	-1.44	6.20	6.09	3.88	10.55	5.49
	Algeria	1.49	1.71	2.39	3.27	2.67	3.57	4.18
	Angola	2.94	1.38	6.50	5.79	8.27	13.24	3.80
	Antigua & Barbuda	1.74	0.98	..	3.52	3.12	2.96	1.85
	Argentina	1.00	0.44	1.21	1.43	2.44	2.67	-0.63
	Armenia	-0.17	2.90	5.77	5.15	3.98	3.98	3.20
	Australia	1.21	-0.75	0.00	2.29	2.08	1.14	0.74
	Austria	0.46	-1.31	0.36	1.33	1.42	1.76	1.46
	Azerbaijan	0.82	3.78	2.68	8.64	1.48	1.39	3.13
	Bahrain	2.27	0.02	..	1.95	4.41	1.95	8.16
	Bangladesh	1.71	1.48	-0.35	3.03	7.40	6.60	2.73

Growth (continued)

Country	Change in Stocks (% per year)			Change in Flows (% per year)			
	Pop.	Live.	Lights	Mat.	Energy	CO_2	EF
Belize	2.37	3.01	..	2.41	9.65	9.64	..
Benin	3.30	3.18	1.74	2.27	11.30	12.36	3.00
Bhutan	2.82	0.32	..	2.41	9.50	4.55	1.75
Bolivia	2.00	2.64	1.91	2.58	6.49	2.86	1.96
Bosnia & Herz.	1.02	3.46	1.82	5.02	5.33	6.73	1.29
Botswana	1.47	-1.42	5.55	2.73	3.08	3.58	0.32
Brazil	1.34	2.79	0.59	3.66	2.28	1.30	0.81
Brunei Darussalam	2.16	9.90	..	2.14	12.48	1.30	-3.17
Burkina Faso	3.25	4.53	3.89	3.79	2.24	5.69	1.67
Burundi	2.35	4.88	0.65	3.42	-0.54	-6.91	2.18
Cambodia	1.77	1.81	6.25	2.86	9.05	8.78	3.22
Cameroon	2.36	1.97	-0.09	1.41	1.87	5.08	2.30
Canada	1.00	1.40	-2.10	0.51	1.30	1.68	1.36
Cape Verde	1.71	3.28	..	-4.04	11.04	8.67	-1.32
Central African Rep.	1.93	2.82	..	1.54	1.55	-0.47	-0.15
Chad	3.48	2.85	4.66	2.48	3.10	16.83	2.78
Chile	1.14	0.61	2.25	3.92	2.96	1.86	2.59
China	0.73	0.49	4.99	5.87	9.12	7.75	3.46
Comoros	2.25	-0.40	..	0.36	4.51	6.06	7.52
Congo	2.20	3.27	4.66	1.26	8.67	..	2.99
Costa Rica	2.00	-1.92	0.70	1.26	4.51	4.72	0.93
Cote d'Ivoire	2.31	1.09	1.84	1.08	1.10	-0.51	0.28
Croatia	-0.40	0.98	2.10	2.44	1.27	2.17	1.65
Cyprus	1.25	0.75	1.85	5.10	2.92	2.47	3.89
Dominican Rep.	1.56	1.75	0.25	3.05	4.77	1.09	1.36
Ecuador	1.23	-0.68	2.47	1.66	3.15	4.43	0.28
Egypt	1.91	2.78	3.09	2.82	4.72	4.71	1.99
El Salvador	0.43	2.75	1.29	0.71	3.43	1.55	2.96
Ethiopia	2.67	3.68	7.80	3.57	9.24	2.87	2.17
Finland	0.27	-1.31	-2.31	2.06	1.23	1.44	2.62
Gambia	3.28	2.48	4.28	5.11	4.93	5.21	..
Ghana	2.34	2.69	-0.12	3.47	2.70	3.86	3.22
Greece	0.26	-0.10	2.33	1.57	2.09	1.54	2.57
Guatemala	2.47	2.72	3.98	2.86	4.84	4.85	3.43
Guinea	1.97	5.67	0.30	3.55	1.70	1.01	3.92
Guinea-Bissau	2.40	1.56	..	1.10	2.55	1.42	0.47
Haiti	1.74	1.31	-3.09	0.99	2.88	6.53	1.25
Honduras	2.06	4.00	5.12	3.69	5.90	7.37	2.73
India	1.65	-0.17	0.71	2.71	4.54	4.15	1.59
Indonesia	1.33	1.47	0.88	3.94	4.24	5.02	0.78
Iran	1.19	0.81	4.33	3.85	6.39	5.43	4.53
Iraq	2.80	0.85	3.90	-0.13	1.47	4.26	4.17
Ireland	1.78	0.16	1.95	4.54	3.14	1.62	2.45
Israel	1.99	1.15	0.09	2.44	2.23	0.28	2.91
Jamaica	0.75	-2.29	-0.93	1.51	1.80	2.23	1.70
Jordan	2.67	0.76	2.46	3.26	4.80	4.71	4.33
Kazakhstan	0.03	2.38	3.19	5.57	3.67	6.01	..
Kenya	2.65	1.54	-0.95	1.41	4.53	2.38	1.55
Kiribati	1.80	4.69	..	1.84	7.24	-0.71	..
Korea, North	0.64	3.61	0.48	1.82	0.99	0.24	1.09
Korea, South	0.54	1.03	0.19	2.41	3.29	2.29	2.85
Kuwait	4.39	3.54	1.82	3.43	3.85	3.83	3.89
Laos	1.83	1.97	5.02	2.29	6.09	7.51	1.63
Lesotho	1.23	1.51	3.61	1.18	5.12	2.92	-2.45
Liberia	4.52	2.39	..	3.83	5.06	7.96	4.79
Libya	2.06	2.29	5.40	2.68	3.06	1.78	3.71
Luxembourg	1.23	-1.06	-1.46	0.15	4.45	4.83	2.14
Madagascar	2.92	-1.13	-1.87	1.03	7.14	1.61	3.00
Malawi	3.01	3.08	0.66	3.40	4.44	2.54	2.70
Malaysia	2.03	3.81	2.42	2.23	3.86	6.06	..
Mali	2.30	4.66	6.33	4.06	2.29	1.01	3.39

		Change in Stocks (% per year)			Change in Flows (% per year)			
	Country	Pop.	Live.	Lights	Mat.	Energy	CO_2	EF
Growth (continued)	Mauritania	2.75	2.66	1.49	1.67	-1.87	-1.19	3.03
	Mauritius	0.96	2.39	0.74	1.00	5.55	6.39	9.29
	Mexico	1.22	0.51	0.80	1.36	2.25	2.04	1.43
	Mongolia	1.27	-2.68	2.83	-0.78	3.50	2.89	-0.93
	Morocco	1.17	1.26	5.73	2.34	2.57	4.12	2.45
	Mozambique	2.64	1.79	5.54	2.66	..	8.31	1.13
	Myanmar	0.83	2.95	-3.19	5.10	8.64	6.58	6.14
	Namibia	2.04	1.58	1.61	1.97	7.93	5.42	5.84
	Nepal	2.22	1.07	2.76	1.73	5.27	1.98	1.04
	Nicaragua	1.42	2.55	1.36	2.25	4.02	3.02	0.82
	Niger	3.54	4.33	0.98	2.67	1.77	-1.66	3.68
	Nigeria	2.45	2.14	0.32	2.42	2.85	2.00	2.61
	Oman	1.79	2.70	5.75	2.59	7.16	9.96	8.24
	Pakistan	2.34	3.03	1.45	2.75	3.67	5.18	1.93
	Panama	1.85	1.65	1.93	2.62	1.46	1.49	5.33
	Papua New Guinea	2.60	1.87	-1.99	0.98	5.94	6.02	1.89
	Peru	1.40	1.93	1.51	5.44	3.04	3.66	0.83
	Philippines	1.96	1.43	-0.13	1.89	1.71	-0.56	0.07
	Portugal	0.56	-0.08	3.63	3.23	1.60	0.43	-0.47
	Qatar	7.29	-3.37	1.55	8.39	4.73	6.32	..
	Rwanda	3.87	8.28	-1.13	4.48	-0.17	0.75	1.86
	Sao Tome & Prin.	1.73	3.11	..	3.56	3.85	5.83	2.10
	Saudi Arabia	2.56	1.27	3.35	2.42	4.81	6.95	10.57
	Senegal	2.66	1.38	4.55	1.66	5.62	5.14	-1.20
	Seychelles	0.59	-5.69	..	2.46	7.58	5.17	..
	Sierra Leone	3.31	3.24	9.12	4.17	4.06	9.82	1.16
	Singapore	1.67	4.07	-0.06	2.68	4.53	-1.21	1.68
	Solomon Islands	2.67	0.92	..	3.10	2.17	1.76	7.29
	Somalia	2.55	0.51	6.90	0.70	3.65	3.06	2.21
	Spain	1.16	1.28	1.31	3.63	3.69	3.27	1.87
	Sri Lanka	0.75	-1.58	3.03	1.57	3.13	5.06	0.70
	St. Kitts & Nevis	1.31	2.12	..	-1.74	7.50	11.52	1.05
	Sudan	2.18	2.21	6.58	2.41	12.22	10.54	2.00
	Suriname	1.34	-3.00	2.20	2.92	0.74	1.43	..
	Swaziland	1.12	-0.38	4.22	1.21	1.60	-2.06	1.35
	Syria	2.93	3.92	2.07	0.99	1.39	2.09	3.07
	Tajikistan	1.21	3.46	0.98	1.92	2.73	2.81	4.08
	Tanzania	2.69	2.50	0.10	3.01	7.97	9.47	1.75
	Thailand	1.00	0.33	1.36	2.95	5.20	4.29	2.53
	Timor-Leste	2.87	1.19	..	3.01	..	..	1.25
	Togo	2.85	4.24	-2.24	1.67	13.35	1.37	1.86
	Trinidad & Tobago	0.37	6.40	3.73	8.68	8.66	6.68	4.02
	Tunisia	0.93	1.35	2.75	2.57	2.12	3.36	3.00
	Turkey	1.42	-0.88	2.14	2.87	4.05	3.23	2.53
	Turkmenistan	1.42	9.35	3.10	9.52	14.41	4.70	5.53
	Uganda	3.24	2.95	-1.19	2.39	4.56	9.50	3.28
	United Arab Emir.	4.85	4.41	3.37	2.77	4.39	3.83	6.71
	Uzbekistan	1.25	3.76	-1.05	2.17	2.19	0.41	1.71
	Venezuela	1.85	1.56	0.15	0.11	1.29	1.01	1.66
	Vietnam	1.35	4.03	7.99	7.70	9.58	10.98	5.39
	Yemen	2.95	3.61	6.89	1.99	5.71	5.18	3.42
	Zambia	2.43	1.06	0.02	4.33	2.45	2.15	-0.17
	World	*1.28*	*0.82*	*0.17*	*2.35*	*2.61*	*2.68*	*1.90*
Mixed	Afghanistan	3.25	0.18	..	0.84	-4.44	-7.33	2.16
	Barbados	0.01	-2.60	..	-1.15	-1.13	2.77	2.25
	Eritrea	3.84	0.48	..	-1.70	-4.39	1.22	0.29
	Estonia	-0.41	-2.00	-1.02	..	1.53	1.03	2.11
	Latvia	-0.71	-1.80	-0.79	..	2.02	0.04	4.82
	St. Vincent & Gren.	0.11	-1.58	..	2.01	3.20	3.48	..
	Serbia	-0.48	-4.14	1.32	-3.32	0.84	1.81	..

Note: Data show annual percentage rates of change and stability classifications for the seven stock and flow indicators, calculated over the ten-year analysis period (1997–2007). Rate-of-change values are classified as *degrowth* (yellow), *stable* (green), and *growth* (red).

Biophysical Stability Index

The second method that I use to assess how close economies are to biophysical stability is to create a composite indicator (or index) from the seven indicators. As discussed in Section 3.3.4, there are dangers associated with aggregating individual indicators together to create an index. In such a process, information is inevitably lost, which may invite overly simplistic policy conclusions. However, the largest danger identified in Section 3.3.4—that of mixing social and environmental objectives in a single measure—is avoided here by creating a purely biophysical index in which the data are normalised as percentage rates of change. Moreover, the index adds value by providing a single measure of stability, thus making the results easier to interpret and communicate.

There are 137 countries for which clean data (i.e. standard error < 2%) are available for all seven indicators. In order to construct an indicator that measures how close economies are to biophysical stability, I take the arithmetic mean of the absolute values of the seven indicators. I refer to the resulting indicator as the Biophysical Stability Index (BSI). In developing this index, I explored a number of different methods of averaging the data (including taking the geometric and quadratic mean). These different methods did not significantly change the results of the analysis, however, and so I have opted to use the simplest approach (the arithmetic mean). This also means that each of the indicators is weighted equally in the index.

I chose to average the absolute values of the indicators as opposed to the raw values in order to create an index that does not allow negative rates of change on some indicators to cancel out positive rates of change on others. Unlike the multi-criteria approach used above, the BSI does not distinguish between growing and degrowing economies. It simply measures how close economies are to biophysical stability. This approach is consistent with the definition of a steady state economy, which aims for stability over growth or degrowth. The index produces continuous (as opposed to categorical) results and allows countries to be ranked. BSI results are shown in Table 7.4, and are ordered from countries with the most stable stocks and flows (lowest scores) to those with the least stable (highest scores).

It is worth noting that I also tested an index calculated from the raw values of the individual indicators (as opposed to their absolute values). The results obtained with this index mirrored those obtained with the BSI and multi-criteria approach, and I have therefore not included them here.

The results of the multi-criteria analysis and index-based analysis paint a similar picture. The top ten countries on the BSI list are all identified as stable economies using the multi-criteria method. Both methods identify Japan as having the most biophysically-stable economy in the world. Japan has the lowest BSI score and is the only country that achieves a stable classification on all seven indicators. Moreover, despite Japan's status as a major resource importer, it achieves stable scores on both of the indicators that account for trade (i.e. energy use and ecological footprint). Although Japan tops the list, seven of the top ten countries on the BSI list are in Europe. While Switzerland only achieved stability in five of the seven indicators using the multi-criteria method, it finishes second on the BSI list because these five rate-of-change indicators are all very close to zero.

The country furthest away from biophysical stability is Turkmenistan, followed by Vietnam and then Angola. The majority of countries at the bottom of the list (i.e. those with the highest rates of increase of stocks and flows), are relatively poor developing nations, although a few wealthier countries in the Middle East are also found near the bottom. China has one of the highest rates of biophysical growth in the world, finishing at number 125 on the list.

Table 7.4: The Biophysical Stability Index (BSI), calculated for 137 countries over the ten-year analysis period (1997–2007).

	Country	Change in Stocks (%/year)			Change in Flows (%/year)				BSI
		Pop.	Live.	Lights	Mat.	Energy	CO_2	EF	
1	Japan	0.11	-0.72	-0.96	-0.03	0.49	0.15	-0.26	0.39
2	Switzerland	0.61	-0.15	-0.11	0.40	0.09	-0.36	1.39	0.44
3	France	0.58	-0.87	-0.13	0.31	0.85	-0.08	0.53	0.48
4	Poland	-0.12	-0.21	1.10	0.59	-0.40	-0.64	0.50	0.51
5	Denmark	0.32	0.08	-1.76	0.82	-0.60	-0.76	0.01	0.62
6	Romania	-0.46	-1.05	0.53	0.39	-0.55	-0.85	0.57	0.63
7	New Zealand	1.12	-0.05	-0.64	1.02	1.02	0.78	-0.19	0.69
8	United States	1.06	0.15	-0.95	0.51	0.64	0.64	0.98	0.70
9	Italy	0.42	-1.14	0.62	0.07	1.08	0.74	1.12	0.74
10	Hungary	-0.26	-0.92	-1.43	1.81	0.99	-0.70	0.03	0.88
11	Paraguay	2.01	0.24	-0.41	0.97	0.37	-0.70	-1.48	0.88
12	Germany	0.06	-1.11	-1.74	-2.38	0.14	-1.02	0.03	0.93
13	Kyrgyzstan	1.18	1.49	-0.96	0.78	-0.92	1.27	0.18	0.97
14	Belgium	0.40	-2.10	-2.00	0.05	0.45	-1.22	0.93	1.02
15	Netherlands	0.51	-1.92	-1.79	0.24	1.51	-0.08	1.14	1.03
16	Colombia	1.62	0.52	-1.48	2.03	0.79	-0.35	0.62	1.06
17	United Kingdom	0.43	-1.81	-1.44	-2.37	-0.05	-0.09	1.22	1.06
18	Uruguay	0.15	0.91	-2.51	2.64	0.06	0.96	-0.21	1.06
19	Lebanon	1.46	1.53	-1.15	1.06	-1.57	-0.49	0.26	1.07
20	Norway	0.67	-0.42	-0.05	0.71	0.49	3.05	2.19	1.08
21	Venezuela	1.85	1.56	0.15	0.11	1.29	1.01	1.66	1.09
22	South Africa	1.39	-0.26	0.90	0.99	2.27	1.53	-0.36	1.10
23	Philippines	1.96	1.43	-0.13	1.89	1.71	-0.56	0.07	1.11
24	Austria	0.46	-1.31	0.36	1.33	1.42	1.76	1.46	1.16
25	Cuba	0.20	-0.99	2.38	-1.50	-1.70	0.56	0.88	1.17
26	Cote d'Ivoire	2.31	1.09	1.84	1.08	1.10	-0.51	0.28	1.17
27	Australia	1.21	-0.75	0.00	2.29	2.08	1.14	0.74	1.17
28	Korea, North	0.64	3.61	0.48	1.82	0.99	0.24	1.09	1.27
29	Lithuania	-0.58	-1.61	-0.55	3.46	0.77	-0.08	1.99	1.29
30	Czech Republic	-0.05	-3.23	-1.47	1.15	1.49	-0.20	1.50	1.30
31	Bulgaria	-0.70	-2.61	1.81	1.23	0.42	0.13	2.23	1.30
32	Canada	1.00	1.40	-2.10	0.51	1.30	1.68	1.36	1.34
33	Mexico	1.22	0.51	0.80	1.36	2.25	2.04	1.43	1.37
34	Argentina	1.00	0.44	1.21	1.43	2.44	2.67	-0.63	1.40
35	Portugal	0.56	-0.08	3.63	3.23	1.60	0.43	-0.47	1.43
36	Greece	0.26	-0.10	2.33	1.57	2.09	1.54	2.57	1.49
37	Moldova	-1.58	-3.29	-2.94	-0.65	0.37	-0.26	-1.50	1.51
38	Congo (Dem. Rep.)	2.89	-2.05	1.79	2.23	0.86	0.17	0.72	1.53
39	Croatia	-0.40	0.98	2.10	2.44	1.27	2.17	1.65	1.57
40	Israel	1.99	1.15	0.09	2.44	2.23	0.28	2.91	1.58
41	Belarus	-0.48	-1.90	-2.36	2.94	1.61	1.33	-0.51	1.59
42	Macedonia	0.27	-2.64	0.16	-1.22	-0.64	-0.57	5.69	1.60
43	Jamaica	0.75	-2.29	-0.93	1.51	1.80	2.23	1.70	1.60
44	Finland	0.27	-1.31	-2.31	2.06	1.23	1.44	2.62	1.61
45	Sweden	0.37	-1.44	-3.24	3.58	-0.56	-0.62	1.46	1.61
46	Slovenia	0.17	-0.50	-0.46	6.28	1.01	-0.17	2.88	1.64
47	Swaziland	1.12	-0.38	4.22	1.21	1.60	-2.06	1.35	1.71
48	Russia	-0.44	-3.46	-1.43	3.43	1.60	0.78	1.12	1.75
49	Uzbekistan	1.25	3.76	-1.05	2.17	2.19	0.41	1.71	1.79
50	Korea, South	0.54	1.03	0.19	2.41	3.29	2.29	2.85	1.80
51	Zambia	2.43	1.06	0.02	4.33	2.45	2.15	-0.17	1.80
52	Brazil	1.34	2.79	0.59	3.66	2.28	1.30	0.81	1.82
53	Slovakia	0.04	-3.94	-3.78	1.81	0.49	-0.89	2.08	1.86
54	El Salvador	0.43	2.75	1.29	0.71	3.43	1.55	2.96	1.87
55	Ukraine	-0.83	-6.14	-2.49	2.53	0.76	0.15	0.87	1.97
56	Dominican Rep.	1.56	1.75	0.25	3.05	4.77	1.09	1.36	1.98
57	Ecuador	1.23	-0.68	2.47	1.66	3.15	4.43	0.28	1.99
58	Guyana	0.11	3.12	-1.98	-4.27	2.07	-1.06	-1.29	1.99
59	Zimbabwe	0.22	-1.03	-3.88	-2.01	-1.96	-4.69	-0.87	2.09
60	Mauritania	2.75	2.66	1.49	1.67	-1.87	-1.19	3.03	2.10

Country		Change in Stocks (%/year)			Change in Flows (%/year)				BSI
		Pop.	Live.	Lights	Mat.	Energy	CO_2	EF	
61	Nigeria	2.45	2.14	0.32	2.42	2.85	2.00	2.61	2.11
62	Mongolia	1.27	-2.68	2.83	-0.78	3.50	2.89	-0.93	2.13
63	Kenya	2.65	1.54	-0.95	1.41	4.53	2.38	1.55	2.15
64	Cameroon	2.36	1.97	-0.09	1.41	1.87	5.08	2.30	2.15
65	Luxembourg	1.23	-1.06	-1.46	0.15	4.45	4.83	2.14	2.19
66	Chile	1.14	0.61	2.25	3.92	2.96	1.86	2.59	2.19
67	Nicaragua	1.42	2.55	1.36	2.25	4.02	3.02	0.82	2.21
68	India	1.65	-0.17	0.71	2.71	4.54	4.15	1.59	2.22
69	Ireland	1.78	0.16	1.95	4.54	3.14	1.62	2.45	2.24
70	Sri Lanka	0.75	-1.58	3.03	1.57	3.13	5.06	0.70	2.26
71	Singapore	1.67	4.07	-0.06	2.68	4.53	-1.21	1.68	2.27
72	Costa Rica	2.00	-1.92	0.70	1.26	4.51	4.72	0.93	2.29
73	Nepal	2.22	1.07	2.76	1.73	5.27	1.98	1.04	2.29
74	Tunisia	0.93	1.35	2.75	2.57	2.12	3.36	3.00	2.30
75	Spain	1.16	1.28	1.31	3.63	3.69	3.27	1.87	2.32
76	Panama	1.85	1.65	1.93	2.62	1.46	1.49	5.33	2.33
77	Syria	2.93	3.92	2.07	0.99	1.39	2.09	3.07	2.35
78	Turkey	1.42	-0.88	2.14	2.87	4.05	3.23	2.53	2.44
79	Tajikistan	1.21	3.46	0.98	1.92	2.73	2.81	4.08	2.46
80	Iraq	2.80	0.85	3.90	-0.13	1.47	4.26	4.17	2.51
81	Indonesia	1.33	1.47	0.88	3.94	4.24	5.02	0.78	2.52
82	Thailand	1.00	0.33	1.36	2.95	5.20	4.29	2.53	2.52
83	Haiti	1.74	1.31	-3.09	0.99	2.88	6.53	1.25	2.54
84	Peru	1.40	1.93	1.51	5.44	3.04	3.66	0.83	2.54
85	Lesotho	1.23	1.51	3.61	1.18	5.12	2.92	-2.45	2.58
86	Guinea	1.97	5.67	0.30	3.55	1.70	1.01	3.92	2.59
87	Botswana	1.47	-1.42	5.55	2.73	3.08	3.58	0.32	2.59
88	Cyprus	1.25	0.75	1.85	5.10	2.92	2.47	3.89	2.60
89	Ghana	2.34	2.69	-0.12	3.47	2.70	3.86	3.22	2.63
90	Niger	3.54	4.33	0.98	2.67	1.77	-1.66	3.68	2.66
91	Madagascar	2.92	-1.13	-1.87	1.03	7.14	1.61	3.00	2.67
92	Algeria	1.49	1.71	2.39	3.27	2.67	3.57	4.18	2.76
93	Somalia	2.55	0.51	6.90	0.70	3.65	3.06	2.21	2.80
94	Morocco	1.17	1.26	5.73	2.34	2.57	4.12	2.45	2.81
95	Malawi	3.01	3.08	0.66	3.40	4.44	2.54	2.70	2.83
96	Pakistan	2.34	3.03	1.45	2.75	3.67	5.18	1.93	2.91
97	Bolivia	2.00	2.64	1.91	2.58	6.49	2.86	1.96	2.92
98	Rwanda	3.87	8.28	-1.13	4.48	-0.17	0.75	1.86	2.94
99	Burundi	2.35	4.88	0.65	3.42	-0.54	-6.91	2.18	2.99
100	Libya	2.06	2.29	5.40	2.68	3.06	1.78	3.71	3.00
101	Papua New Guinea	2.60	1.87	-1.99	0.98	5.94	6.02	1.89	3.04
102	Azerbaijan	0.82	3.78	2.68	8.64	1.48	1.39	3.13	3.13
103	Egypt	1.91	2.78	3.09	2.82	4.72	4.71	1.99	3.15
104	Senegal	2.66	1.38	4.55	1.66	5.62	5.14	-1.20	3.17
105	Jordan	2.67	0.76	2.46	3.26	4.80	4.71	4.33	3.29
106	Bangladesh	1.71	1.48	-0.35	3.03	7.40	6.60	2.73	3.33
107	Mali	2.30	4.66	6.33	4.06	2.29	1.01	3.39	3.43
108	Bosnia and Herz.	1.02	3.46	1.82	5.02	5.33	6.73	1.29	3.52
109	Kuwait	4.39	3.54	1.82	3.43	3.85	3.83	3.89	3.54
110	Burkina Faso	3.25	4.53	3.89	3.79	2.24	5.69	1.67	3.58
111	Armenia	-0.17	2.90	5.77	5.15	3.98	3.98	3.20	3.59
112	Guatemala	2.47	2.72	3.98	2.86	4.84	4.85	3.43	3.59
113	Mauritius	0.96	2.39	0.74	1.00	5.55	6.39	9.29	3.76
114	Laos	1.83	1.97	5.02	2.29	6.09	7.51	1.63	3.76
115	Namibia	2.04	1.58	1.61	1.97	7.93	5.42	5.84	3.77
116	Iran	1.19	0.81	4.33	3.85	6.39	5.43	4.53	3.79
117	Uganda	3.24	2.95	-1.19	2.39	4.56	9.50	3.28	3.87
118	Tanzania	2.69	2.50	0.10	3.01	7.97	9.47	1.75	3.93
119	Togo	2.85	4.24	-2.24	1.67	13.35	1.37	1.86	3.94
120	Yemen	2.95	3.61	6.89	1.99	5.71	5.18	3.42	4.25

Country		Change in Stocks (%/year)			Change in Flows (%/year)				BSI
		Pop.	Live.	Lights	Mat.	Energy	CO_2	EF	
121	United Arab Emir.	4.85	4.41	3.37	2.77	4.39	3.83	6.71	4.33
122	Honduras	2.06	4.00	5.12	3.69	5.90	7.37	2.73	4.41
123	Saudi Arabia	2.56	1.27	3.35	2.42	4.81	6.95	10.57	4.56
124	Ethiopia	2.67	3.68	7.80	3.57	9.24	2.87	2.17	4.57
125	China	0.73	0.49	4.99	5.87	9.12	7.75	3.46	4.63
126	Myanmar	0.83	2.95	-3.19	5.10	8.64	6.58	6.14	4.77
127	Cambodia	1.77	1.81	6.25	2.86	9.05	8.78	3.22	4.82
128	Albania	0.18	-1.44	6.20	6.09	3.88	10.55	5.49	4.83
129	Sierra Leone	3.31	3.24	9.12	4.17	4.06	9.82	1.16	4.98
130	Chad	3.48	2.85	4.66	2.48	3.10	16.83	2.78	5.17
131	Benin	3.30	3.18	1.74	2.27	11.30	12.36	3.00	5.31
132	Sudan	2.18	2.21	6.58	2.41	12.22	10.54	2.00	5.45
133	Oman	1.79	2.70	5.75	2.59	7.16	9.96	8.24	5.46
134	Trinidad & Tobago	0.37	6.40	3.73	8.68	8.66	6.68	4.02	5.50
135	Angola	2.94	1.38	6.50	5.79	8.27	13.24	3.80	5.99
136	Vietnam	1.35	4.03	7.99	7.70	9.58	10.98	5.39	6.72
137	Turkmenistan	1.42	9.35	3.10	9.52	14.41	4.70	5.53	6.86

Note: Data show annual percentage rates of change for the seven stock and flow indicators, as well as the Biophysical Stability Index (BSI), calculated over the ten-year analysis period (1997–2007).

7.1.2. Scale Indicator

A steady state economy is not just an economy where stocks and flows are stable over time. It is also an economy where the level of flows is within the carrying capacity of ecosystems. The indicator of scale used in the Biophysical Accounts is the ratio of per capita ecological footprint to a fair earthshare (FES), calculated for the year 2007. I have placed economies into three categories based on their performance on this indicator: small, optimal, and large (Table 7.5).

Table 7.5: The scale criteria used to categorise economies.

Category	Criteria	Number of Countries	% of People
Small	< 0.8 FES	48	38.0
Optimal	0.8 to 1.2 FES	34	10.4
Large	> 1.2 FES	98	51.6

Roughly half of the global population live in countries with an ecological footprint above a fair earthshare, while the other half live in countries where the footprint is at or below a fair earthshare. A relatively small number of people (10% of the global population) live in countries where the footprint is roughly equal to a fair earthshare. The countries with the lowest per capita ecological footprint tend to be relatively poor countries in Africa and Asia, while those with the highest footprint tend to be relatively wealthy countries in the Middle East and Europe (Table 7.6). There is a diverse mix of countries with a per capita ecological footprint close to a fair earthshare, although the majority are in Africa, Latin America, and Western Asia.

Between the beginning and end of the analysis period (i.e. between 1997 and 2007), the distribution of countries among the three categories (small, optimal, and large) changed substantially. In 1997, only 28% of the global population lived in countries with an ecological footprint above a fair earthshare (compared to 52% in 2007), while 72% lived in countries where the footprint was at or below a fair earthshare (compared to 48% in 2007). These results suggest that a remarkable shift away from sustainability has occurred over only a ten-year time period.

Table 7.6: The Biophysical Accounts: scale indicator.

Class	Country	EF:FES
Small	Timor-Leste	0.24
	Bangladesh	0.35
	Afghanistan	0.35
	Haiti	0.38
	Malawi	0.41
	Congo (Dem. Rep.)	0.42
	Pakistan	0.43
	Mozambique	0.43
	Eritrea	0.50
	Burundi	0.51
	Zambia	0.51
	India	0.51
	Yemen	0.53
	Guinea-Bissau	0.54
	Congo	0.54
	Togo	0.55
	Tajikistan	0.56
	Angola	0.56
	Cote d'Ivoire	0.57
	Rwanda	0.57
	Cambodia	0.58
	Cameroon	0.59
	Sierra Leone	0.59
	Lesotho	0.60
	Senegal	0.61
	Ethiopia	0.62
	Kenya	0.62
	Cape Verde	0.66
	Tanzania	0.66
	Indonesia	0.68
	Sri Lanka	0.68
	Morocco	0.68
	Benin	0.69
	Kyrgyzstan	0.70
	Zimbabwe	0.70
	Liberia	0.71
	Laos	0.72
	Sao Tome & Prin.	0.72
	Philippines	0.73
	Burkina Faso	0.74
	Central African Rep.	0.74
	Korea, North	0.74
	Iraq	0.76
	Moldova	0.78
	Vietnam	0.79
	Gabon	0.79
	Somalia	0.80
	Comoros	0.80
Optimal	Nigeria	0.81
	Dominican Rep.	0.83
	Vanuatu	0.83
	Swaziland	0.84
	Syria	0.85
	Uganda	0.86
	Peru	0.86
	Nicaragua	0.87
	Djibouti	0.88
	Algeria	0.89
	Egypt	0.93
	Guinea	0.93
Optimal (continued)	Chad	0.97
	Sudan	0.97
	Uzbekistan	0.98
	Armenia	0.98
	Ghana	0.98
	Guatemala	0.99
	Myanmar	1.00
	Madagascar	1.01
	Georgia	1.02
	Cuba	1.04
	Colombia	1.05
	Azerbaijan	1.05
	Ecuador	1.06
	Bahamas	1.06
	Tunisia	1.06
	Albania	1.07
	Honduras	1.07
	Jamaica	1.08
	Mali	1.08
	El Salvador	1.14
	Jordan	1.15
	Papua New Guinea	1.20
Large	Namibia	1.21
	Fiji	1.24
	China	1.24
	Solomon Islands	1.28
	South Africa	1.30
	Niger	1.32
	Thailand	1.33
	Guyana	1.33
	Tonga	1.33
	Serbia	1.34
	Bolivia	1.44
	Argentina	1.46
	Mauritania	1.46
	Grenada	1.48
	Suriname	1.48
	Botswana	1.50
	Iran	1.51
	Costa Rica	1.51
	Turkey	1.51
	Romania	1.52
	Bosnia & Herz.	1.54
	Samoa	1.59
	Panama	1.61
	St. Lucia	1.62
	Venezuela	1.62
	Ukraine	1.63
	Lebanon	1.63
	Brazil	1.63
	Dominica	1.66
	Hungary	1.68
	Mexico	1.68
	Brunei	1.71
	Libya	1.71
	Trinidad & Tobago	1.73
	Paraguay	1.79
	St. Kitts & Nevis	1.79
	Chile	1.82
	Gambia	1.93
Large (continued)	Antigua & Barbuda	1.98
	Nepal	2.00
	Belize	2.04
	Kiribati	2.09
	Croatia	2.10
	Belarus	2.13
	Turkmenistan	2.20
	Slovakia	2.28
	Bulgaria	2.28
	Mauritius	2.39
	Poland	2.44
	Russia	2.47
	Nauru	2.47
	Portugal	2.50
	Bhutan	2.51
	Kazakhstan	2.55
	Lithuania	2.62
	Barbados	2.62
	Japan	2.65
	Israel	2.70
	Malaysia	2.73
	Korea, South	2.73
	New Zealand	2.74
	United Kingdom	2.74
	St. Vincent & Gren.	2.74
	Oman	2.80
	Italy	2.80
	France	2.81
	Switzerland	2.81
	Germany	2.85
	Uruguay	2.88
	Saudi Arabia	2.88
	Austria	2.97
	Slovenia	2.97
	Singapore	2.99
	Greece	3.02
	Spain	3.04
	Mongolia	3.10
	Norway	3.12
	Latvia	3.16
	Macedonia	3.18
	Czech Republic	3.21
	Sweden	3.30
	Finland	3.45
	Netherlands	3.47
	Ireland	3.53
	Kuwait	3.55
	Malta	3.63
	Iceland	3.70
	Australia	3.84
	Cyprus	3.85
	Canada	3.93
	Estonia	4.42
	United States	4.48
	Belgium	4.49
	Denmark	4.63
	Luxembourg	5.26
	Bahrain	5.63
	Qatar	5.89
	United Arab Emir.	5.99

Note: Data show the ratio of per capita ecological footprint to a fair earthshare for the year 2007. Values are classified as *small* (yellow), *optimal* (green), and *large* (red).

7.1.3. Proximity to a Steady State Economy

Having calculated indicators of both stability and scale, it is now possible to assess whether there are any countries that are close to a steady state economy. In Table 7.7, I show the scale indicator for the 22 countries that were classified as biophysically "stable" using the multi-criteria approach. The data reveal that the majority of countries that have achieved biophysical stability have done so at a level of resource use that is substantially above a fair earthshare. While we might refer to these as "stable economies", they are not "steady state economies" because their level of resource use is beyond what is globally sustainable. There are only a handful of countries that achieve something approaching both biophysical stability and optimal scale. These include Colombia, Cuba, Kyrgyzstan, Romania, and South Africa.

Table 7.7: Biophysical scale of economies classified as biophysically stable.

		Change in Stocks (% per year)			Change in Flows (% per year)				Scale
	Country	Pop.	Live.	Lights	Mat.	Energy	CO_2	EF	EF:FES
Stable	Belgium	0.40	-2.10	-2.00	0.05	0.45	-1.22	0.93	4.49
	Colombia	1.62	0.52	-1.48	2.03	0.79	-0.35	0.62	1.05
	Cuba	0.20	-0.99	2.38	-1.50	-1.70	0.56	0.88	1.04
	Denmark	0.32	0.08	-1.76	0.82	-0.60	-0.76	0.01	4.63
	France	0.58	-0.87	-0.13	0.31	0.85	-0.08	0.53	2.81
	Hungary	-0.26	-0.92	-1.43	1.81	0.99	-0.70	0.03	1.68
	Italy	0.42	-1.14	0.62	0.07	1.08	0.74	1.12	2.80
	Japan	0.11	-0.72	-0.96	-0.03	0.49	0.15	-0.26	2.65
	Kyrgyzstan	1.18	1.49	-0.96	0.78	-0.92	1.27	0.18	0.70
	Macedonia	0.27	-2.64	0.16	-1.22	-0.64	-0.57	5.69	3.18
	Malta	0.63	0.07	..	1.67	0.44	0.69	-0.37	3.63
	Nauru	0.10	0.15	..	..	0.88	0.48	-0.54	2.47
	New Zealand	1.12	-0.05	-0.64	1.02	1.02	0.78	-0.19	2.74
	Norway	0.67	-0.42	-0.05	0.71	0.49	3.05	2.19	3.12
	Paraguay	2.01	0.24	-0.41	0.97	0.37	-0.70	-1.48	1.79
	Poland	-0.12	-0.21	1.10	0.59	-0.40	-0.64	0.50	2.44
	Romania	-0.46	-1.05	0.53	0.39	-0.55	-0.85	0.57	1.52
	Slovenia	0.17	-0.50	-0.46	6.28	1.01	-0.17	2.88	2.97
	South Africa	1.39	-0.26	0.90	0.99	2.27	1.53	-0.36	1.30
	Switzerland	0.61	-0.15	-0.11	0.40	0.09	-0.36	1.39	2.81
	United States	1.06	0.15	-0.95	0.51	0.64	0.64	0.98	4.48
	Uruguay	0.15	0.91	-2.51	2.64	0.06	0.96	-0.21	2.88

Note: Change in stocks/flows data measure annual percentage rates of change, calculated over the ten-year analysis period (1997–2007). Scale data measure the ratio of per capita ecological footprint to a fair earthshare for the year 2007. Rate-of-change values are classified as *degrowth* (yellow), *stable* (green), and *growth* (red). Scale values are classified as *small* (yellow), *optimal* (green), and *large* (red).

In Section 5.9, I suggested a method of plotting the data in the Biophysical Accounts to show how close economies are to a steady state economy and whether they are moving closer to, or further away from, such an economy. I refer to this method as the "pathway approach". The approach interprets the three types of indicators in the Biophysical Accounts (i.e. change in stocks, changes in flows, and scale) as orthogonal dimensions that form a three-dimensional space. A point for each country may be plotted in this space, based on the values of its individual indicators.

Although the pathway approach is appealing conceptually, there are some difficulties with implementing it in practice. The Biophysical Accounts contain three separate indicators that measure the rate of change of stocks, four separate indicators that measure the rate of change of flows, and a single indicator that measures the scale of flows in relation to a sustainability threshold. However, the pathway approach requires a single indicator for each category, not eight separate indicators. Thus it is either necessary to aggregate the seven rate-of-change indicators into two composite indicators (one for change in stocks and one for change in flows), or to choose a single "representative" indicator from each of these two sets to complement the single indicator of scale.

While using all of the data to construct two composite indicators has a certain appeal, the results would be difficult to interpret. For example, if the ecological footprint for a country was increasing at 5% per year, but the other three flow indicators were decreasing at 5% per year, an aggregated flow indicator calculated by averaging the four indicators might indicate that the country was experiencing degrowth of 2.5% per year. If the country had a footprint that was twice a fair earthshare, the pathway analysis would indicate that the country was experiencing "desirable degrowth", even if its ecological footprint was still increasing. It's questionable whether the pathway analysis would contribute to a better understanding of the data in this case.

To make the results easier to interpret, I therefore choose one indicator from each of the three categories to demonstrate the pathway approach. To complement the single scale indicator (i.e. the ratio of per capita ecological footprint to a fair earthshare), I choose two indicators that may be simply and meaningfully compared to this indicator. These are the rate of change of per capita ecological footprint (a change-in-flows measure), and the rate of change of population (a change-in-stocks measure).

I present the results using a two-dimensional plot, with the third dimension shown by the colour of the point (Figure 7.4). I use colour-coded groups for the values of the third indicator, as opposed to a continuous colour scheme, to make the results a bit easier to interpret. The boundaries used to create the groups are the same as in the multi-criteria analysis (i.e. -0.5% and +0.5% for the rate of change of population, -1% and +1% for the rate of change of per capita ecological footprint, and 0.8 and 1.2 for the ratio of per capita ecological footprint to a fair earthshare).

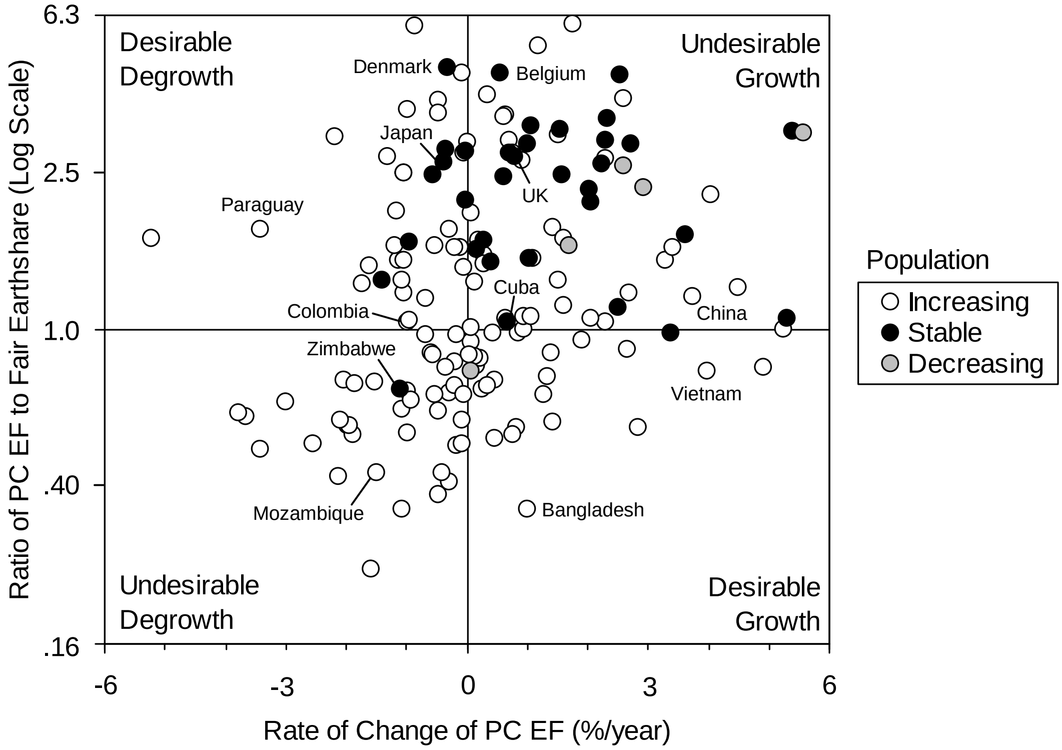

Figure 7.4: The rate of change of per capita ecological footprint vs. biophysical scale (as measured by the ratio of per capita ecological footprint to a fair earthshare). The rate of change of population is shown as the third dimension. N = 168.

The results suggest a somewhat uneven distribution of countries between the four quadrants (i.e. undesirable growth, desirable degrowth, undesirable degrowth, and desirable growth). In general, there are more countries experiencing *undesirable* growth/degrowth (106 in total), than countries experiencing *desirable* growth/degrowth (62 in total). In other words, more countries are moving away from a fair earthshare than towards it.

When viewing the results in Figure 7.4 it is important to bear in mind that the ecological footprint and its rate of change are both measured in per capita terms. If a country has a stable per capita ecological footprint, but a growing population (as many countries do), then the country's total ecological footprint will still increase over time. For a country to be classified as a steady state economy based on the three indicators in the pathway analysis, it needs to be near the origin in all three dimensions. There is only one country (Cuba) that satisfies these criteria.

Many of the countries in the undesirable degrowth quadrant in Figure 7.4 (e.g. Mozambique, Sierra Leone, and Tanzania) are countries where total ecological footprint is actually increasing, but at a lower rate than population is increasing. Per capita resource use is falling in these countries, while total ecological impact is increasing—a highly undesirable combination.

Countries located in the desirable growth and desirable degrowth quadrants are moving closer to a fair earthshare. Assuming that the current rates of change of per capita ecological footprint experienced in these countries continue, it is possible to estimate the amount of time t required for these countries to reach a fair earthshare using the formula:

$$t = -\frac{\log y}{\log(1+x)}, \qquad (7.2)$$

where x is the fractional rate of change of per capita ecological footprint, and y is the ratio of per capita ecological footprint to a fair earthshare.

The results of this simple calculation (see Table 7.8) suggest that many of the countries experiencing desirable growth will reach a fair earthshare very soon (if they have not already, since the results are referenced to the year 2007). However, it will take decades for most of the countries experiencing desirable degrowth to reach a fair earthshare, given their low rates of degrowth and large distances from this point.

It is also worth noting that as long as global population continues to increase, the size of a fair earthshare will decrease over time. Thus the target of achieving a fair earthshare is really a moving target. This effectively lengthens the amount of time required for countries to degrow to optimal scale, and shortens the amount of time required for countries to grow to optimal scale. Moreover, some of the countries experiencing desirable degrowth (e.g. Colombia) are only experiencing degrowth because their population is increasing faster than their total ecological footprint (thus leading to a decline in per capita ecological footprint). The results of the pathway approach should therefore be interpreted cautiously.

Table 7.8: Time required for countries experiencing desirable growth or degrowth to reach a fair earthshare, given their current rates of change of per capita ecological footprint.

Desirable Degrowth	
Country	Time to FES (Years)
Colombia	5
Ecuador	6
Brunei Darussalam	10
South Africa	15
Paraguay	17
Fiji	20
Guyana	20
Argentina	23
Papua New Guinea	26
Tonga	27
Botswana	36
Costa Rica	39
Lebanon	41
Mongolia	52
Dominica	54
Nepal	60
New Zealand	77
Bhutan	87
Portugal	89
Brazil	93
Malta	130
Nauru	166
Qatar	206
St. Kitts & Nevis	207
Japan	260
Venezuela	263
Kuwait	264
Australia	290
Uruguay	297
St. Lucia	416
Denmark	492
Bolivia	962
United States	2123
France	2141
Belarus	2672
Germany	3554

Desirable Growth	
Country	Time to FES (Years)
Armenia	1
Guatemala	1
Ghana	2
Guinea	4
Algeria	4
Comoros	5
Uzbekistan	5
Vietnam	6
Djibouti	10
Tajikistan	21
Iraq	21
Morocco	30
Cambodia	39
Korea, North	66
Angola	69
Swaziland	75
Congo	80
Egypt	89
Sao Tome & Prin.	94
Bangladesh	106
Syria	121
Liberia	136
Nigeria	138
Yemen	141
Moldova	302
Uganda	355

7.1.4. Relationship between Indicators

Besides indicating which countries are closer to a steady state economy, and which are further away, the data in the Biophysical Accounts may also be used to build a better understanding of economic systems. It is particularly informative to look at the degree of correlation between the indicators. Doing so allows us to investigate whether there is any relationship between change in stocks and change in flows, for example, or between the scale of economies and their biophysical growth rates. Moreover, if two or more indicators are highly correlated, then it may only be necessary to measure one of them to adequately categorise countries (thus simplifying the required system of accounts for a SSE).

There are two statistical tests commonly used to measure the correlation between variables: Spearman's rank correlation (Spearman's ρ), and Pearson's product-moment correlation (Pearson's r). Pearson's r measures the strength of the linear dependence between two variables. It is a high-power statistical test, but it requires that the data follow a normal distribution. Spearman's ρ does not require that the data follow a normal distribution, and it measures the strength of any monotonic relationship. However, it is a lower-power statistical test because it only uses rank information. Both tests measure correlation on a scale from -1 (perfect negative correlation) to +1 (perfect positive correlation).

This chapter contains a number of correlation analyses. For each of these analyses, I have conducted both statistical tests, calculating Spearman's ρ on the raw data, and Pearson's r on data that have been transformed to approximate a normal distribution. In general, the two tests produce almost identical results. For simplicity, I therefore present the results for Spearman's test. This saves reporting the transformations that are required in order to use Pearson's test, the inclusion of which would distract from the main results of the chapter.

I calculate Spearman's ρ using data for the 137 countries for which all seven rate-of-change indicators are available. The test shows that there is a moderate positive correlation between all of the biophysical rate-of-change indicators (Table 7.9). The strongest correlations are between growth in energy use and growth in CO_2 emissions, growth in night-time lighting and growth in CO_2 emissions, and growth in population and growth in livestock numbers. The weakest correlation is between growth in population and growth in material extraction.

Table 7.9: Correlation between the rate-of-change indicators in the Biophysical Accounts (Spearman's ρ).

	ΔPop	ΔLive	ΔLights	ΔMat	ΔEnergy	ΔCO_2	ΔEF
ΔPopulation	1	**.588**	.351	.231	.470	.418	.322
ΔLivestock	**.588**	1	.335	.435	.444	.357	.426
ΔLights	.351	.335	1	.386	.492	**.541**	.387
ΔMaterials	.231	.435	.386	1	.452	.411	.439
ΔEnergy	.470	.444	.492	.452	1	**.803**	.439
ΔCO_2	.418	.357	**.541**	.411	**.803**	1	.458
ΔEF	.322	.426	.387	.439	.439	.458	1

Note: The strongest correlations ($|\rho| \geq .5$) are shown in bold. All correlations are significant at $p < .001$, with the exception of ΔPopulation/ΔMaterials which is only significant at $p < .01$. $N = 137$.

In general, the correlation among the rates of change of flows is greater than the correlation among the rates of change of stocks. The correlation between the rates of change of stocks and the rates of change of flows is rather low. The rate-of-change indicator that is most correlated with all other rate-of-change indicators is energy use.

In order to investigate whether there is any relationship between the scale of economies and their biophysical growth rates, I also calculate the correlation between the indicator of scale (the ratio of per capita ecological footprint to a fair earthshare) and the seven rate-of-change indicators in the Biophysical Accounts. The test shows a weak to moderate negative correlation between the scale of an economy and the rate of change of several biophysical indicators (Table 7.10).

Table 7.10: Correlation between the indicator of scale (the ratio of per capita ecological footprint to a fair earthshare) and the rate-of-change indicators in the Biophysical Accounts (Spearman's ρ).

	ΔPop	ΔLive	ΔLights	ΔMat	ΔEnergy	ΔCO_2	ΔEF
Ratio of PC EF to FES	-.484 ***	-.419 ***	-.250 **	-.184 *	-.311 ***	-.340 ***	-.024 ns

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. $N = 137$.

The strongest negative correlation is between scale and population growth (Figure 7.5), while there is no correlation between scale and the rate of change of ecological footprint or material extraction. The results imply that larger-scale economies grow more slowly (in biophysical terms) than smaller-scale economies. This suggests a gradual tendency towards biophysical stability in larger-scale economies, although it is worth stressing that the relationship is not particularly strong, and it does not hold for all of the indicators.

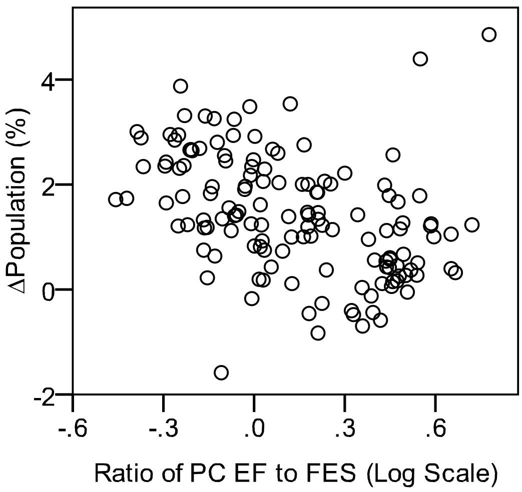

Figure 7.5: The relationship between the rate of change of population and biophysical scale (as measured by the ratio of per capita ecological footprint to a fair earthshare).

Although it is not one of the indicators included in the Biophysical Accounts, I also calculate the correlation between the rate of change of GDP and the rates of change of the seven biophysical indicators. GDP data with a standard error less than 2% are available for 132 of the 137 countries for which all seven biophysical indicators are available (see Table A.3 in the Appendix for the GDP data).

The test shows that there is a moderate correlation between GDP growth and growth in each of the biophysical indicators, with the exception of population growth, which is not correlated with GDP growth (Table 7.11). Interestingly, the strongest correlation is between GDP growth and growth in domestic material extraction.

Table 7.11: Correlation between the rate of change of GDP and the rate-of-change indicators in the Biophysical Accounts (Spearman's ρ).

	ΔPop	ΔLive	ΔLights	ΔMat	ΔEnergy	ΔCO_2	ΔEF
ΔGDP	.156 ns	.256 **	.450 ***	**.568** ***	.412 ***	.470 ***	.397 ***

Note: *** $p < .001$, ** $p < .01$, 'ns' not significant. The strongest correlations ($|\rho| \geq .5$) are shown in bold. $N = 132$.

7.2. *The Social Accounts*

7.2.1. Country Results

One of the research questions investigated in this thesis is whether countries with biophysically stable economies are better or worse places to live than countries with growing or degrowing economies. To answer this question it is necessary to investigate whether there is a relationship between the rate of change of biophysical indicators and the absolute level of social indicators. For this reason, I do not calculate the rate of change of the indicators in the Social Accounts (as I do with the indicators in the Biophysical Accounts). The only exception is the inflation rate, which is by definition a rate of change.

Of the 181 countries included in the analysis, social data are available for between 48 and 181 depending on the individual indicator (Table 7.12). In general, data are widely available for all indicators except for the poverty indicator (which is only available for 131 relatively poor countries) and the working time indicator (which is only available for 48 relatively wealthy countries).

I have attempted to calculate the social indicators using data covering the same ten-year period (1997–2007) as the biophysical data. For some indicators, data are not available for this exact period. In these cases, I use data for the closest corresponding period. If data are available for multiple years within the analysis period, then I generally calculate the average value over the period. Since the inflation indicator is a rate of change (of consumer prices), I calculate it using the same method of log-linear regression that I use for the biophysical rate-of-change indicators (see Section 7.1.1).

Table 7.12: Data availability for the indicators in the Social Accounts.

Indicator	Period	Calculation Method	Number of Countries
Life satisfaction	2000–2009	Average	143
Healthy life expectancy	2007	Single year	181
Gini coefficient	1997–2007	Average	153
Interpersonal safety and trust	2005	Single year	148
Voice and accountability	1998–2007	Average	181
Unemployment rate	1997–2007	Average	148
Inflation rate	1997–2007	Rate of change	155
Human Poverty Index	1999–2007	Multiple years*	131
Annual working hours	1997–2007	Average	48
Per capita GDP	2007	Single year	175

* The Human Poverty Index is calculated from four sub-indicators, with individual data points spanning the period 1999–2007.

Although it is not part of the Social Accounts, I also investigate the relationship between the social indicators and per capita GDP throughout the analysis. GDP data are obtained from the World Bank's (2011a) *World Development Indicators*, and are expressed in 2005 purchasing power parity (PPP) dollars. The social indicator data for all countries are shown in Table 7.13 (while per capita GDP data are provided in Table A.3 of the Appendix).

Table 7.13: The Social Accounts.

Country	Life Sat. (0-10)	Health (Years)	Gini (0-100)	Trust (0-1)	Voice (-2.5-2.5)	Unemp. (%)	Inflat. (%)	Poverty (0-100)	Work (Hours)
Afghanistan	..	36	..	..	-1.44	8.5	..	59.8	..
Albania	4.6	64	29.2	.484	-0.08	22.7	3.3	4.0	..
Algeria	5.4	62	36.0	.493	-1.03	21.5	2.8	17.5	..
Angola	4.3	45	59.1	..	-1.30	..	99.1	37.2	..
Antigua & Barbuda	..	66	..	..	0.34	8.4	..	..	..
Argentina	7.3	67	46.0	.415	0.27	13.7	7.6	3.7	1,919
Armenia	5.0	61	39.1	.553	-0.59	33.6	2.9	3.7	..
Australia	7.7	74	31.4	.517	1.44	6.2	3.0	..	1,747
Austria	7.6	72	26.4	.545	1.38	4.2	1.8	..	1,655
Azerbaijan	5.3	59	31.6	.558	-1.03	9.3	3.6	10.7	..
Bahamas	..	65	41.2	.381	1.09	8.8	1.9	..	..
Bahrain	..	66	..	.536	-0.82	5.5	0.7	8.0	..
Bangladesh	5.3	56	36.2	.389	-0.47	4.0	5.5	36.1	..
Barbados	..	67	30.7	.406	1.24	10.2	2.5	2.6	..
Belarus	5.2	62	25.3	.509	-1.45	..	53.6	4.3	..
Belgium	7.3	72	26.1	.582	1.41	8.0	2.0	..	1,568
Belize	6.6	60	46.2	..	0.76	11.0	2.0	17.5	..
Benin	3.0	50	37.0	.385	0.22	0.7	2.8	43.2	..
Bhutan	..	55	47.7	.577	-1.01	2.9	4.3	33.7	..
Bolivia	6.5	58	53.8	.353	0.02	4.9	3.7	11.6	..
Bosnia & Herz.	5.6	67	30.6	.469	-0.01	30.8	..	2.8	..
Botswana	4.7	49	52.5	.432	0.62	19.3	8.1	22.9	..
Brazil	7.5	64	50.5	.280	0.37	8.9	7.4	8.6	1,724
Brunei	..	66	..	.611	-0.92	..	0.2	..	..
Bulgaria	4.4	66	26.5	.461	0.53	13.3	6.5	..	..
Burkina Faso	4.4	43	50.0	.291	-0.39	2.4	2.1	51.8	..
Burundi	2.9	43	37.1	.352	-1.17	..	8.8	36.4	..
Cambodia	4.9	53	44.0	.405	-0.87	2.4	3.4	27.7	..
Cameroon	3.9	45	46.7	.280	-1.07	5.2	2.2	30.8	..
Canada	7.6	73	31.4	.529	1.51	7.3	2.2	..	1,757
Cape Verde	..	61	51.5	.439	0.65	..	1.5	14.5	..
Central African Rep.	4.6	42	..	..	-0.98	..	2.1	42.4	..
Chad	5.4	40	40.2	..	-1.18	..	2.2	53.1	..
Chile	6.6	70	50.8	.452	0.96	8.1	..	3.2	2,228
China	6.3	66	39.2	.557	-1.51	3.7	1.0	7.7	..
Colombia	7.7	66	51.0	.261	-0.39	13.8	7.5	7.6	1,911
Comoros	..	56	64.4	..	-0.56	..	..	20.4	..
Congo	4.0	48	43.6	..	-1.17	..	..	24.3	..
Congo (Dem. Rep.)	..	45	42.6	..	-1.63	..	84.3	38.0	..
Costa Rica	8.5	69	44.3	.450	0.99	5.9	10.9	3.7	1,868
Cote d'Ivoire	4.5	47	45.2	.331	-1.21	4.1	2.9	..	..
Croatia	6.0	68	29.6	.531	0.43	13.4	3.1	1.9	..
Cuba	..	69	..	.469	-1.78	3.8	..	4.6	..
Cyprus	7.0	70	27.7	.557	1.06	4.5	2.8	..	..
Czech Republic	6.5	70	25.3	.535	0.94	7.3	2.8	1.5	2,022
Denmark	8.2	72	22.9	.601	1.61	4.7	2.1	..	1,574
Djibouti	5.7	48	39.9	.463	-0.85	59.5	..	25.6	..
Dominica	..	66	25.2	.441	1.03	16.6	1.5	..	..
Dominican Rep.	7.6	63	47.1	.395	0.10	15.9	14.1	9.1	..
Ecuador	6.4	64	52.3	.357	-0.23	9.4	22.0	7.9	1,923
Egypt	5.7	60	36.5	.542	-1.02	9.6	5.0	23.4	..
El Salvador	6.7	61	47.0	.296	0.05	6.9	3.0	14.6	1,845
Eritrea	..	55	..	.498	-1.78	..	..	33.7	..
Estonia	6.0	66	34.7	.469	1.04	9.6	4.0	..	1,992
Ethiopia	4.2	50	34.5	.435	-1.09	13.4	5.6	50.9	..
Fiji	..	62	43.4	.509	-0.10	5.9	2.8	21.2	..
Finland	7.9	72	24.7	.591	1.61	9.3	1.5	..	1,734
France	6.6	73	27.3	.524	1.23	9.8	1.7	..	1,579
Gabon	..	52	42.1	.350	-0.69	..	1.1	17.5	..
Gambia	..	51	48.0	..	-0.80	..	7.1	40.9	..

Country	Life Sat. (0-10)	Health (Years)	Gini (0-100)	Trust (0-1)	Voice (-2.5-2.5)	Unemp. (%)	Inflat. (%)	Poverty (0-100)	Work (Hours)
Georgia	4.3	64	38.8	.464	-0.27	12.8	6.9	4.7	..
Germany	7.1	73	27.6	.552	1.42	9.2	1.4	..	1,460
Ghana	5.2	50	39.4	.423	0.14	10.3	18.7	28.1	..
Greece	6.4	72	33.6	.536	1.03	10.1	3.3	..	2,102
Grenada	..	61	32.6	..	0.69	12.7	2.4	0.0	..
Guatemala	7.2	60	52.0	.284	-0.34	2.2	7.0	19.7	..
Guinea	4.5	47	40.6	..	-1.25	..	..	50.5	..
Guinea-Bissau	..	42	38.2	..	-0.81	..	2.3	34.9	..
Guyana	6.5	53	42.7	.342	0.33	10.5	5.8	10.2	..
Haiti	3.9	54	51.4	..	-1.01	7.2	16.9	31.5	..
Honduras	7.0	62	51.3	.314	-0.22	4.1	8.9	13.7	1,810
Hungary	5.5	66	28.2	.508	1.13	6.9	6.9	2.2	2,020
Iceland	8.2	74	25.8	.612	1.53	2.8	4.3	..	1,826
India	5.5	56	33.7	.532	0.38	3.9	4.7	28.0	..
Indonesia	6.3	60	34.5	.507	-0.37	8.2	11.7	17.0	..
Iran	5.9	61	43.4	.582	-1.21	11.5	14.7	12.8	..
Iraq	4.7	54	33.8	.395	-1.62	22.6	22.0	19.4	..
Ireland	7.6	73	31.6	.588	1.39	5.3	3.7	..	1,701
Israel	7.0	73	35.0	.447	0.65	9.0	2.1	..	1,926
Italy	6.7	74	33.8	.497	1.03	9.3	2.3	..	1,841
Jamaica	6.7	64	49.0	.307	0.58	13.2	9.5	10.9	..
Japan	6.5	76	32.2	.599	0.96	4.5	-0.3	..	1,807
Jordan	5.9	63	38.1	.530	-0.57	14.6	2.5	6.6	..
Kazakhstan	6.1	56	33.8	.413	-1.02	10.2	8.1	7.9	..
Kenya	3.7	48	47.9	.271	-0.41	9.8	8.4	29.5	..
Kiribati	..	58	..	..	0.78	..	..	..	..
Korea, North	..	59	..	..	-2.17	..	..	..	..
Korea, South	6.0	71	31.4	.575	0.67	4.1	3.1	..	2,442
Kuwait	6.6	69	..	.582	-0.41	1.1	2.0	..	..
Kyrgyzstan	5.5	57	34.3	.415	-0.91	8.9	8.7	7.3	..
Laos	6.2	54	35.8	..	-1.54	1.4	21.2	30.7	..
Latvia	5.4	64	34.5	.446	0.80	11.4	4.2	..	..
Lebanon	4.7	62	43.4	.440	-0.43	8.5	..	7.6	..
Lesotho	..	40	54.2	.354	-0.18	33.3	..	34.3	..
Liberia	3.4	48	44.2	..	-0.92	5.6	..	35.2	..
Libya	..	64	..	.561	-1.79	..	-2.4	13.4	..
Lithuania	5.5	63	33.4	.455	0.90	11.8	1.4	..	..
Luxembourg	7.7	73	26.9	.520	1.49	3.3	2.2	..	1,622
Macedonia	4.7	66	33.8	.502	-0.10	34.5	2.3	3.2	..
Madagascar	3.7	52	42.9	.368	-0.03	4.7	10.2	36.1	..
Malawi	6.2	44	44.3	.417	-0.36	7.8	18.7	28.2	..
Malaysia	6.6	64	39.1	.495	-0.37	3.3	2.1	6.1	..
Mali	4.7	42	43.3	.430	0.21	6.1	1.6	54.5	..
Malta	7.1	72	28.2	.571	1.26	7.0	2.4	..	..
Mauritania	5.0	51	37.2	..	-0.89	26.8	6.3	36.2	..
Mauritius	..	63	40.8	.491	0.87	8.6	5.7	9.5	..
Mexico	7.9	67	47.5	.394	0.16	3.2	6.7	5.9	1,885
Moldova	4.9	61	40.1	.401	-0.36	7.7	14.6	5.9	..
Mongolia	5.7	58	35.2	.398	0.27	3.9	7.1	12.7	..
Morocco	5.4	62	40.6	.525	-0.62	12.8	1.7	31.1	..
Mozambique	3.8	42	41.6	.349	-0.08	2.2	10.7	46.8	..
Myanmar	..	50	..	.510	-2.10	..	22.8	20.4	..
Namibia	5.2	52	65.5	.358	0.35	20.6	..	17.1	..
Nauru	..	55	..	..	0.98	..	..	..	..
Nepal	5.3	55	45.9	.506	-0.75	5.3	4.9	32.1	..
Netherlands	7.6	73	26.2	.556	1.59	3.7	2.3	..	1,415
New Zealand	7.5	73	34.0	.569	1.60	5.3	2.3	..	1,814
Nicaragua	7.1	64	50.3	.368	-0.11	8.8	..	17.0	1,935
Niger	3.8	44	45.3	..	-0.40	1.5	1.8	55.8	..
Nigeria	5.7	42	46.8	.388	-0.76	..	12.5	36.2	..
Norway	7.9	73	24.5	.581	1.57	3.7	2.0	..	1,436

Country	Life Sat. (0-10)	Health (Years)	Gini (0-100)	Trust (0-1)	Voice (-2.5-2.5)	Unemp. (%)	Inflat. (%)	Poverty (0-100)	Work (Hours)
Oman	..	65	..	.621	-0.83	..	..	14.7	..
Pakistan	5.0	55	30.1	.457	-1.08	6.4	5.3	33.4	..
Panama	7.8	67	50.7	.464	0.52	12.2	1.2	6.7	1,743
Papua New Guinea	..	56	49.3	.311	-0.04	..	8.9	39.6	..
Paraguay	6.9	64	51.8	.389	-0.41	7.0	8.8	10.5	1,890
Peru	6.2	67	52.2	.384	-0.09	7.9	2.5	10.2	2,048
Philippines	5.9	62	43.8	.504	0.08	9.7	5.3	12.4	..
Poland	6.4	67	30.1	.494	0.96	15.3	4.1	..	1,983
Portugal	5.7	71	36.1	.492	1.36	5.9	3.0	..	1,770
Qatar	6.8	67	..	.686	-0.63	2.1	4.4	5.0	..
Romania	5.7	65	28.5	.476	0.41	6.8	23.2	5.6	..
Russia	5.6	60	42.9	.388	-0.65	9.2	20.0	7.4	1,980
Rwanda	4.2	43	44.9	.420	-1.35	..	5.8	32.9	..
St. Kitts & Nevis	..	64	..	.357	0.94	5.1	3.3	..	..
Saint Lucia	..	66	39.1	..	1.09	19.2	2.5	6.3	..
St. Vincent & Gren.	..	63	..	..	1.00	..	2.0	..	..
Samoa	..	61	..	..	0.63	5.0	4.5	..	..
Sao Tome & Prin.	..	53	..	..	0.31	15.6	13.8	12.6	..
Saudi Arabia	6.5	62	..	.590	-1.54	5.1	0.2	12.1	..
Senegal	4.5	51	38.6	.484	0.11	10.0	1.6	41.6	..
Serbia	5.4	65	35.9	.436	-0.26	19.6	30.1	3.1	..
Seychelles	..	63	..	.463	0.04	7.7	3.3	..	..
Sierra Leone	3.6	35	48.2	..	-0.72	3.4	..	47.7	..
Singapore	6.9	73	37.4	.584	-0.05	4.3	0.7	3.9	..
Slovakia	5.9	67	24.7	.513	0.90	15.8	6.7	..	1,804
Slovenia	6.9	71	24.8	.560	1.10	6.5	5.7	..	1,754
Solomon Islands	5.8	59	..	..	0.28	31.9	8.5	21.8	..
Somalia	7.3	45	44.2	..	-1.82	..	..	..	..
South Africa	5.8	48	64.5	.335	0.68	26.6	5.3	25.4	..
Spain	7.0	74	32.7	.536	1.20	12.6	3.1	..	1,702
Sri Lanka	5.1	63	41.6	.440	-0.23	8.2	9.2	16.8	..
Sudan	5.0	50	..	.339	-1.68	..	8.7	34.0	..
Suriname	..	61	48.7	..	0.23	11.1	26.9	10.1	..
Swaziland	..	42	49.5	.305	-1.35	22.5	7.3	35.1	..
Sweden	7.8	74	23.3	.546	1.57	6.8	1.3	..	1,622
Switzerland	8.0	75	28.0	.624	1.52	3.6	0.9	..	1,662
Syria	5.9	63	..	.575	-1.60	9.6	2.7	12.6	..
Tajikistan	5.1	57	31.6	.495	-1.33	..	..	18.2	..
Tanzania	2.8	45	36.5	.407	-0.35	4.7	6.0	30.0	..
Thailand	6.6	62	45.0	.482	0.02	1.9	2.4	8.5	..
Timor-Leste	..	53	40.5	..	0.08	..	..	40.8	..
Togo	2.6	51	34.8	..	-1.28	..	2.0	36.6	..
Tonga	..	63	..	.605	-0.09	3.2	8.3	..	..
Trinidad & Tobago	7.0	62	37.5	.368	0.61	10.4	5.0	6.4	..
Tunisia	5.9	66	40.9	.463	-0.96	14.9	2.9	15.6	..
Turkey	5.6	66	43.7	.494	-0.23	9.0	33.4	8.3	1,924
Turkmenistan	7.2	55	33.6	..	-1.91	..	..	..	..
Uganda	4.8	42	41.0	.392	-0.70	3.2	4.5	28.8	..
Ukraine	5.0	60	32.5	.440	-0.36	9.3	11.4	5.8	..
United Arab Emir.	7.3	68	..	.645	-0.80	2.7	..	7.7	..
United Kingdom	7.1	72	34.5	.538	1.36	5.3	1.5	..	1,693
United States	7.4	70	37.0	.505	1.28	4.9	2.6	..	1,818
Uruguay	6.8	67	42.1	.465	0.93	12.8	9.0	3.0	1,733
Uzbekistan	6.0	59	35.5	.474	-1.79	..	..	8.5	..
Vanuatu	..	61	..	..	0.58	..	2.4	23.6	..
Venezuela	7.5	66	42.6	.292	-0.48	12.6	20.5	6.6	1,708
Vietnam	6.1	64	36.7	.586	-1.45	2.4	4.2	12.4	..
Yemen	5.8	54	34.9	.507	-1.01	15.0	10.2	35.7	..
Zambia	5.0	40	50.2	.390	-0.40	12.5	20.2	35.5	..
Zimbabwe	3.1	39	..	.341	-1.40	5.7	264.8	34.0	..

7.2.2. Social Performance Index

On their own, the nine indicators in the Social Accounts are difficult to interpret, particularly since some of them (e.g. the indicator of interpersonal safety/trust and the indicator of voice/accountability) are dimensionless indices. Without some kind of summary indicator that normalises and aggregates the data, it is difficult to say how countries are performing overall on the social objectives described in the Paris Declaration.

In order to assess the relative social performance of different countries (and eventually compare this to their biophysical performance), I therefore create an index using the social indicator data. Ideally this index would include data for all of the intermediate ends. However, since the poverty indicator and the working time indicator are available for a much smaller number of countries than the other indicators (and in general not for the same countries), I exclude them from the index.

I calculate the Social Performance Index (SPI) using data from the first seven indicators in Table 7.13. In some ways, this index goes against the conceptual framework used to organise the indicators by mixing a measure of the ultimate end (human well-being) with measures of intermediate ends. It would be more consistent to have a separate index of intermediate ends, to complement a robust measure of human well-being. However, as was noted in Section 6.2.6, the measure of human well-being used in this analysis is not ideal (it lacks information from the hedonic and eudaimonic approaches to well-being). Moreover, two of the intermediate ends cannot be included in an overall index due to lack of data. I therefore merge all of the social indicators together into a single index of social performance. Although not an ideal approach, the largest danger identified in Section 3.3.4—that of mixing social and environmental objectives in a single measure—is avoided here by creating a purely social index.

I calculate the index only for countries for which all seven of the included indicators are available, and give equal weighting to each indicator within the index. I calculate the index by normalising each indicator so that it is on a zero to ten scale (where zero represents the worst score and ten the best score for the indicator), and then take the arithmetic mean of these seven values.

An aggregated indicator such as the SPI can be distorted by the presence of extreme values or outliers in the data (OECD, 2008, p. 28). Prior to normalising or aggregating the data, I therefore analyse how close the seven social indicators are to a normal distribution, and whether there are any extreme values in the data.

There are 108 countries for which all seven social indicators are available. Visual inspection of the data using histograms and box plots suggests that extreme values are a problem for three of the indicators: the Gini coefficient, the unemployment rate, and the inflation rate. While there is only a single outlier in the Gini coefficient data (South Africa, which has a very high Gini coefficient of 64.5), numerous outliers appear in the box plots for the unemployment rate and inflation rate data due to the large right skew in these two indicators.

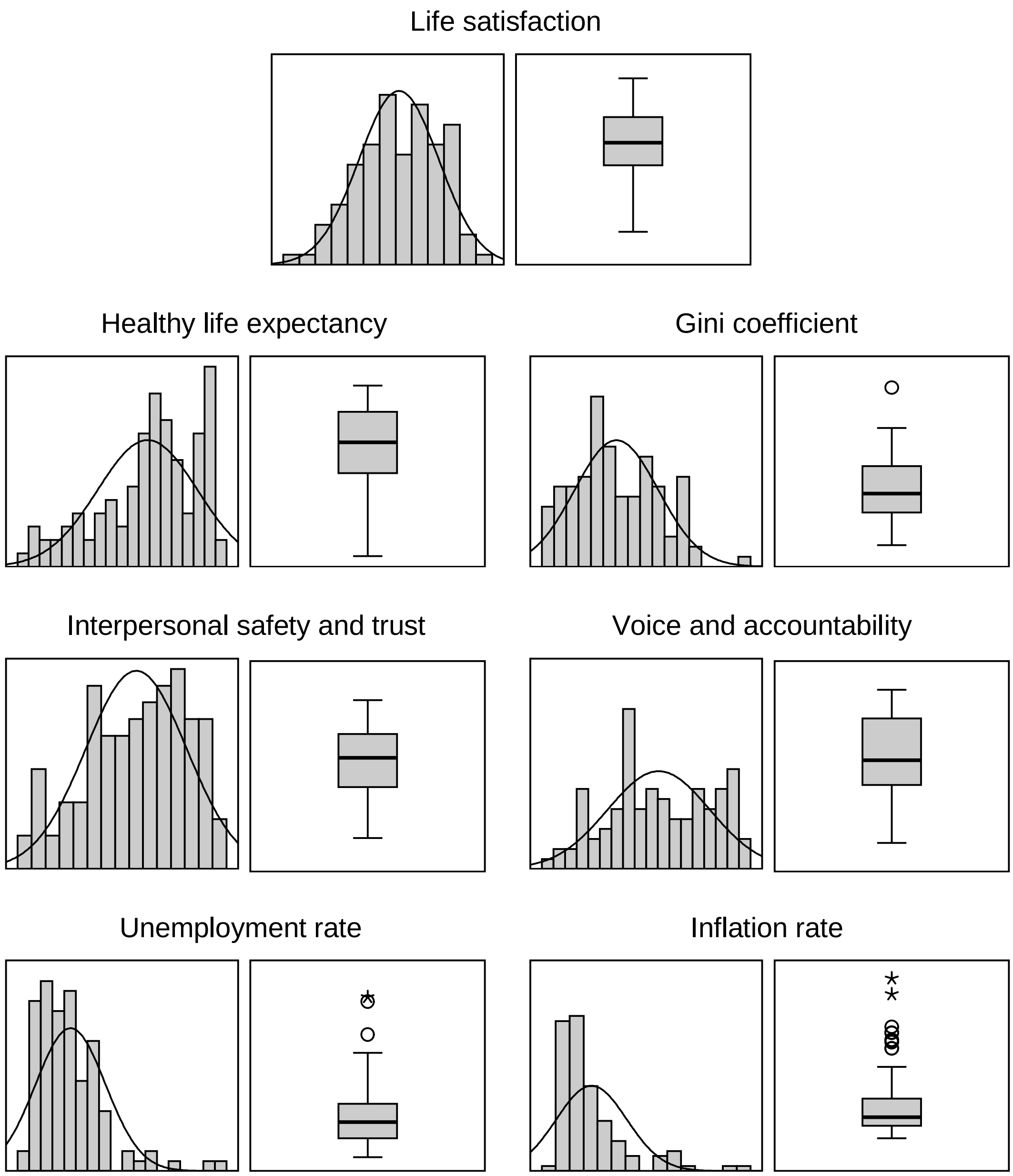

Figure 7.6: Histograms (left) and box plots (right) for the seven social indicators used to calculate the Social Performance Index, prior to data transformation and normalisation. $N = 108$.

In order to reduce the effect of outliers (and bring the indicators somewhat closer to a normal distribution) I adjust the inequality value for South Africa to the highest non-outlying value (53.8, the value for Bolivia), and apply the following logarithmic transformation to the unemployment rate and inflation rate data:

$$x_c' = \log[1 - \min(x) + x_c] \quad (7.3)$$

where x_c is the untransformed data point for country c, and x_c' is the transformed data point. This transformation maps the smallest observed value to zero, and removes the right skew.

In order to transform all seven indicators to a common scale, I apply "min-max normalisation" (OECD, 2008, p. 85). For indicators where a high score is considered better (i.e. life satisfaction, healthy life expectancy, interpersonal safety and trust, and voice and accountability) I apply the following formula to the data:

$$I_c = \frac{x_c - \min(x)}{\max(x) - \min(x)} \tag{7.4}$$

where I_c is the normalised indicator value for country c, and x is the unnormalised data. For indicators where a low score is considered better (i.e. Gini coefficient, unemployment rate, and inflation rate), I use a reversed form of the formula:

$$I_c = \frac{\max(x) - x_c}{\max(x) - \min(x)} \tag{7.5}$$

Following this procedure, all indicators are normalised to a zero to ten scale, where zero represents the worst value observed for a given indicator, and ten represents the best value observed. The transformed data are much closer to a normal distribution, and are free of extreme values (Figure 7.7).

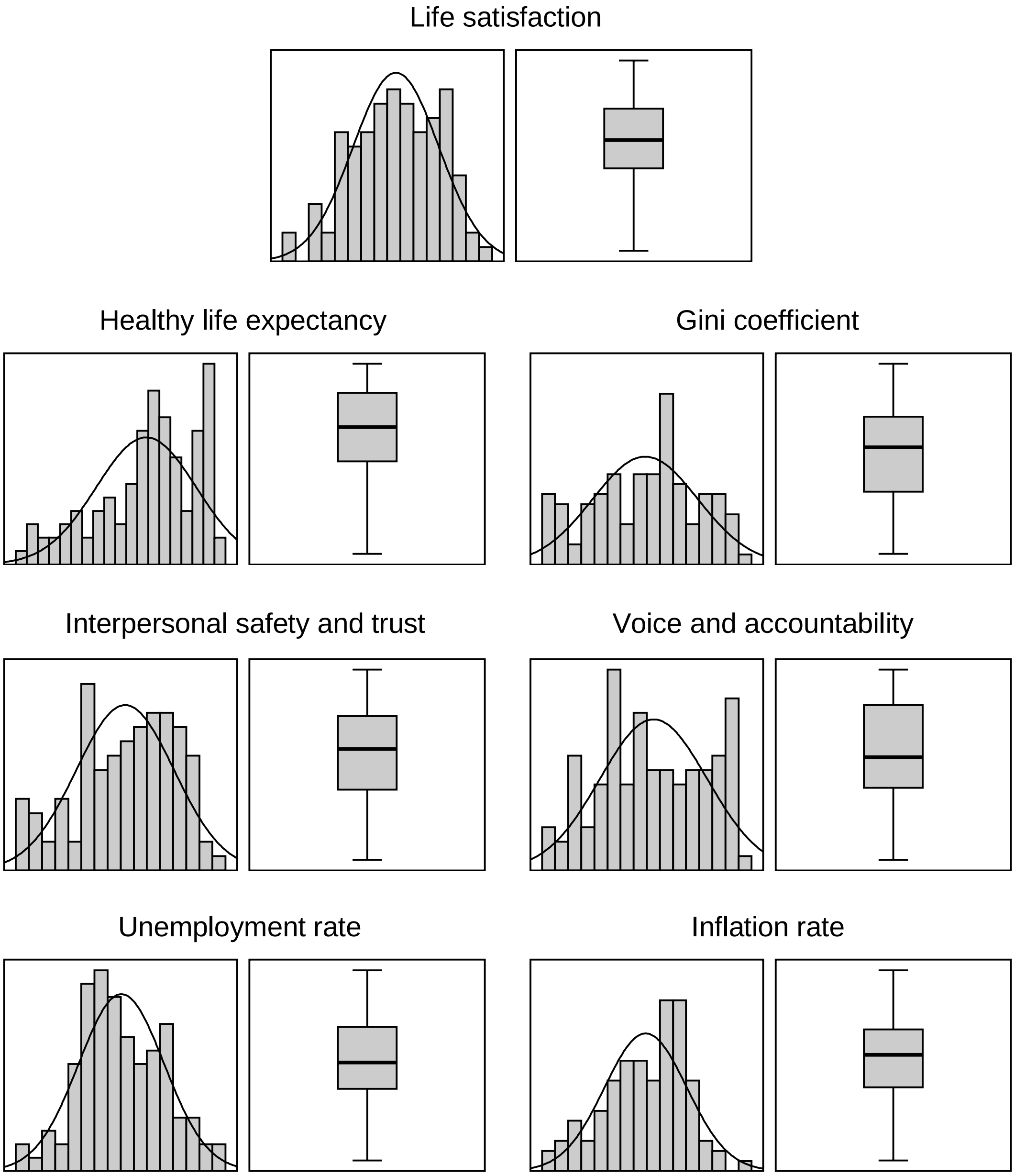

Figure 7.7: Histograms (left) and box plots (right) for the seven social indicators used to calculate the Social Performance Index, following data transformation and normalisation. $N = 108$.

The Social Performance Index (SPI) for a country c is then calculated by taking the arithmetic mean of the seven normalised indicators:

$$SPI_c = \frac{1}{7}\sum_{n=1}^{7} I_c^n \qquad (7.6)$$

The full SPI results, and normalised sub-indicators, are shown in Table 7.14.

Table 7.14: The Social Performance Index (SPI) and normalised sub-indicators, calculated for 108 countries.

Country		Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	SPI
1	Switzerland	9.14	9.72	8.35	10.00	9.71	7.94	8.76	9.09
2	Denmark	9.54	8.89	10.00	9.35	10.00	6.98	7.12	8.84
3	Iceland	9.38	9.44	9.07	9.68	9.75	8.73	5.46	8.79
4	Norway	8.87	9.17	9.49	8.82	9.87	7.86	7.25	8.76
5	Sweden	8.80	9.44	9.87	7.84	9.87	5.76	8.07	8.52
6	Netherlands	8.35	9.17	8.95	8.11	9.94	7.81	6.93	8.46
7	Finland	8.93	8.89	9.41	9.09	9.98	4.65	7.76	8.39
8	Luxembourg	8.52	9.17	8.71	7.14	9.63	8.19	6.97	8.33
9	Austria	8.38	8.89	8.86	7.82	9.28	7.36	7.39	8.28
10	Japan	6.48	10.00	6.99	9.30	7.98	7.15	10.00	8.27
11	Belgium	7.94	8.89	8.96	8.82	9.36	5.19	7.26	8.06
12	New Zealand	8.17	9.17	6.41	8.47	9.97	6.59	6.88	7.95
13	Ireland	8.43	9.17	7.19	9.00	9.32	6.61	5.85	7.94
14	Germany	7.57	9.17	8.49	8.02	9.40	4.70	7.88	7.89
15	Malta	7.55	8.89	8.29	8.53	8.91	5.64	6.87	7.81
16	Canada	8.42	9.17	7.25	7.38	9.70	5.49	6.99	7.77
17	Cyprus	7.34	8.33	8.46	8.16	8.28	7.20	6.51	7.76
18	Australia	8.64	9.44	7.25	7.04	9.45	6.07	6.34	7.75
19	United Kingdom	7.61	8.89	6.25	7.62	9.23	6.58	7.85	7.72
20	France	6.67	9.17	8.57	7.23	8.82	4.48	7.59	7.51
21	Slovenia	7.13	8.61	9.41	8.24	8.42	5.90	4.73	7.49
22	Singapore	7.15	9.17	5.31	8.90	4.84	7.31	9.09	7.40
23	Czech Republic	6.48	8.33	9.23	7.54	7.93	5.49	6.46	7.35
24	United States	8.13	8.33	5.43	6.72	8.96	6.87	6.64	7.30
25	Korea, South	5.63	8.61	7.26	8.64	7.09	7.47	6.27	7.28
26	Spain	7.36	9.44	6.84	7.57	8.72	3.58	6.24	7.11
27	Italy	6.85	9.44	6.47	6.50	8.20	4.64	6.92	7.00
28	Greece	6.37	8.89	6.56	7.57	8.20	4.38	6.08	6.86
29	Portugal	5.09	8.61	5.72	6.35	9.21	6.21	6.31	6.79
30	Israel	7.29	9.17	6.10	5.14	7.02	4.76	7.15	6.66
31	Hungary	4.65	7.22	8.30	6.81	8.50	5.72	4.25	6.49
32	Croatia	5.63	7.78	7.84	7.43	6.34	3.38	6.26	6.38
33	Poland	6.27	7.50	7.68	6.41	7.98	2.90	5.56	6.33
34	Slovakia	5.44	7.50	9.42	6.93	7.80	2.79	4.33	6.31
35	Costa Rica	10.00	8.06	3.07	5.21	8.07	6.21	3.05	6.24
36	Malaysia	6.57	6.67	4.76	6.45	3.86	8.21	7.13	6.24
37	Thailand	6.62	6.11	2.86	6.07	5.08	10.00	6.81	6.22
38	Estonia	5.56	7.22	6.18	5.74	8.21	4.53	5.66	6.16
39	China	6.14	7.22	4.73	8.14	0.33	7.82	8.50	6.13
40	Lithuania	4.77	6.39	6.60	5.34	7.80	3.83	7.89	6.09
41	India	4.74	4.44	6.51	7.47	6.18	7.68	5.24	6.04
42	Vietnam	5.79	6.67	5.53	8.94	0.54	9.26	5.52	6.04
43	Panama	8.75	7.50	1.02	5.59	6.61	3.71	8.17	5.91
44	Mexico	8.86	7.50	2.06	3.66	5.52	8.33	4.36	5.75
45	Latvia	4.47	6.67	6.27	5.11	7.50	3.93	5.54	5.64
46	Romania	5.07	6.94	8.19	5.91	6.28	5.76	1.01	5.60
47	Bulgaria	2.80	7.22	8.85	5.52	6.66	3.41	4.43	5.55
48	Uruguay	6.92	7.50	3.81	5.61	7.90	3.54	3.56	5.55
49	Trinidad & Tobago	7.39	6.11	5.29	2.95	6.89	4.27	5.10	5.43
50	Mongolia	5.00	5.00	6.02	3.79	5.85	7.61	4.18	5.35
51	Jordan	5.46	6.39	5.09	7.41	3.24	3.07	6.73	5.34
52	Azerbaijan	4.33	5.28	7.19	8.18	1.81	4.64	5.92	5.34
53	Indonesia	6.09	5.56	6.27	6.78	3.88	5.11	2.88	5.22
54	Morocco	4.51	6.11	4.29	7.28	3.11	3.54	7.61	5.21
55	Albania	3.17	6.67	7.97	6.14	4.76	1.50	6.11	5.19

Country		Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	SPI
56	Philippines	5.40	6.11	3.25	6.69	5.24	4.51	4.94	5.16
57	Egypt	5.00	5.56	5.59	7.73	1.85	4.56	5.10	5.06
58	Argentina	7.96	7.50	2.52	4.23	5.85	3.29	4.01	5.05
59	Macedonia	3.24	7.22	6.48	6.64	4.72	0.00	6.91	5.03
60	Senegal	2.92	3.06	4.92	6.15	5.36	4.40	7.72	4.93
61	Benin	0.35	2.78	5.43	3.43	5.71	10.00	6.45	4.88
62	Peru	5.99	7.50	0.54	3.38	4.73	5.24	6.75	4.87
63	Bangladesh	4.33	4.44	5.69	3.54	3.55	7.59	4.86	4.86
64	Tunisia	5.40	7.22	4.19	5.57	2.04	3.00	6.41	4.83
65	Pakistan	3.89	4.17	7.68	5.39	1.66	5.94	4.96	4.81
66	El Salvador	6.80	5.83	2.22	0.97	5.16	5.68	6.29	4.71
67	Algeria	4.52	6.11	5.77	6.38	1.84	1.69	6.49	4.69
68	Ukraine	3.80	5.56	6.92	4.93	3.90	4.67	2.94	4.67
69	Nepal	4.40	4.17	2.58	6.75	2.68	6.61	5.14	4.62
70	Armenia	3.89	5.83	4.78	8.04	3.19	0.10	6.39	4.60
71	Guatemala	7.71	5.56	0.59	0.64	3.96	9.52	4.24	4.60
72	Sri Lanka	3.94	6.39	3.96	4.93	4.29	5.11	3.52	4.59
73	Cambodia	3.64	3.61	3.18	3.97	2.32	9.24	6.01	4.57
74	Bolivia	6.48	5.00	0.00	2.54	5.08	6.90	5.83	4.55
75	Georgia	2.54	6.67	4.85	5.59	4.17	3.54	4.27	4.52
76	Brazil	8.20	6.67	1.09	0.53	6.15	4.81	4.09	4.51
77	Mali	3.33	0.56	3.42	4.66	5.67	6.15	7.67	4.49
78	Honduras	7.39	6.11	0.83	1.47	4.33	7.51	3.62	4.47
79	Dominican Rep.	8.40	6.39	2.17	3.69	5.31	2.77	2.37	4.44
80	Paraguay	7.13	6.67	0.66	3.53	3.75	5.67	3.64	4.44
81	Kazakhstan	5.83	4.44	6.48	4.19	1.85	4.32	3.87	4.43
82	Guyana	6.53	3.61	3.59	2.23	6.04	4.25	4.71	4.42
83	Iran	5.39	5.83	3.39	8.84	1.28	3.93	2.25	4.42
84	Turkey	4.82	7.22	3.28	6.42	4.30	4.77	0.00	4.40
85	Kyrgyzstan	4.79	4.72	6.31	4.24	2.19	4.83	3.68	4.39
86	Yemen	5.25	3.89	6.13	6.77	1.88	2.98	3.23	4.30
87	Jamaica	6.83	6.67	1.57	1.27	6.80	3.42	3.42	4.28
88	Moldova	3.59	5.83	4.45	3.85	3.90	5.30	2.27	4.17
89	Serbia	4.60	6.94	5.80	4.83	4.22	2.03	0.29	4.10
90	Venezuela	8.27	7.22	3.64	0.87	3.52	3.60	1.35	4.07
91	Uganda	3.50	0.56	4.16	3.62	2.85	8.31	5.38	4.05
92	Colombia	8.63	7.22	0.90	0.00	3.80	3.28	4.06	3.99
93	Ghana	4.23	2.78	4.67	4.46	5.44	4.32	1.61	3.93
94	Tanzania	0.00	1.39	5.61	4.03	3.93	7.02	4.61	3.80
95	Madagascar	1.60	3.33	3.54	2.94	4.92	7.03	3.23	3.80
96	Russia	4.81	5.56	3.55	3.50	3.00	4.69	1.42	3.79
97	Ecuador	6.34	6.67	0.50	2.64	4.30	4.64	1.16	3.75
98	Mozambique	1.80	0.56	3.97	2.43	4.76	9.52	3.11	3.73
99	Ethiopia	2.45	2.78	6.26	4.79	1.64	3.37	4.80	3.73
100	Burkina Faso	2.71	0.83	1.24	0.84	3.80	9.24	7.10	3.68
101	Malawi	5.95	1.11	3.08	4.31	3.90	5.27	1.61	3.60
102	Cote d'Ivoire	2.87	1.94	2.79	1.94	1.26	7.48	6.43	3.53
103	Botswana	3.31	2.50	0.43	4.71	6.93	2.07	3.84	3.40
104	South Africa	5.28	2.22	0.00	2.06	7.12	0.93	4.93	3.22
105	Cameroon	1.97	1.39	2.29	0.52	1.70	6.67	7.06	3.09
106	Iraq	3.26	3.89	6.48	3.70	0.00	1.51	1.16	2.86
107	Kenya	1.50	2.22	1.92	0.29	3.75	4.47	3.76	2.56
108	Zambia	3.79	0.00	1.16	3.55	3.79	3.63	1.39	2.47

Note: All indicators are normalised to a scale from 0 (worst) to 10 (best).

The countries that achieve the highest scores on the SPI are almost exclusively wealthy European nations, with Switzerland, Denmark, and Iceland topping the list. Nine of the top ten social performers (and sixteen of the top twenty) are European countries. Japan is the only non-European country to finish in the top ten.

By contrast, the countries that achieve the lowest scores on the SPI are almost exclusively poor African nations, with Zambia and Kenya finishing at the bottom of the list. Nine of the bottom ten social performers (and fourteen of the bottom twenty) are African countries. Iraq is the only country in the bottom ten that is not located in Africa.

7.2.3. Relationship between Indicators

As with the indicators in the Biophysical Accounts, it is also useful to look at the correlation between indicators in the Social Accounts. The relationship between life satisfaction and the other social indicators is of particular interest, as human well-being (as measured by life satisfaction) is taken to be the ultimate end within the accounts, while the other social indicators measure intermediate ends in service of this end.

Unfortunately it is not possible to construct a correlation matrix using data for all nine social indicators and a large common set of countries, since data are only available for a small number of countries for the poverty and working hours indicators. In fact, all nine social indicators are only available for 17 countries. Therefore I construct a correlation matrix for the social indicators using pairwise deletion (as opposed to listwise deletion). This approach maximises the number of data points used in each correlation, but means that each correlation is performed using a different subset of the full data set. The results are shown in Table 7.15.

Table 7.15: Correlation between the indicators in the Social Accounts (Spearman's ρ).

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
Life Sat.	1	**.746**	-.217	.384	.554	-.151	-.283	-.588	-.571
		***	*	***	***	ns	**	***	***
	143	*143*	*134*	*127*	*143*	*128*	*128*	*105*	*48*
Health	**.746**	1	-.527	.588	**.636**	-.090	-.394	**-.850**	-.497
	***		***	***	***	ns	***	***	***
	143	*181*	*153*	*148*	*181*	*148*	*155*	*131*	*48*
Gini	-.217	-.527	1	**-.683**	-.387	.036	.332	.244	.499
	*	***		***	***	ns	***	**	***
	134	*153*	*153*	*131*	*153*	*132*	*136*	*114*	*48*
Trust	.384	.588	**-.683**	1	.200	-.221	-.460	-.304	-.463
	***	***	***		*	*	***	**	***
	127	*148*	*131*	*148*	*148*	*133*	*135*	*106*	*48*
Voice	.554	**.636**	-.387	.200	1	.000	-.326	-.377	-.597
	***	***	***	*		ns	***	***	***
	143	*181*	*153*	*148*	*181*	*148*	*155*	*131*	*48*
Unemp.	-.151	-.090	.036	-.221	.000	1	.218	-.199	.255
	ns	ns	ns	*	ns		*	*	ns
	128	*148*	*132*	*133*	*148*	*148*	*135*	*105*	*48*
Inflat.	-.283	-.394	.332	-.460	-.326	.218	1	-.005	.515
	**	***	***	***	***	*		ns	***
	128	*155*	*136*	*135*	*155*	*135*	*155*	*111*	*46*
Poverty	-.588	**-.850**	.244	-.304	-.377	-.199	-.005	1	-.163
	***	***	**	**	***	*	ns		ns
	105	*131*	*114*	*106*	*131*	*105*	*111*	*131*	*19*
Work	-.571	-.497	.499	-.463	-.597	.255	.515	-.163	1
	***	***	***	***	***	ns	***	ns	
	48	*48*	*48*	*48*	*48*	*48*	*46*	*19*	*48*

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. N for each correlation is shown in italics. The strongest correlations ($|\rho| \geq .6$) are shown in bold.

The strongest positive correlations among the indicators in the Social Accounts are between health and life satisfaction, and health and voice/accountability. The strongest negative correlations are between poverty and health, and inequality and safety/trust.

Life satisfaction and health are both positively correlated with safety/trust and voice/accountability, and negatively correlated with inequality, poverty, and working hours. Inequality is associated with poorer health, lower safety/trust, lower voice/accountability, and longer working hours. Poverty is associated with lower life satisfaction and poorer health.

While interpersonal safety/trust and voice/accountability are only weakly correlated with each other, they are both positively correlated with life satisfaction and health, and negatively correlated with inequality, inflation, poverty, and working hours. Higher inflation is most strongly correlated with longer working hours and lower safety/trust.

Interestingly, the unemployment rate is not strongly correlated with any of the other indicators. In fact, there is no significant correlation between unemployment and life satisfaction, health, inequality, voice/accountability, or working hours. Longer working hours are associated with numerous social ills, however, including lower life satisfaction, lower health, lower safety/trust, lower voice/accountability, higher inequality, and higher inflation.

Although it is not one of the indicators included in the Social Accounts, I also calculate the correlation between per capita GDP and the nine social indicators. The results (Table 7.16) show that per capita GDP is strongly correlated with a number of the social indicators. Higher per capita GDP is associated with higher life satisfaction, better health, greater safety/trust, greater voice/accountability, lower inequality, less poverty, less inflation, and less time at work. There is no statistically significant relationship between per capita GDP and the unemployment rate, however.

Table 7.16: Correlation between per capita GDP and the indicators in the Social Accounts (Spearman's ρ).

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
PC GDP	**.738**	**.877**	-.508	.574	**.606**	-.070	-.400	**-.806**	-.576
	***	***	***	***	***	ns	***	***	***
	141	*175*	*152*	*145*	*175*	*146*	*153*	*128*	*48*

Note: *** $p < .001$, 'ns' not significant. *N* for each correlation is shown in italics. The strongest correlations ($|\rho| \geq .6$) are shown in bold.

7.2.4. Testing the Determinants of Well-being

The ultimate end of the system of indicators proposed in this thesis is human well-being, which is measured by an indicator of life satisfaction in the Social Accounts. A key question to answer is how much the different intermediate ends contribute towards the ultimate end of human well-being. If some ends contribute more than others, then policy choices aimed at achieving a socially sustainable steady state economy should reflect this.

The correlation analysis in the previous section suggests that higher life satisfaction is associated with better health, greater safety/trust, greater voice/accountability, lower inequality, less poverty, less inflation, and fewer working hours. Besides these social indicators, higher life satisfaction is also strongly associated with higher per capita GDP. However, many of these potential drivers of well-being are correlated with one another, and the correlation analysis does not tell us which of the intermediate ends are the dominant factors influencing well-being.

In order to test which of the intermediate ends are most important to well-being, I use multiple regression. Ideally, I would like to perform the regression analysis using all of the social indicators. However, since the poverty and working hours indicators are not available for a sufficient number of countries, I exclude them from the analysis. I do, however, include per capita GDP in the analysis, as income has been shown to predict well-being in some studies (see Section 6.2.7).

To test the influence of the social indicators on life satisfaction, I construct three regression models. The first model includes the six social indicators for which a large common data set is available. The second model also includes per capita GDP, while the third model includes per capita GDP but removes healthy life expectancy. All models consider the same set of 106 countries. The results are shown in Table 7.17.

Table 7.17: Multiple regression models for life satisfaction as a function of intermediate ends and per capita GDP.

Independent variable	Model 1			Model 2			Model 3		
	β	t		β	t		β	t	
Constant		-1.342	ns		-1.890	ns		-2.046	*
Healthy life expectancy	.751	8.546	***	.577	4.198	***			
Gini coefficient	.298	3.329	**	.311	3.494	***	.351	3.659	***
Interpersonal safety and trust	.012	.120	ns	.015	.154	ns	.112	1.114	ns
Voice and accountability	.253	3.042	**	.188	2.057	*	.177	1.790	ns
Unemployment rate	-.181	-2.928	**	-.194	-3.138	**	-.193	-2.891	**
Inflation rate	.082	1.178	ns	.088	1.274	ns	.089	1.183	ns
Per capita GDP				.248	1.628	ns	.742	7.125	***
Adjusted R^2	.644			.650			.591		

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. All regression coefficients β are standardised. $N = 106$.

The first model, which considers only intermediate ends as determinants of well-being, suggests that four of the six intermediate ends considered contribute to well-being. The strongest determinant of life satisfaction is health, but inequality, the unemployment rate, and voice/accountability are significant determinants of life satisfaction as well. The sign of the coefficient for inequality is positive, indicating—somewhat counter intuitively—that greater inequality leads to higher life satisfaction (a result also found by Bjørnskov, 2003). This relationship may be due to the high inequality in Latin American countries, which also tend to have high life satisfaction. The fact that the unemployment rate is significant to the regression is also interesting, considering that there is not a statistically significant bivariate correlation between unemployment and life satisfaction (Table 7.15). It appears that unemployment explains some residual well-being after the other variables are controlled for.

The second model, which includes per capita GDP, indicates that GDP is not a statistically significant predictor of well-being, despite the strong bivariate correlation between per capita GDP and life satisfaction. GDP is likely not significant because of the very strong correlation between per capita GDP and healthy life expectancy (where the latter dominates the regression). This is confirmed by the third model, where healthy life expectancy is removed, and per capita GDP is found to be highly significant. However, the third model (which includes GDP) does not predict life satisfaction as well as the first model (which includes health instead).

7.3. Resource Use and Social Performance

Having calculated indicators to measure both biophysical stability and biophysical scale, as well as indicators to measure performance on the main social objectives described in the Paris Declaration, it is now possible to use these indicators to investigate the social performance of countries that are closer to a steady state economy, in comparison to those that are further away.

In Table 7.18, I show the social indicator data for the 22 countries that were classified as biophysically "stable" using the multi-criteria approach. There is a wide range in the social performance of biophysically stable economies—from low performers on the SPI such as Colombia and South Africa, to the very highest performers on this indicator (Switzerland and Denmark). The results illustrate that it is possible to have biophysical stability and strong social performance, as well as biophysical stability and weak social performance.

Table 7.18: Social performance of economies classified as biophysically stable.

Country	Life Sat. (0-10)	Health (Years)	Gini (0-100)	Trust (0-1)	Voice (-2.5-2.5)	Unemp. (%)	Inflat. (%)	Poverty (0-100)	Work (Hours)	SPI (0-10)
Belgium	7.3	72	26.1	0.582	1.41	8.0	2.0	..	1568	8.06
Colombia	7.7	66	51.0	0.261	-0.39	13.8	7.5	7.6	1911	3.99
Cuba	..	69	..	0.469	-1.78	3.8	..	4.6	..	..
Denmark	8.2	72	22.9	0.601	1.61	4.7	2.1	..	1574	8.84
France	6.6	73	27.3	0.524	1.23	9.8	1.7	..	1579	7.51
Hungary	5.5	66	28.2	0.508	1.13	6.9	6.9	2.2	2020	6.49
Italy	6.7	74	33.8	0.497	1.03	9.3	2.3	..	1841	7.00
Japan	6.5	76	32.2	0.599	0.96	4.5	-0.3	..	1807	8.27
Kyrgyzstan	5.5	57	34.3	0.415	-0.91	8.9	8.7	7.3	..	4.39
Macedonia	4.7	66	33.8	0.502	-0.10	34.5	2.3	3.2	..	5.03
Malta	7.1	72	28.2	0.571	1.26	7.0	2.4	..	..	7.81
Nauru	..	55	..	..	0.98	..	..	..	..	..
New Zealand	7.5	73	34.0	0.569	1.60	5.3	2.3	..	1814	7.95
Norway	7.9	73	24.5	0.581	1.57	3.7	2.0	..	1436	8.76
Paraguay	6.9	64	51.8	0.389	-0.41	7.0	8.8	10.5	1890	4.44
Poland	6.4	67	30.1	0.494	0.96	15.3	4.1	..	1983	6.33
Romania	5.7	65	28.5	0.476	0.41	6.8	23.2	5.6	..	5.60
Slovenia	6.9	71	24.8	0.560	1.10	6.5	5.7	..	1754	7.49
South Africa	5.8	48	64.5	0.335	0.68	26.6	5.3	25.4	..	3.22
Switzerland	8.0	75	28.0	0.624	1.52	3.6	0.9	..	1662	9.09
United States	7.4	70	37.0	0.505	1.28	4.9	2.6	..	1818	7.30
Uruguay	6.8	67	42.1	0.465	0.93	12.8	9.0	3.0	1733	5.55
Average	*6.8*	*67.8*	*32.6*	*0.501*	*0.73*	*7.9*	*3.6*	*6.8*	*1759*	*6.66*

Nevertheless, the results hint that there may also be a general relationship between biophysical stability and social performance. Ten of the top twenty countries on the Biophysical Stability Index also finish within the top twenty positions on the Social Performance Index. The most notable country is Switzerland, which has the second best score on the BSI and the best score on the SPI. Japan and Denmark also finish within the top ten positions on both indicators.

In addition to looking at the social performance of biophysically stable economies, it is also important to look at the social performance of economies that are close to optimal scale. In Table 7.19, I therefore show the social indicator data for the 34 countries with a per capita ecological footprint close to a fair earthshare. In general, the social performance of these countries is quite low. Moreover, there is a small range in values: the difference between the lowest and highest SPI value is only 1.59 points, compared to a range of 5.87 points for the biophysically stable economies in Table 7.18.

Table 7.19: Social performance of economies with biophysical scale close to a fair earthshare.

Country	Life Sat. (0-10)	Health (Years)	Gini (0-100)	Trust (0-1)	Voice (-2.5-2.5)	Unemp. (%)	Inflat. (%)	Poverty (0-100)	Work (Hours)	SPI (0-10)
Albania	4.6	64	29.2	0.484	-0.08	22.7	3.3	4.0	..	5.19
Algeria	5.4	62	36.0	0.493	-1.03	21.5	2.8	17.5	..	4.69
Armenia	5.0	61	39.1	0.553	-0.59	33.6	2.9	3.7	..	4.60
Azerbaijan	5.3	59	31.6	0.558	-1.03	9.3	3.6	10.7	..	5.34
Bahamas	..	65	41.2	0.381	1.09	8.8	1.9	..	..	..
Chad	5.4	40	40.2	..	-1.18	..	2.2	53.1	..	..
Colombia	7.7	66	51.0	0.261	-0.39	13.8	7.5	7.6	1911	3.99
Cuba	..	69	..	0.469	-1.78	3.8	..	4.6	..	..
Djibouti	5.7	48	39.9	0.463	-0.85	59.5	..	25.6	..	..
Dominican Rep.	7.6	63	47.1	0.395	0.10	15.9	14.1	9.1	..	4.44
Ecuador	6.4	64	52.3	0.357	-0.23	9.4	22.0	7.9	1923	3.75
Egypt	5.7	60	36.5	0.542	-1.02	9.6	5.0	23.4	..	5.06
El Salvador	6.7	61	47.0	0.296	0.05	6.9	3.0	14.6	1845	4.71
Georgia	4.3	64	38.8	0.464	-0.27	12.8	6.9	4.7	..	4.52
Ghana	5.2	50	39.4	0.423	0.14	10.3	18.7	28.1	..	3.93
Guatemala	7.2	60	52.0	0.284	-0.34	2.2	7.0	19.7	..	4.60
Guinea	4.5	47	40.6	..	-1.25	..	..	50.5	..	..
Honduras	7.0	62	51.3	0.314	-0.22	4.1	8.9	13.7	1810	4.47
Jamaica	6.7	64	49.0	0.307	0.58	13.2	9.5	10.9	..	4.28
Jordan	5.9	63	38.1	0.530	-0.57	14.6	2.5	6.6	..	5.34
Madagascar	3.7	52	42.9	0.368	-0.03	4.7	10.2	36.1	..	3.80
Mali	4.7	42	43.3	0.430	0.21	6.1	1.6	54.5	..	4.49
Myanmar	..	50	..	0.510	-2.10	..	22.8	20.4	..	..
Nicaragua	7.1	64	50.3	0.368	-0.11	8.8	..	17.0	1935	..
Nigeria	5.7	42	46.8	0.388	-0.76	..	12.5	36.2	..	..
Papua N. Guinea	..	56	49.3	0.311	-0.04	..	8.9	39.6	..	..
Peru	6.2	67	52.2	0.384	-0.09	7.9	2.5	10.2	2048	4.87
Sudan	5.0	50	..	0.339	-1.68	..	8.7	34.0	..	..
Swaziland	..	42	49.5	0.305	-1.35	22.5	7.3	35.1	..	..
Syria	5.9	63	..	0.575	-1.60	9.6	2.7	12.6	..	..
Tunisia	5.9	66	40.9	0.463	-0.96	14.9	2.9	15.6	..	4.83
Uganda	4.8	42	41.0	0.392	-0.70	3.2	4.5	28.8	..	4.05
Uzbekistan	6.0	59	35.5	0.474	-1.79	..	..	8.5	..	..
Vanuatu	..	61	..	..	0.58	..	2.4	23.6	..	..
Average	*5.8*	*57*	*43.2*	*0.415*	*-0.57*	*9.6*	*5.7*	*19.1*	*1912*	*4.55*

These results hint that there may also be a relationship between biophysical scale and social performance. This relationship may be investigated visually using a rather novel approach. Data from the Social Accounts may be overlaid on the pathway plot developed in Section 7.1.3 to provide a graphical picture of the social performance of countries as they move towards a steady state economy. The revised pathway plot in Figure 7.8 shows life satisfaction in each country using colour-coded points. Within the plot countries are divided into four roughly equal-sized groups: *happy* (life satisfaction greater than 7 out of 10), *relatively happy* (6 to 7), *relatively unhappy* (5 to 6), and *unhappy* (less than 5).

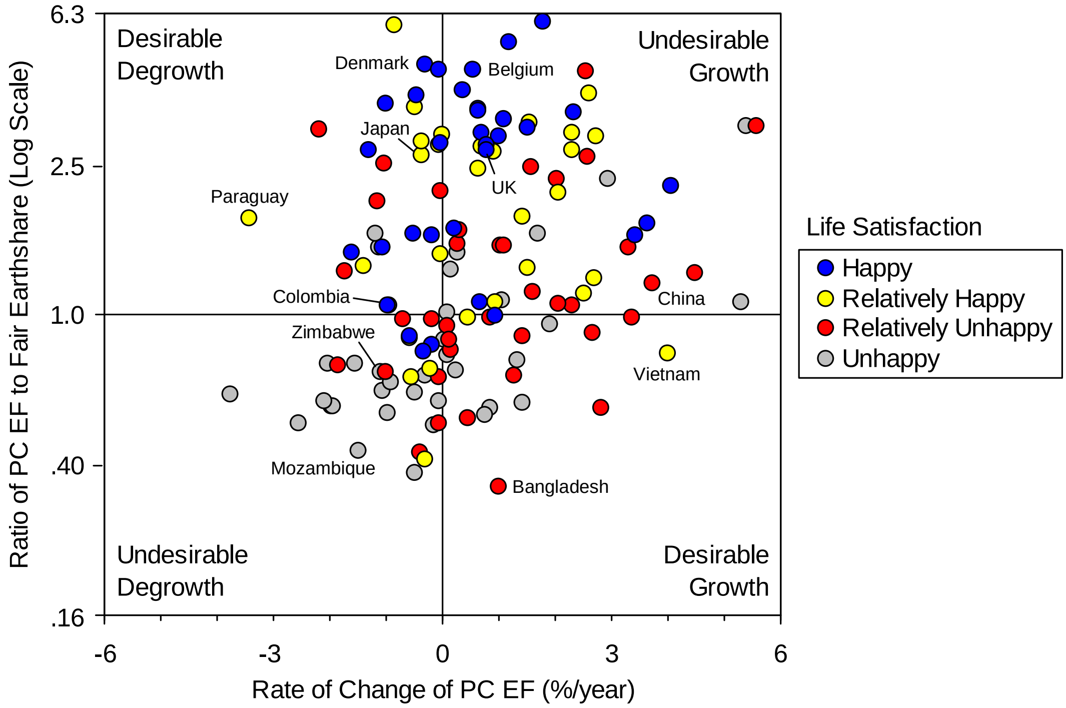

Figure 7.8: The rate of change of per capita ecological footprint vs. biophysical scale (as measured by the ratio of per capital ecological footprint to a fair earth-share). Points are colour-coded according to life satisfaction. *N* = 137.

The pathway plot clearly shows a correlation between biophysical scale and human well-being. Countries with a large per capita ecological footprint tend to score highly on life satisfaction (most of the blue points are near the top of the plot), while countries with a small per capita footprint tend to score poorly (most of the grey points are near the bottom). In this plot, however, there is no obvious relationship between the rate of change of per capita ecological footprint and life satisfaction.

In the next two subsections, I investigate the relationship between resource use and social performance further. I use a number of statistical techniques to test for a relationship between both biophysical stability and social performance, and biophysical scale and social performance.

7.3.1. Stability and Social Performance

To test for a relationship between biophysical stability and social performance, I use two different methods. First I place countries into four groups based on their performance on the biophysical rate-of-change indicators, and investigate whether there is a statistically significant difference between the groups in terms of their average scores on the nine social indicators (a comparison of means). Second, I test whether there is any correlation between a country's performance on the Biophysical Stability Index and its performance on the social indicators.

Comparison of Means

For the comparison of means, I place countries into the following groups: partial degrowth, stable, partial growth, and growth. These groups correspond to the groups used in the multi-criteria categorisation (see Table 7.2), except that I have merged the "degrowth" and "partial degrowth" groups into a single "partial degrowth" group due to the small number of countries in these two groups. The four resulting groups include 174 of the 181 countries in the accounts. The seven countries categorised as "mixed" are not included in the analysis. I perform the comparison of means using all available data for each of the nine social indicators, and I test for statistical significance using analysis of variance (ANOVA).

The results (Table 7.20) show that there is a statistically significant relationship between the biophysical stability groups and five of the social indicators (life satisfaction, health, inequality, democracy, and poverty). The strongest relationships involve inequality and democracy. In general countries in the "stable" group perform better on the social indicators than countries in the two shoulder groups ("partial degrowth" and "partial growth"), who in turn perform better than countries in the "growth" group (Figure 7.9).

Table 7.20: Comparison of means and analysis of variance for the nine indicators in the Social Accounts, grouped according to biophysical stability.

Indicator	*F*		Group	*N*	Mean	SE
Life satisfaction	**3.466**	*****	Partial Degrowth	9	5.9	0.5
			Stable	20	6.8	0.2
			Partial Growth	9	5.8	0.5
			Growth	102	5.7	0.1
			All	*140*	*5.9*	*0.1*
Healthy life expectancy	**7.937**	*******	Partial Degrowth	9	62.4	3.7
			Stable	22	67.8	1.5
			Partial Growth	19	62.2	1.7
			Growth	124	57.9	0.9
			All	*174*	*59.9*	*0.7*
Gini coefficient	**10.892**	*******	Partial Degrowth	8	32.4	2.4
			Stable	19	32.6	1.9
			Partial Growth	16	35.0	2.0
			Growth	103	41.1	0.7
			All	*146*	*38.9*	*0.7*
Interpersonal safety and trust	1.486	ns	Partial Degrowth	9	0.458	0.028
			Stable	21	0.501	0.020
			Partial Growth	14	0.479	0.021
			Growth	99	0.456	0.010
			All	*143*	*0.465*	*0.008*
Voice and accountability	**10.868**	*******	Partial Degrowth	9	0.49	0.34
			Stable	22	0.73	0.19
			Partial Growth	19	0.19	0.22
			Growth	124	-0.33	0.08
			All	*174*	*-0.10*	*0.07*
Unemployment rate	0.227	ns	Partial Degrowth	9	8.6	1.0
			Stable	21	7.9	1.1
			Partial Growth	14	7.9	1.3
			Growth	97	7.3	0.6
			All	*141*	*7.6*	*0.4*
Inflation rate	1.081	ns	Partial Degrowth	8	4.0	1.4
			Stable	20	3.6	0.8
			Partial Growth	15	3.7	0.7
			Growth	102	5.0	0.4
			All	*145*	*4.6*	*0.3*
Human Poverty Index	**5.716**	******	Partial Degrowth	4	12.3	5.9
			Stable	9	6.8	1.9
			Partial Growth	12	10.6	3.4
			Growth	102	20.7	1.5
			All	*127*	*18.2*	*1.3*
Annual working hours	1.818	ns	Partial Degrowth	4	1645	72
			Stable	15	1759	43
			Partial Growth	4	1811	138
			Growth	23	1838	31
			All	*46*	*1793*	*25*

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. Statistically significant results are shown in bold. SE is the standard error of the mean.

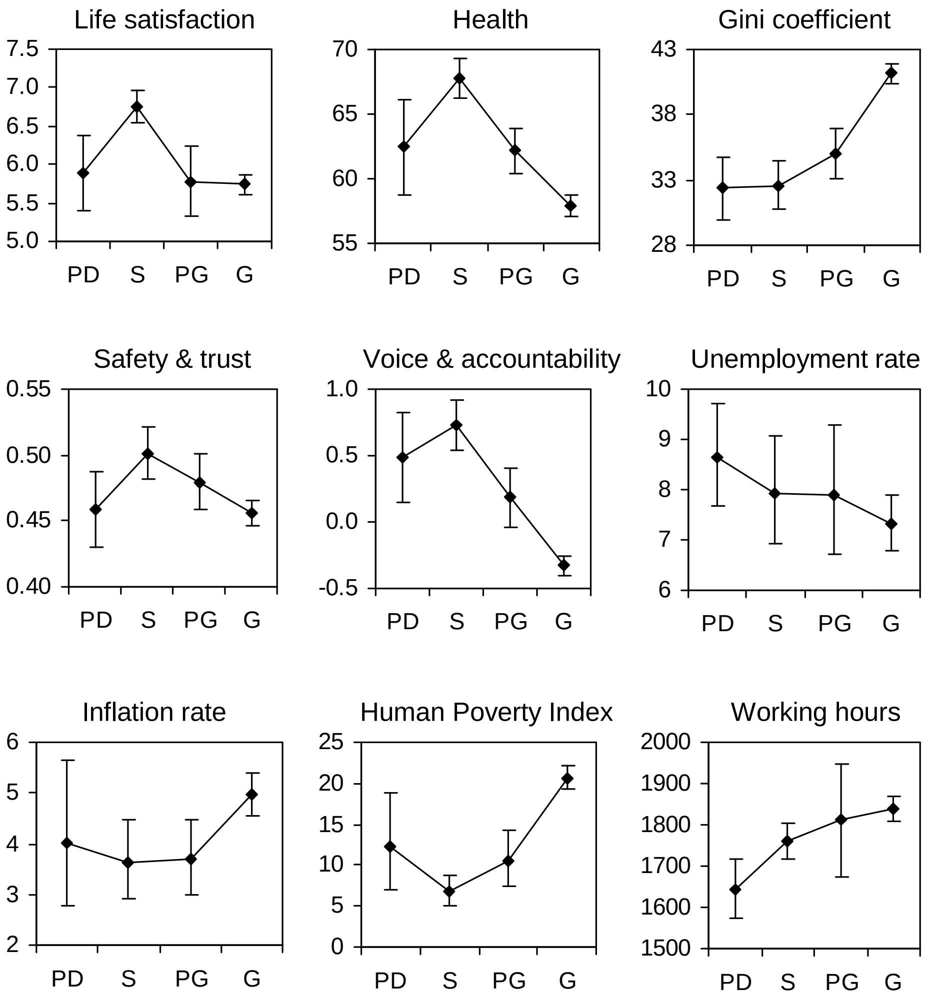

Figure 7.9: Means plots (with standard errors) for the nine indicators in the Social Accounts, grouped according to biophysical stability. Note: PD = Partial Degrowth, S = Stable, PD = Partial Growth, G = Growth.

Interestingly, countries in the two shoulder groups ("partial degrowth" and "partial growth") perform similarly to each other on the social indicators. In fact, there is not a statistically significant difference between the two shoulder groups for any of the social indicators. Whether an economy is partially growing or partially degrowing does not seem to matter—it is stability that is important to social performance.

By contrast, there is almost always a significant difference between the "stable" group and the "growth" group. The biophysically stable economies have higher life satisfaction, better health, lower inequality, stronger democracy, and less poverty than the growing economies. Average life satisfaction in stable economies is a full point higher than in growing economies (6.8 versus 5.7 out of

10), while healthy life expectancy is almost ten years longer (68 versus 58 years). Furthermore, although the ANOVA suggests that the biophysical groups do not explain the variation in the interpersonal safety and trust indicator, the means plot for this indicator shows that safety and trust is significantly higher in stable economies than growing economies (Figure 7.9).

Finally, the comparison of means also reveals that there is no statistically significant relationship between biophysical growth and the unemployment rate. The average unemployment rate in biophysically stable economies (7.9%) is almost the same as the average unemployment rate in growing economies (7.3%). The variation in the unemployment rate within the four groups is greater than the variation between them.

Correlation Analysis

The second method that I use to evaluate the relationship between biophysical stability and social performance is to examine the degree of correlation between performance on the Biophysical Stability Index and performance on the social indicators. There are advantages and disadvantages of the correlation method compared to the comparison of means method. One of the advantages of the comparison of means is that it uses almost all of the available data, considering 174 of the 181 countries in the accounts. The correlation method, on the other hand, uses a limited subset of the data since the BSI is only available for 137 countries. The comparison of means is also able to reveal a wider range of possible relationships between the groups and the social indicators than the BSI. The inverted-V-shaped relationship shown in many of the means plots suggests a non-linear relationship between biophysical growth rates and social performance, with stable economies performing better than either growing or degrowing economies. Since the BSI measures the distance from stability (effectively treating growth and degrowth the same), it is also a very good indicator for testing for this kind of relationship. (A positive linear correlation between the BSI and life satisfaction, for example, would actually suggest an inverted-V-shaped relationship between biophysical growth and well-being.)

The main advantage of the correlation method over the comparison of means is that it treats biophysical growth as a continuous variable, and thus avoids the arbitrariness that is involved in choosing thresholds to classify countries. Although the correlation method considers fewer countries, it uses more information within the data. The correlation method also measures something slightly different than the comparison of means. While the comparison of means assesses stability based on how many indicators are stable, the correlation method assesses stability based on the average value of these indicators. Thus it is less forgiving of one or two high values among the seven indicators than the comparison of means method.

I calculate Spearman's correlation between the BSI and each of the nine social indicators. The results paint a similar picture to the comparison of means. Greater biophysical stability (i.e. a lower score on the BSI) is associated with higher life satisfaction, better health, lower inequality, greater voice/accountability, and less poverty. The strongest correlations are with health and voice/accountability, while there is no significant correlation between biophysical stability and safety/trust, unemployment, inflation, or working hours.

Table 7.21: Correlation between the Biophysical Stability Index (BSI) and the nine indicators in the Social Accounts (Spearman's ρ).

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
BSI	**-.411**	**-.521**	.305	-.102	**-.518**	-.097	.099	**.431**	.268
	***	***	***	ns	***	ns	ns	***	ns
	127	*137*	*126*	*124*	*137*	*118*	*121*	*102*	*46*

Note: *** $p < .001$, 'ns' not significant. *N* for each correlation is shown in italics. The strongest correlations ($|\rho| \geq .4$) are shown in bold.

The relationship between biophysical stability and inequality is somewhat weaker according to the correlation analysis than the comparison of means. This result makes sense given the shape of the means plot for inequality, which does not follow the V-shape (or inverted-V shape) of the other strong correlates. It suggests that inequality would be more closely correlated with an indicator that differentiates between growth and degrowth, than one that simply measures the distance from biophysical stability.

Given that there is a correlation between the BSI and a number of the social indicators, it seems likely that there would also be a correlation between the BSI and the Social Performance Index, since the latter is composed of seven of the nine social indicators. I calculate Spearman's ρ for the 97 countries where data are available for both indices, and find that there is a moderate negative correlation (ρ = -.459, significant at $p < .001$) between the two indices. In other words, greater biophysical stability (i.e. a lower BSI) is associated with higher social performance. Figure 7.10 provides a scatter plot showing the relationship between the two indices.

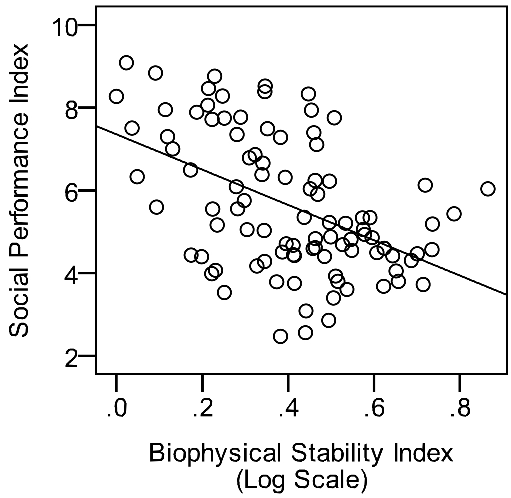

Figure 7.10: Relationship between the Biophysical Stability Index and the Social Performance Index. N = 97.

Which Rates of Change Are Most Important?

The comparison of means and the correlation analysis have suggested that there is a relationship between biophysical stability and performance on several of the indicators in the Social Accounts. Until this point, however, biophysical stability has been measured in an aggregate sense by either placing countries into one of four groups based on their performance on the biophysical indicators, or aggregating the biophysical indicators together into an index. The question that remains is whether stability in some of the biophysical indicators is more important to social performance than stability in others. In order to answer this question, I examine the correlation between each of the biophysical rate-of-change indicators and each of the social indicators.

The results presented earlier in Figure 7.9 suggest that the relationship between biophysical rates of change and social performance may not be linear for many of the social indicators. For example, it appears that life satisfaction is highest when stocks and flows are stable, and lower when there is biophysical growth *or* degrowth (an inverted-V-shaped relationship). In order to test for this type of non-linear relationship between individual indicators, I perform two correlations for each pair of biophysical rate-of-change indicators and social indicators. The first is a simple correlation between the biophysical rate-of-change indicator and the social indicator. This correlation tests the extent to which a monotonic increase in one variable is matched by a monotonic increase in the other. The second is the correlation between the absolute value of the rate-of-change indicator and the social indicator. The absolute value correlation treats growth and degrowth the same, and thus tests for V-shaped (or inverted-V-shaped) relationships in the data. In addition to the correlation between the rate of change of the biophysical indicators and the social indicators, I also calculate the correlation between the rate of change of GDP and the social indicators.

Within the table of results (Table 7.22), I show whichever of the two correlation coefficients (simple or absolute value) is greater. If the correlation coefficient is underlined, then the absolute value correlation is stronger (implying a V-shaped or inverted V-shaped-relationship). If the correlation coefficient is shown in plain text, then the simple correlation is stronger (implying a monotonically-increasing or monotonically-decreasing relationship). To aid in the interpretation of the results, I also present a table that depicts the shape of the relationship between each pair of indicators (Table 7.23).

In general, the results (Tables 7.22 and 7.23) show that higher biophysical growth rates are associated with lower social performance across all indicators, with the exception of three statistically significant correlations involving the unemployment rate. Growth in population, energy use, and CO_2 emissions are associated with lower unemployment (a positive social outcome). However, the three unemployment correlations are very weak, and only marginally significant.

Table 7.22: The correlation between rate-of-change indicators and social indicators (Spearman's ρ).

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
ΔPopulation	-.371	**-.571**	**.548**	-.243	**-.509**	-.240	.122	**.690**	.095
	***	***	***	**	***	**	ns	***	ns
	143	*181*	*153*	*148*	*181*	*148*	*155*	*131*	*48*
ΔLivestock	-.341	**-.435**	.327	-.179	**-.446**	-.095	.121	.357	.174
	***	***	***	*	***	ns	ns	***	ns
	143	*181*	*153*	*148*	*181*	*148*	*155*	*131*	*48*
ΔLights	-.235	-.273	.297	.043	-.379	.060	.067	.189	.392
	**	***	***	ns	***	ns	ns	*	**
	136	*149*	*137*	*133*	*149*	*127*	*132*	*112*	*47*
ΔMaterials	-.164	-.160	.128	.076	-.226	.017	.163	.045	.347
	ns	*	ns	ns	**	ns	*	ns	*
	141	*178*	*151*	*146*	*178*	*146*	*153*	*131*	*47*
ΔEnergy	-.165	-.306	.339	-.066	-.278	-.209	.053	.276	.388
	*	***	***	ns	***	*	ns	**	**
	142	*179*	*151*	*147*	*179*	*147*	*154*	*129*	*48*
ΔCO_2	-.393	-.322	.293	-.162	-.351	-.177	.122	.180	.222
	***	***	***	*	***	*	ns	*	ns
	143	*180*	*151*	*148*	*180*	*148*	*155*	*130*	*48*
ΔEF	-.158	-.137	.059	.144	-.287	.038	-.107	.114	.112
	ns	ns	ns	ns	***	ns	ns	ns	ns
	136	*167*	*143*	*139*	*167*	*138*	*142*	*122*	*47*
ΔGDP	-.313	-.204	-.009	.065	-.284	-.091	.166	-.027	**.455**
	***	**	ns	ns	***	ns	*	ns	**
	139	*169*	*149*	*144*	*169*	*143*	*149*	*122*	*48*

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. N for each correlation is shown in italics. Correlation coefficients that are underlined are absolute value correlations; others are simple monotonic correlations. The strongest correlations ($|\rho| \geq .4$) are shown in bold.

Table 7.23: The shape of the relationship between rate-of-change indicators and social indicators.

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
ΔPopulation	∧	∧	∨	∧	∧	╲		╱	
ΔLivestock	∧	╲	╱	∧	╲			╱	
ΔLights	∧	╲	╱		╲			╱	╱
ΔMaterials		∧			╲		╲		╱
ΔEnergy	∧	∧	∨		∧	∧		∨	╱
ΔCO_2	∧	∧	╱	∧	∧	╲		∨	
ΔEF					∧				
ΔGDP	∧	∧			∧		∨		╱

Note: The symbols show the shape of the relationship between variables. Only statistically significant correlations ($p < .05$) are shown.

Of the seven biophysical rate-of-change indicators, the rate of change of population is most strongly correlated with social performance, and the relationship is largely non-linear. Countries with a stable population are in general better places to live than countries with either an increasing or decreasing population. They have higher life satisfaction, better health, lower inequality, higher safety/trust, and greater voice/accountability. The strongest correlation between any two indicators, however, is a linear correlation between population growth and poverty (ρ = .690, p < .001). The higher the rate of population growth, the more poverty there is (and vice versa).

Interestingly, the rate of change of livestock is the second strongest correlate of social performance. It seems somewhat strange that a change in the number of domesticated animals could have an influence on a social indicator such as voice and accountability (or vice versa), but this is one of the strongest relationships in the correlation matrix. However, as we shall see in the next subsection, this may be a spurious correlation that simply reflects the relatively strong relationship between human population growth and livestock population growth.

The correlations involving night-time lights, energy use, and CO_2 emissions all have a similar magnitude. The relationship between night-time lights and social performance is largely linear (the strongest social performance is associated with decreasing built capital), while the relationships involving energy use and CO_2 emissions are largely non-linear (the strongest social performance is associated with the stability of these indicators).

The weakest correlations are with material use and ecological footprint. There is no significant relationship between the rate of change of the ecological footprint and any of the social indicators, with the exception of voice and accountability. The rate of change of material use also shows little relationship to social performance.

The correlations between the rate of change of GDP and the social indicators are stronger than the correlations involving ecological footprint or material use, but weaker than the other biophysical correlations. The strongest correlation between the rate of change of GDP and a social indicator is between GDP growth and working hours (higher GDP growth is associated with longer working hours). Notably, there is no significant correlation between the rate of GDP growth and the level of unemployment.

Viewing the results from the other direction, the social indicators that are most strongly correlated with the biophysical indicators are voice/accountability, health, and inequality, while those most weakly correlated are inflation and unemployment. There is a positive correlation between working hours and three of the biophysical indicators (night-time lights, material use, and energy use). Higher growth rates in these indicators are associated with longer working hours. Interestingly, life satisfaction shows an inverted-V-shaped relationship with every biophysical rate-of-change indicator. Biophysical stability, regardless of how it is measured, is consistently associated with higher well-being.

Per Capita Rates of Change

The results above suggest that there is a relationship between biophysical stability and social performance, where biophysical stability is measured according to the rate of change of total stocks and flows. This is the truest definition of stability for a steady state economy, and it is encouraging to see a positive relationship between stability measured in this way and social performance.

Another way to measure the rate of change of stocks and flows, however, is in *per capita* terms (e.g. the rate of change of energy use per person). Although per capita measures are not appropriate for measuring biophysical stability (from an ecosystem perspective), one would expect there to be a stronger relationship between per capita rates of change and social performance, since per capita measures should more closely reflect how the biophysical resources available to people are changing over time.

In order to test this hypothesis, I repeat the correlation analysis from the previous subsection using per capita rates of change instead of total rates of change. I calculate per capita rates of change for all of the biophysical indicators, as well as GDP (see Tables A.2 and A.3 in the Appendix for per capita rate-of-change data).

In general, the results (Tables 7.24 and 7.25) do not show a stronger relationship between per capita measures and social performance. There are only two rate-of-change indicators where the correlation coefficients are stronger in the per capita rate-of-change analysis than in the total rate-of-change analysis: ecological footprint and material use. Moreover, these two indicators show very similar behaviour to one another. Viewing the correlation matrix from the other direction, there is only one social indicator (working hours) where the correlations are stronger in the per capita analysis than in the total rate-of-change analysis. Longer working hours are associated with higher per capita rates of change.

Table 7.24: Correlation between per capita rate-of-change indicators and social indicators (Spearman's ρ).

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
ΔPC Livestock	-.121	-.175	.086	-.072	-.222	<u>.076</u>	-.086	<u>-.185</u>	.178
	ns	*	ns	ns	**	ns	ns	*	ns
	143	*181*	*153*	*148*	*181*	*148*	*155*	*131*	*48*
ΔPC Lights	<u>-.293</u>	<u>-.263</u>	.096	.027	<u>-.266</u>	.196	<u>.181</u>	<u>.233</u>	**.404**
	***	**	ns	ns	**	*	*	*	**
	136	*149*	*137*	*133*	*149*	*127*	*132*	*112*	*47*
ΔPC Materials	.059	.188	-.185	.184	<u>-.097</u>	<u>.191</u>	<u>.158</u>	-.304	.296
	ns	*	*	*	ns	*	ns	***	*
	141	*177*	*150*	*146*	*177*	*146*	*153*	*130*	*47*
ΔPC Energy	<u>-.262</u>	<u>-.261</u>	<u>.169</u>	<u>-.158</u>	<u>-.225</u>	-.071	<u>.101</u>	<u>.115</u>	<u>**.459**</u>
	**	***	*	ns	**	ns	ns	ns	**
	141	*178*	*150*	*146*	*178*	*146*	*153*	*128*	*48*
ΔPC CO_2	<u>**-.403**</u>	<u>-.328</u>	<u>.185</u>	<u>-.162</u>	<u>-.360</u>	-.076	<u>.122</u>	<u>.186</u>	.298
	***	***	*	*	***	ns	ns	*	*
	143	*180*	*152*	*148*	*180*	*148*	*155*	*130*	*48*
ΔPC EF	.139	.303	-.343	.303	.059	<u>.198</u>	<u>-.146</u>	-.366	<u>.310</u>
	ns	***	***	***	ns	*	ns	***	*
	137	*168*	*143*	*140*	*168*	*139*	*143*	*123*	*47*
ΔPC GDP	<u>-.164</u>	.081	-.261	.168	<u>-.090</u>	<u>.044</u>	<u>.143</u>	-.295	.345
	ns	ns	**	*	ns	ns	ns	***	*
	140	*170*	*150*	*144*	*170*	*144*	*149*	*123*	*48*

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. N for each correlation is shown in italics. Correlation coefficients that are underlined are absolute value correlations; others are simple monotonic correlations. The strongest correlations ($|\rho| \geq .4$) are shown in bold.

Table 7.25: Shape of the relationship between per capita rate-of-change indicators and social indicators.

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
ΔPC Livestock		╲			╲			∧	
ΔPC Lights	∧	∧			∧	╱	∨	∨	╱
ΔPC Materials		╱	╲	╱		∨		╲	╱
ΔPC Energy	∧	∧	∨		∧				∨
ΔPC CO_2	∧	∧	∨	∧	∧			∨	╱
ΔPC EF		╱	╲	╱		∨		╲	∨
ΔPC GDP			╲	╱				╲	╱

Note: The symbols show the shape of the relationship between variables. Only statistically significant correlations ($p < .05$) are shown.

The relationship between per capita livestock growth and social performance is particularly weak. This suggests that the correlation between total livestock growth and social performance seen in Table 7.22 is a spurious relationship that results from the relatively strong correlation between human population growth and livestock population growth (see Table 7.9). Once population growth is controlled for, the correlation between livestock growth and social performance largely disappears.

In general, there is somewhat less consistency across indicators in the per capita rate-of-change results than in the total rate-of-change results. There appear to be two distinct—and opposing—patterns. For one group of indicators (night-time lights, energy use, and CO_2 emissions), the best social performance is associated with per capita stability. Per capita stability in these three indicators is associated with higher life satisfaction, better health, lower inequality, greater voice/accountability, and less poverty. However, for a second group of indicators (material use, ecological footprint, and GDP), the best social performance is associated with per capita growth. Higher per capita growth in these three indicators is associated with better health, lower inequality, greater safety/trust, less poverty, and longer working hours. Interestingly, stability in per capita material use and per capita ecological footprint is associated with the lowest unemployment, but there is no statistically significant relationship between per capita GDP growth and the unemployment rate.

7.3.2. Scale and Social Performance

A steady state economy is not just an economy where stocks and flows are stable over time. It is also an economy where the level of flows is within the carrying capacity of ecosystems. The second important relationship between biophysical and social indicators to investigate is the relationship between the biophysical scale of the economy and its social performance.

In order to investigate whether there is a relationship between biophysical scale and social performance, I use two different techniques, which roughly parallel the methods used to investigate the relationship between biophysical stability and social performance. First, I compare the average social performance of four groups of countries with different biophysical scale, using analysis of variance (ANOVA) to test for a statistically significant difference between groups (a comparison of means). Second, I test whether there is any correlation between a country's performance on the biophysical scale indicator and its performance on each of the social indicators.

Comparison of Means

For the comparison of means, I classify countries into four groups based on their performance on the biophysical scale indicator (i.e. the ratio of per capita ecological footprint to a fair earthshare). The groups are *small* (less than 0.8 times a fair earthshare), *optimal* (0.8 to 1.2 times a fair earthshare), *large* (1.2 to 2.5 times a fair earthshare), and *very large* (greater than 2.5 times a fair earthshare). These groups correspond to the groups used in the previous scale categorisation (see Table 7.5), except that I have split the "large" group into two separate groups due to the sizeable number of countries it contains. The four resulting groups include 180 of the 181 countries in the accounts.

The results (Table 7.26) show that there is a statistically significant relationship between biophysical scale (as measured by per capita ecological footprint) and all nine of the social indicators. The strongest relationship is with healthy life expectancy, while the weakest relationship is with unemployment. In general, the larger a country's per capita ecological footprint, the better its social performance (Figure 7.11).

The relationship between biophysical scale and four of the indicators (life satisfaction, healthy life expectancy, voice/accountability, and poverty) appears to be monotonic, with higher biophysical scale associated with better scores on these indicators. On average, countries with a "very large" ecological footprint enjoy life satisfaction values more than two full points higher, and healthy life expectancies almost 20 years longer, than countries with a "small" footprint.

For three of the indicators (inequality, safety/trust, and unemployment), there appears to be a V-shaped (or inverted V-shaped) relationship between scale and social performance. In all three cases the best performance is achieved at very large scale, and the worst performance is achieved at optimal scale. For example, the average Gini coefficient is almost 12 points lower in countries with very large scale than in countries with optimal scale, while the average unemployment rate is close to 3% lower. Interestingly, the unemployment rate in countries with small scale is also relatively low.

For the two remaining social indicators (inflation and working hours) the best performance is achieved at very large scale, with worse (and statistically indistinguishable) performance at the other scales. For example, the inflation rate is about 3% lower on average in countries with very large scale than countries with optimal scale, while average working hours are almost 200 hours less per year. Unfortunately there are no working hours data available for countries with small biophysical scale (and only six countries at optimal scale), which limits the conclusions that can be drawn from this indicator.

Table 7.26: Comparison of means and analysis of variance for the nine indicators in the Social Accounts, grouped according to bio-physical scale.

Indicator	*F*	Group	*N*	Mean	SE
Life satisfaction	**34.332** ***	Small	37	4.6	0.2
		Optimal	28	5.8	0.2
		Large	36	6.1	0.2
		Very Large	42	6.9	0.1
		All	*143*	*5.9*	*0.1*
Healthy life expectancy	**65.134** ***	Small	48	50.4	1.1
		Optimal	34	57.3	1.5
		Large	51	61.5	0.8
		Very Large	47	69.4	0.7
		All	*180*	*59.8*	*0.7*
Gini coefficient	**22.119** ***	Small	41	41.5	1.0
		Optimal	29	43.2	1.2
		Large	40	40.1	1.4
		Very Large	40	31.3	0.9
		All	*150*	*38.7*	*0.7*
Interpersonal safety and trust	**23.128** ***	Small	32	0.417	0.014
		Optimal	31	0.415	0.016
		Large	38	0.452	0.013
		Very Large	46	0.540	0.009
		All	*147*	*0.464*	*0.008*
Voice and accountability	**37.386** ***	Small	48	-0.79	0.09
		Optimal	34	-0.57	0.13
		Large	51	0.08	0.11
		Very Large	47	0.77	0.13
		All	*180*	*-0.09*	*0.07*
Unemployment rate	**5.309** **	Small	31	6.8	0.9
		Optimal	25	9.6	1.3
		Large	44	9.5	1.0
		Very Large	45	5.9	0.5
		All	*145*	*7.7*	0.4
Inflation rate	**11.917** ***	Small	34	5.9	0.9
		Optimal	29	5.7	0.8
		Large	41	6.1	0.8
		Very Large	45	2.4	0.2
		All	*149*	*4.6*	0.3
Human Poverty Index	**22.505** ***	Small	45	30.0	1.9
		Optimal	33	19.1	2.5
		Large	39	10.6	1.6
		Very Large	14	7.6	1.8
		All	*131*	*18.2*	1.3
Annual working hours	**7.628** **	Small	0	..	..
		Optimal	6	1912	34
		Large	13	1898	39
		Very Large	28	1726	31
		All	*47*	*1797*	*25*

Note: *** $p < .001$, ** $p < .01$. Statistically significant results are shown in bold. SE is the standard error of the mean.

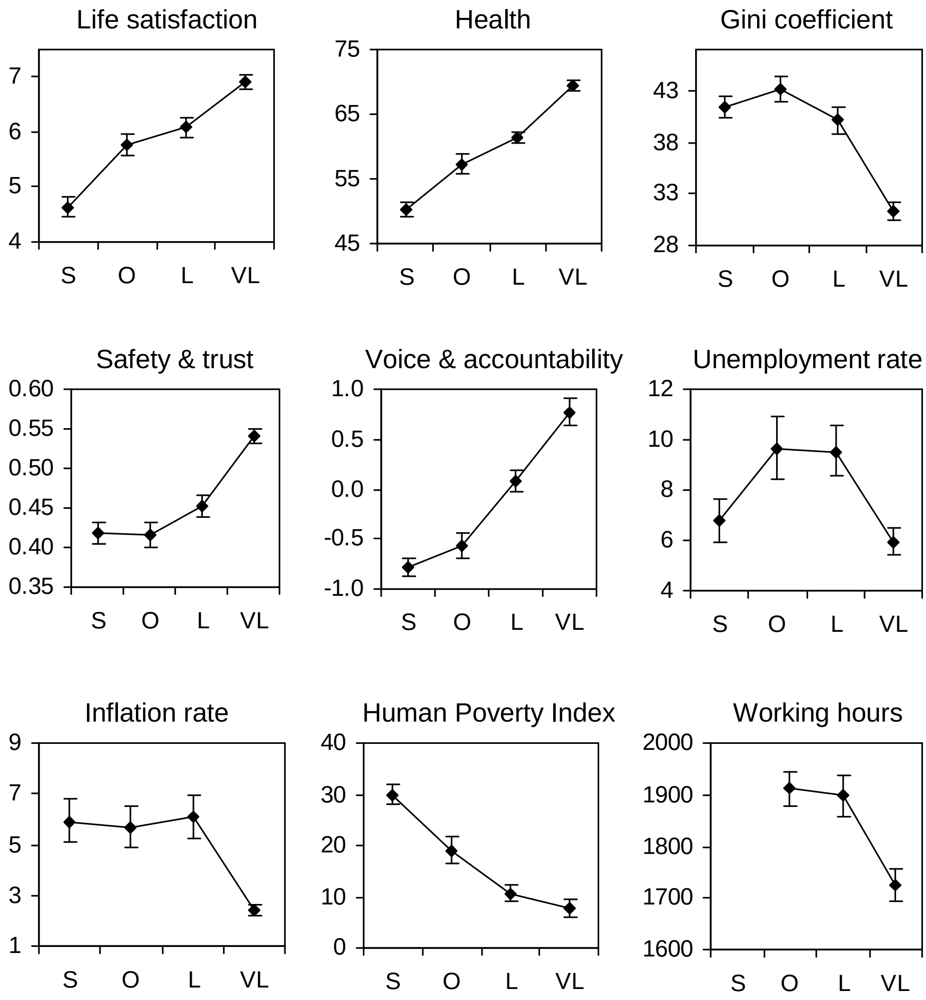

Figure 7.11: Means plots (with standard errors) for the nine indicators in the Social Accounts, grouped according to biophysical scale. Note: S = Small, O = Optimal, L = Large, VL = Very Large.

Correlation Analysis

To further investigate the relationship between biophysical scale and social performance, I test whether there is any correlation between a country's performance on the scale indicator and its performance on each of the social indicators.

The results (Table 7.27) show that there is a statistically significant correlation between biophysical scale and all of the social indicators, with the exception of the unemployment rate. Larger biophysical scale is associated with higher life satisfaction, better health, less inequality, higher safety/trust, greater voice/accountability, less poverty, fewer working hours, and—to some extent—lower inflation. The social indicator that is most strongly correlated with biophysical scale is healthy life expectancy.

Table 7.27: Correlation between biophysical scale (as measured by per capita ecological footprint) and the nine indicators in the Social Accounts (Spearman's ρ).

	Life Sat.	Health	Gini	Trust	Voice	Unemp.	Inflat.	Poverty	Work
Ratio of PC EF to FES	**.659**	**.766**	-.491	.547	**.609**	-.127	-.381	**-.646**	-.482
	***	***	***	***	***	ns	***	***	***
	143	*180*	*153*	*147*	*180*	*147*	*154*	*131*	*48*

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. N for each correlation is shown in italics. The strongest correlations ($|\rho| \geq .6$) are shown in bold.

Given that there is a correlation between per capita ecological footprint and all of the social indicators (except for the unemployment rate), it seems likely that there would also be a correlation between per capita ecological footprint and the Social Performance Index. This is indeed the case: there is a strong positive correlation ($\rho = .760$, $p < .001$) between per capita footprint and the SPI (see Figure 7.13).

Sufficiency Analysis

The strong relationship between biophysical scale and social performance is a worrying finding for achieving an economy that is both socially and environmentally sustainable. It immediately raises the issue of the shape of the relationship. Does social performance increase linearly with biophysical scale, or are there diminishing returns? What per capita ecological footprint is necessary to achieve a score on the social indicators that is sufficient for a good life?

In order to investigate whether social gains diminish as per capita ecological footprint grows, I fit two regression models to the data for each of the social indicators: a linear model of the form $y = b_0 + b_1x$, and a semi-logarithmic model of the form $y = b_0 + b_1\ln(x)$. Of the two models, I choose the one with the highest R^2 value and the most normally-distributed residuals as the more accurate reflection of the relationship between social performance and resource use.

For three of the indicators (unemployment rate, inflation rate, and working hours), neither of the models explains more than 20% of the variance in the data. Performance on these indicators appears to be largely unrelated to the biophysical scale of the economy. Of the remaining six indicators, a semi-logarithmic model provides the best fit for four of the indicators, while a linear model provides the best fit for the other two (Figure 7.12). Thus it would seem that the general behaviour is for social gains to level off somewhat as biophysical scale increases, although not in all cases.

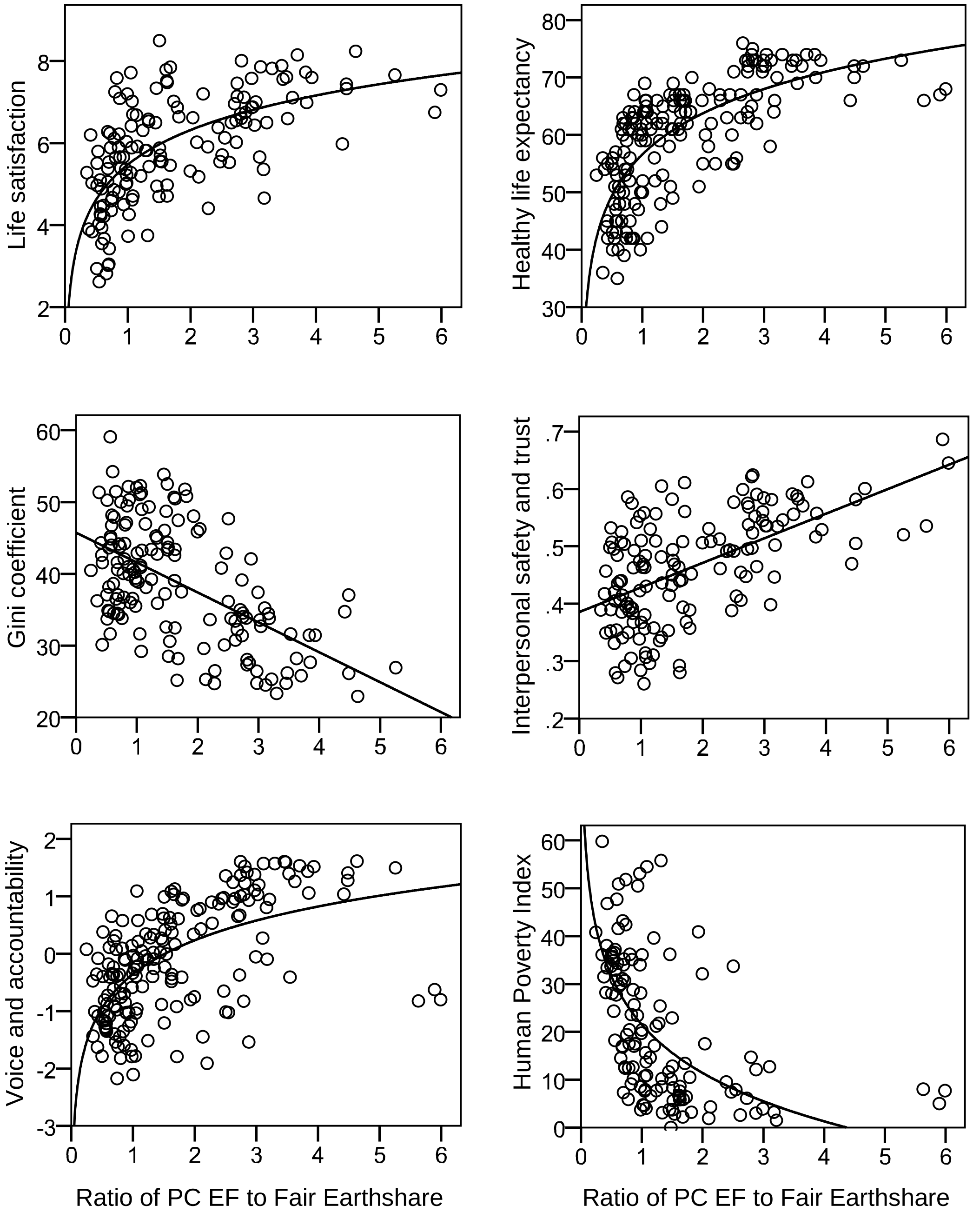

Figure 7.12: Relationship between biophysical scale (as measured by the ratio of per capita ecological footprint to a fair earthshare) and the six most strongly correlated social indicators. Note: Regression lines show the best-fit model (either linear or semi-logarithmic), as determined using OLS regression.

Interestingly, the relationship between per capita ecological footprint and the Social Performance Index appears to be more linear than logarithmic (Figure 7.13).

The R^2 value of the linear model (0.646) is somewhat higher than the semi-logarithmic model (0.594). Given that the SPI is only calculated for countries where data for seven of the nine social indicators are available, the SPI regressions do not include as many data points, which could have an effect on the shape of the relationship. The SPI also excludes the Human Poverty Index, which has a strongly logarithmic shape.

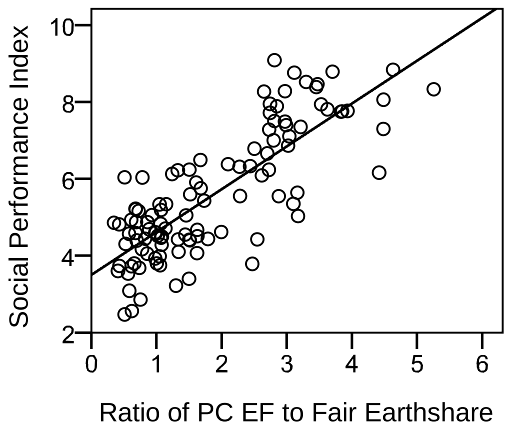

Figure 7.13: Relationship between biophysical scale (as measured by the ratio of per capita ecological footprint to a fair earthshare) and the Social Performance Index. $N = 108$.

Using the equation for the best-fit curve in each of the plots, it is possible to estimate the per capita ecological footprint associated with a given score on each social indicator. For each indicator, I choose a relatively high target score that might be considered a sufficient value for "a good life" (e.g. a score of 7 out of 10 on life satisfaction). While chosen rather subjectively, each of these target scores is about one standard deviation above the mean of the indicator.

The results of this simple extrapolation (Table 7.28) are somewhat troubling. The per capita ecological footprint associated with a good life is over three times a fair earthshare for all indicators, including the SPI. The level of resource use associated with a sufficient score on the voice and accountability indicator is particularly large (although this is likely due to the influence of three apparent outliers on the regression curve; see Figure 7.12). The implications of these findings are discussed more fully in the next chapter, but on the surface at least, it appears that for all seven billion citizens of planet Earth to lead a good life would require the resources of more than three planets. Or, alternatively, to manage within global ecological capacity, world population would need to decrease by a factor of more than three.

Table 7.28: Regression models and sufficiency analysis for the six social indicators as a function of per capita ecological footprint.

Indicator	Best-fit Model	N	R^2	b_0	b_1	Target	EF:FES at Target
Life satisfaction	Log	143	.414	5.47	1.22	7.0	3.5
Healthy life expectancy	Log	180	.532	56.60	10.36	70	3.6
Gini coefficient	Linear	150	.317	45.74	-4.17	30.0	3.8
Interpersonal safety and trust	Linear	147	.326	.386	.043	.550	3.8
Voice and accountability	Log	180	.351	-0.355	.848	.90	4.4
Human Poverty Index	Log	131	.348	21.53	-14.60	5.0	3.1
Social Performance Index	Linear	108	.646	3.50	1.12	7.0	3.1

Note: N is the number of data points used in each regression, R^2 is the coefficient of determination for the best-fit model, and b_0 and b_1 are the coefficients of the best-fit curve.

However, the amount of variation around the best-fit curve at a fair earthshare is quite large, suggesting that high social performance may be possible at a low level of resource use, even if it is not the norm. While the average score at a fair earthshare is far from the target for all six social indicators, there is generally at least one country near a fair earthshare that achieves the target value for each of the individual social indicators (Table 7.29). The only exception is healthy life expectancy, where the highest value achieved at a fair earthshare is one year below the target.

Table 7.29: Average and best social performance within a fair earthshare, compared to targets for a good life.

Indicator	Target	Avg. Score at FES	Best Score within FES
Life satisfaction	≥ 7.0	5.8	7.7
Healthy life expectancy	≥ 70	57	69
Gini coefficient	≤ 30.0	43.2	29.2
Interpersonal safety and trust	≥ .550	.415	.586
Voice and accountability	≥ .90	-.57	1.09
Human Poverty Index	≤ 5.0	19.1	3.7
Social Performance Index	≥ 7.0	4.6	6.0

There is no country in the world, however, that performs well enough on all of the indicators to achieve the target value for the Social Performance Index while at the same time maintaining resource use within a fair earthshare. India and

Vietnam come closest, both achieving a score of 6.0 on the SPI (a full point below the target), but at a very low per capita ecological footprint (0.51 times a fair earthshare for India, and 0.79 times a fair earthshare for Vietnam).

7.3.3. Is Stability Robust to the Inclusion of Scale?

The previous two sections of this chapter have shown a correlation between social performance and both biophysical stability (Section 7.3.1) and biophysical scale (Section 7.3.2). Economies where stocks and flows are relatively constant appear to be better places to live than economies where stocks and flows are either growing or degrowing. And yet at the same time, economies with a larger per capita ecological footprint appear to be better places to live than economies with a smaller per capita footprint.

The correlations between scale and social performance are in general stronger than the correlations between stability and social performance (e.g. compare Table 7.22 to Table 7.27). Moreover, there seems to be a modest tendency for larger-scale economies to have lower rates of biophysical growth than smaller-scale economies (Table 7.10). An important question that remains to be answered, therefore, is whether biophysical stability is actually a significant predictor of social performance, or just a correlate of biophysical scale.

To answer this question, I use multiple regression and regress each social indicator against both the indicator of scale (per capita ecological footprint) and the Biophysical Stability Index. As in the previous section, I test both a linear and a semi-logarithmic model for each indicator. I choose the model that gives the best fit, as determined by the coefficient of determination and the normality of the residuals. Since the BSI is only calculated for countries where all seven rate-of-change indicators are available, the number of countries considered in the multiple regressions is lower than in the regressions from the previous section. Moreover, I exclude two countries from the analysis (Luxembourg and the United Arab Emirates) due to their very high footprint values, and another two countries (Turkmenistan and Vietnam) due to their very high BSI values.

The results (Table 7.30) show that the scale indicator (per capita ecological footprint) is a statistically significant predictor of all of the social indicators. With larger scale, comes better social performance. However, for three of the social indicators (unemployment rate, inflation rate, and working hours), the regression models explain very little of the variance in the data. The unemployment rate, in particular, appears to be almost completely unrelated to biophysical quantities.

Table 7.30: Multiple regression models for all social indicators as a function of scale (per capita ecological footprint) and stability (Biophysical Stability Index).

Dependent variable	Best-fit Model	*N*	Adj. R^2	Independent variable	*β*	*t*
Life satisfaction	Log	123	.396	Constant		20.30 ***
				PC EF	.526	6.26 ***
				BSI	-.174	-2.07 *
Healthy life expectancy	Log	133	.597	Constant		35.71 ***
				PC EF	.655	10.45 ***
				BSI	-.209	-3.33 **
Gini coefficient	Linear	121	.313	Constant		19.46 ***
				PC EF	-.571	-6.38 ***
				BSI	-.003	-.03 ns
Interpersonal safety and trust	Linear	121	.358	Constant		14.67 ***
				PC EF	.645	7.95 ***
				BSI	.145	1.79 ns
Voice and accountability	Log	133	.517	Constant		1.24 ns
				PC EF	.570	8.30 ***
				BSI	-.253	-3.68 ***
Unemployment rate	Linear	114	.027	Constant		11.98 ***
				PC EF	-.221	-2.12 *
				BSI	-.174	-1.67 ns
Inflation rate	Linear	114	.198	Constant		12.71 ***
				PC EF	-.519	-5.39 ***
				BSI	-.170	-1.77 ns
Human Poverty Index	Log	100	.466	Constant		5.80 ***
				PC EF	-.547	-7.22 ***
				BSI	.308	4.06 ***
Working hours	Linear	44	.219	Constant		19.02 ***
				PC EF	-.481	-3.13 **
				BSI	.047	.31 ns
Social Performance Index	Linear	97	.666	Constant		9.30 ***
				PC EF	.823	11.72 ***
				BSI	.005	.08 ns

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. *N* is the number of data points in each regression and R^2 is the adjusted coefficient of determination for the best-fit model. All regression coefficients β are standardised.

There are four social indicators (life satisfaction, health, voice/accountability, and poverty) where both scale and stability are significant to the model. The *t*-value for scale is larger than the *t*-value for stability in each model, but stability is a significant predictor of performance nonetheless. In all four cases, greater biophysical stability (i.e. a lower rate of change of stocks and flows) is associated with better social performance. For both health and voice/accountability, more than 50% of the variance in the data is explained by the two biophysical indicators.

Interestingly, the four indicators where stability is significant are also the four indicators where the best fit for scale is semi-logarithmic. For these indicators, it may be the case that as per capita resource use increases, the stability of stocks and flows becomes a more important determinant of social performance than additional resource use.

For the three remaining social indicators (Gini coefficient, interpersonal safety/trust, and the aggregated Social Performance Index), scale is significant to the model, but stability is not. The findings for the Gini coefficient and interpersonal safety/trust are not surprising given that the bivariate correlations between these indicators and the BSI are not strong (see Table 7.21). In general, if there is a relatively strong bivariate correlation between the BSI and a social indicator, then the BSI is significant in the multiple regression for that indicator. The one exception is the Social Performance Index. There is a relatively strong bivariate correlation between the BSI and the SPI, but the BSI is not a significant predictor of the SPI when scale is taken into account. Instead, a single biophysical measure—per capita ecological footprint—is able to explain 67% of the variance in the SPI, a surprising finding given that the SPI aggregates performance on seven individual social indicators.

7.3.4. Retesting the Determinants of Well-being

Finally, it is worth revisiting the determinants of human well-being, as this is the ultimate end in the system of accounts developed in this thesis. In Section 7.2.4, I tested three models to explain life satisfaction in terms of the other social indicators. I found that four of the seven social indicators tested (healthy life expectancy, Gini coefficient, voice/accountability, and the unemployment rate) were significant predictors of life satisfaction.

I now test whether biophysical stability and biophysical scale are robust predictors of well-being as well by adding the BSI and per capita ecological footprint to the best model developed in Section 7.2.4 (i.e. Model 1). I continue to use the logarithmic form for the scale variable, as it is the best biophysical predictor of well-being.

The results (Table 7.31) indicate that neither of the biophysical indicators is a significant predictor of life satisfaction when the social indicators are taken into account. The same four social indicators continue to be significant, and the same coefficient signs are maintained, even with the biophysical indicators in the model, and slightly fewer countries being considered.[31] While, on the surface, these findings might seem to suggest that biophysical resources are not important to human well-being, I would argue that this is not the right conclusion if interpreted through the lens of the Ends–Means framework. The results show that the intermediate ends contribute more directly to well-being than resource use, but it is only possible to achieve the intermediate ends by using biophysical resources. Each level in the hierarchy is dependent on the one below it. The hierarchical relationship is confirmed by Table 7.30, which shows that each of the intermediate ends is dependent on the intermediate and ultimate means below it. Thus, it seems safe to say that human well-being is inevitably dependent on biophysical resource use.

Table 7.31: Multiple regression model for life satisfaction as a function of intermediate ends, biophysical stability, and biophysical scale.

Independent variable	β	t	
Constant		-1.490	ns
Healthy life expectancy	.765	7.280	***
Gini coefficient	.316	3.395	**
Interpersonal safety and trust	.002	.016	ns
Voice and accountability	.318	2.979	**
Unemployment rate	-.156	-2.453	*
Inflation rate	.101	1.390	ns
Per capita ecological footprint	-.019	-.165	ns
Biophysical Stability Index	.049	.608	ns
Adjusted R^2	.652		

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, 'ns' not significant. All regression coefficients β are standardised. $N = 97$.

[31] The addition of the BSI to the regression model reduces the number of countries for which data are available for all indicators.

7.4. *Summary*

The results presented in this chapter should be interpreted cautiously. It is important to stress that the indicators that are used to measure how close countries are to a steady state economy, and the social performance of these countries, are simple proxies. Issues of data availability and data quality inevitably restrict the weight that should be attached to the results. Moreover, many of the findings are based on correlation between variables, which of course, does not imply causation.

Nevertheless, the empirical analysis suggests a number of interesting results. Although the vast majority of countries in the world are biophysical growth economies, there are several countries that achieve stable stocks and flows over the analysis period. These include Denmark, France, Japan, Poland, Romania, and the U.S., among others. However, there are no countries in the world that achieve a true steady state economy, in the sense of complete biophysical stability at the scale of a fair earthshare. That said, a small number of countries come relatively close, including Colombia, Cuba, Kyrgyzstan, Romania, and South Africa. Unfortunately, more countries are experiencing *undesirable* growth or degrowth than *desirable* growth or degrowth. In other words, more countries are heading away from a fair earthshare than towards it.

The countries with the highest social performance, as measured using an index based on the stated goals of the degrowth movement, are almost exclusively wealthy European nations, with Switzerland, Denmark, and Iceland topping the list. Positive social outcomes are in general correlated with one another, and roughly two thirds of the variation in national well-being may be explained by four intermediate ends (health, inequality, democracy, and unemployment).

Perhaps the most important findings of the empirical analysis, however, involve the relationship between biophysical and social indicators. Performance on a number of social indicators (e.g. life satisfaction, healthy life expectancy, voice/accountability, and poverty), is correlated with both biophysical stability and biophysical scale. These findings suggest that while a biophysically stable economy may be socially sustainable, it may not be possible to extend the level of resource use associated with "a good life" to everyone on the planet without exceeding ecological limits.

Finally, the empirical analysis also reveals a number of important relationships between individual biophysical and social indicators. These include a relationship between a stable population and high social performance, a relationship between strong democracies and overall biophysical stability, and *no* relationship between biophysical/economic growth rates and the level of unemployment. This last finding is particularly interesting, as it suggests that unemployment could be less of a concern for a steady state economy than previously thought.

8. Discussion

It deserves to be remarked, perhaps, that it is in the progressive state, while the society is advancing to the further acquisition, rather than when it has acquired its full complement of riches, that the condition of the labouring poor, of the great body of the people, seems to be the happiest and the most comfortable. It is hard in the stationary, and miserable in the declining state. The progressive state is in reality the cheerful and the hearty state to all the different orders of the society. The stationary is dull; the declining, melancholy.

— Adam Smith [32]

Within this chapter, I discuss the implications of the main theoretical and empirical results of the thesis. These include the implications of the overall empirical results regarding growth, degrowth, and stability (Section 8.1), as well as the results for three particular indicators: population growth, democracy, and unemployment (Section 8.2). Following these results, I discuss the finding that to achieve a "sufficient" score on the social indicators in all countries would likely require a level of resource use that surpasses what is ecologically sustainable (Section 8.3). Turning to more theoretical issues, I then propose a new efficiency measure that could be used to prioritise intermediate ends (Section 8.4), before revisiting the definition of a steady state economy and considering whether all of the biophysical indicators should continue to be included in the accounts (Section 8.5). Finally, in Section 8.6, I make a number of recommendations both for a new system of accounts to replace GDP, and for how to achieve a steady state economy that is socially sustainable.

8.1. Implications of Overall Results

It would seem that Adam Smith was wrong—at least in the context of modern economies. The results of the empirical analysis conducted in this thesis suggest that it is much better to live in a society that has acquired "the full complement of riches", and has stopped increasing these riches, than to live in a society that is still "advancing to further acquisition". Countries with a larger per capita ecological footprint are, in general, better places to live than countries with a smaller per capita ecological footprint. Greater per capita resource use is associated with higher life satisfaction, better health, less inequality, greater safety and trust,

[32] Smith (1776, p. 120)

stronger democracy, less poverty, fewer working hours, and—to some extent—lower inflation.

Furthermore, although the empirical analysis shows that the level of resource use is a more significant predictor of social performance than its rate of change, the rate of change of stocks and flows predicts social performance as well, but not in the direction suggested by Smith. The stationary is not "dull", as declared by Smith, but is in fact more cheerful and hearty than either the "progressive" or "declining" state. Countries with stable stocks and flows have higher life satisfaction, longer healthy life expectancies, stronger democracies, and less poverty than those with either increasing or decreasing stocks and flows.

The empirical analysis suggests that there are very few countries experiencing degrowth, and thus it is difficult to draw any firm conclusions about the social performance of degrowing economies. Nevertheless, the data suggest that countries experiencing partial growth and countries experiencing partial degrowth are indistinguishable from each other in terms of their social performance. Stability appears to be more important for achieving positive social outcomes than either growth or degrowth.

This tentative finding has both positive and negative implications for advocates of degrowth. On the one hand, it suggests that degrowth may be no worse than growth (from a social perspective), and thus there is less to fear from a degrowth transition to a steady state economy than people might think. On the other hand, if lower social performance is associated with degrowth than with stability, then it may still be difficult to find support for a degrowth transition to a steady state economy, especially if the end point of that transition is a much lower level of resource use than wealthy countries enjoy at present.

The empirical analysis identified around twenty countries that have achieved relatively stable stocks and flows over the ten-year analysis period. However, the majority of these countries have done so at a level of resource use that is well above a fair earthshare. While we might refer to these as "stable economies", they are not "steady state economies" because the level of resource use that they enjoy is above what is globally sustainable.

Research on social metabolism (e.g. Fischer-Kowalski and Haberl, 2007; Krausmann et al., 2008b; Haberl et al., 2011) describes two major transitions that have occurred (and are still occurring) in human societies. The first is the transition from a hunter-gatherer regime to an agrarian regime, and the second is the transition from an agrarian regime to an industrial regime. Although it is tempting to view the biophysically stable economies identified in this thesis as potential models of sustainability, these economies may simply be experiencing the completion (or final stages) of the transition to an industrial regime. Biophysical stability at a high level of resource may be "business as usual"—the inevitable outcome of the transition to an industrial society. If this is the case, then a third major transition is still required in these countries in order to reduce resource use to a sustainable level. This would be the degrowth transition to a steady state economy.

Nevertheless, the fact that around twenty countries have managed to stabilise resource use, even if it's at a level that is too high, is still an important finding. It demonstrates that continuous growth is not needed in order to achieve a high level of social performance. A biophysically stable economy can also be socially sustainable. Furthermore, as Daly (1977) points out, the first step in achieving a steady state economy is to stabilise resource use at existing or nearby levels. The second step is to decide whether the optimum level of resource use is greater than or less than the present level. In Daly's words, "[W]e cannot go into reverse without first coming to a stop" (p. 52).

8.2. Implications of Individual Indicator Results

At the level of individual indicators, a number of findings stand out. These include (1) the social importance of stabilising population, (2) the association between democracy and biophysical stability, and (3) the absence of a statistically significant relationship between rate-of-change indicators and the level of unemployment. I discuss each of these in turn.

8.2.1. Population Growth

The empirical analysis suggests that the stability of stocks and flows is associated with better performance on a number of social indicators. Of the stocks and flows tested, the rate of change of population is most strongly correlated with social performance (while the rate of change of material extraction and ecological footprint are least strongly correlated). A stable population is associated with higher life satisfaction, better health, lower inequality, greater safety and trust, and stronger democracy than either an increasing or decreasing population (see Table 7.22). There are only two social indicators where a changing population is associated with better performance than a stable population: poverty and unemployment. A declining population is associated with less poverty, and a growing population is associated with lower unemployment (albeit weakly).

There are clearly questions of causality that emerge from the correlation analysis. For example, does a stable population result in better health, or does better health lead to a stable population? Do stronger democratic institutions help stabilise population, or does a stable population lead to stronger democracies? Although these are important questions that warrant further research, it is beyond the scope of this thesis to attempt to answer them. But regardless of the direction of causality, the population growth findings contain important information for advocates of degrowth or a steady state economy.

As discussed in Section 5.2, there is a strong environmental argument for stabilising population. All else being equal, the total resource use of a country will increase when either the number of people living in the country increases, or the amount that each person consumes increases. To achieve a steady state economy, it is therefore necessary to stabilise both per capita resource use and population numbers. However, what the results of the empirical analysis suggest is that population growth is also important to monitor because of its relationship to social indicators.

If the direction of the causal relationship is that a stable population leads to better social performance, then the case for achieving a steady state economy is improved. Not only is stabilising population a biophysical necessity, but it could be expected to improve people's lives as well. However, if the causal relationship goes the other way—if better social performance leads to a stable population—this finding would still lend support to the argument made by advocates of degrowth that reducing inequality, alleviating poverty, and strengthening democratic institutions are a necessary part of the degrowth transition to a steady state economy. Regardless of the direction of causality, the important result suggested by the empirical analysis is that the two aims of a stable population and strong social performance are compatible with one another. These findings might encourage advocates of degrowth such as Latouche (2009) to take a firmer stand on the issue of stabilising population, as advocated by Kerschner (2010).

8.2.2. Democracy

Another important finding of the empirical analysis is the strong correlation between biophysical stability and the indicator of participatory democracy (i.e. the World Bank's measure of voice and accountability). There is a statistically significant relationship between the democracy indicator and every rate-of-change indicator in the Biophysical Accounts (see Table 7.22), as well the overall Biophysical Stability Index (see Table 7.21). For most of the rate-of-change indicators, the strongest democratic performance is associated with stability. The only exceptions are the livestock, night-time lights, and material use indicators, where stronger democracy is associated with biophysical degrowth than with biophysical stability.

These results call into question the notion that a steady state economy could only be achieved under an authoritarian regime (a topic discussed by Lawn, 2005b). Instead, the results suggest that biophysical stability and participatory democracy are compatible aims, which is good news for achieving a socially sustainable steady state economy.

In part, the findings also support the view held by many degrowth scholars that the transition to a more ecologically sustainable society and the transition to a more participatory and democratic society are mutually supportive goals (Cattaneo and Gavaldà, 2010; Schneider et al., 2010). The problem for advocates of degrowth, however, is that it is not just biophysical stability and strong democracy that seem to go hand in hand, but also biophysical scale and strong democracy. Strong democracies are characterised by both stable stocks and flows, and high resource use. This would not be a problem if the level of resource use associated with strong democratic institutions were near a fair earthshare— but it is instead three or four times a fair earthshare. This creates something of a Catch-22: while strong democratic institutions might help a country to maintain a steady state economy (once achieved), such institutions could also make the degrowth transition to such an economy less likely to occur in the first place.

8.2.3. Unemployment

A third very interesting finding is that the unemployment rate is largely unrelated to the rate of change of biophysical stocks and flows, or the rate of change of GDP. In some ways this finding flies in the face of conventional economic theory which posits that economic growth is necessary to prevent rising unemployment. It calls into question the concern that the stabilisation of consumer demand, coupled with steadily increasing labour productivity, would inevitably lead to job losses in a steady state economy unless some preventive action were taken. As discussed in Section 2.4.4, this concern has led a number of authors to suggest that special policies, such as working time reduction or a job guarantee, would be needed to maintain full employment in a steady state economy.

So how do we explain this somewhat surprising finding? A number of possible explanations exist. One possibility is that the international comparison of unemployment rates is simply not valid because the definition of who is unemployed varies too much between countries. The unemployment data used in the analysis are obtained from the World Bank (2011a), who warn that definitions of labour force and unemployment differ from country to country. The analysis would certainly be improved by using standardised unemployment statistics, such as those published by the International Labour Organization (ILO, 2011b). Unfortunately, the ILO data are only available for 30 countries, and the series ends in 2005, limiting their usefulness for the Social Accounts. Nevertheless, to explore the incomparable data hypothesis, I correlate the standardised ILO unemployment data with the rate-of-change indicators to test whether the results are any different than with the World Bank data. Since the ILO data series ends in 2005, I use average unemployment rates for the 1995–2005 period (as opposed to 1997–2007).

The ILO results (Table 8.1) are very similar to the World Bank results (Table 7.22), and show no significant correlation between the level of unemployment and any of the rate-of-change indicators, including the rate of change of GDP. Given the small number of countries considered, these findings do not rule out the possibility that differences in the definition of unemployment could be behind the non-significant results in the larger analysis, but they certainly don't support this hypothesis.

Table 8.1: Correlation between unemployment rate (as measured by ILO comparable data) and rate-of-change indicators (Spearman's ρ).

	BSI	ΔPop	ΔLive	ΔLights	ΔMat	ΔEnergy	ΔCO_2	ΔEF	ΔGDP
Unemployment	.155	-.226	-.215	-.185	.150	-.089	-.143	.046	.227
(ILO)	ns	ns	ns	ns	ns	ns	ns	ns	ns
	28	*30*	*30*	*30*	*28*	*30*	*30*	*30*	*30*

Note: 'ns' indicates not significant (i.e. $p > .05$). *N* for each correlation is shown in italics.

Another possibility is that the cross-country analysis conducted in this thesis does not adequately test for the type of unemployment that might be expected in a steady state economy. According to Goodwin et al. (2009, pp. 155-157), there are three types of unemployment: *frictional unemployment* (which reflects people's transitions between jobs), *structural unemployment* (which arises when there is a mismatch between the kinds of jobs offered by employers and those sought by job seekers), and *cyclical unemployment* (which results from a drop in consumer demand). The type of unemployment feared in a steady state economy is largely cyclical unemployment.

Evidence of cyclical unemployment may be found by examining time series data of unemployment and GDP for individual countries. For example, Figure 8.1 shows the unemployment rate in the U.S., in comparison to periods of economic recession, as determined by the National Bureau of Economic Research (NBER). The figure shows that unemployment has tended to increase sharply during periods of recession (when GDP has stopped growing). The relationship between the unemployment rate and GDP growth is often referred to as "Okun's law", after economist Arthur Okun who estimated in the early 1960s that a 1% drop in the unemployment rate was associated with a 3% increase in real GDP (Goodwin et al., 2009, p. 204).

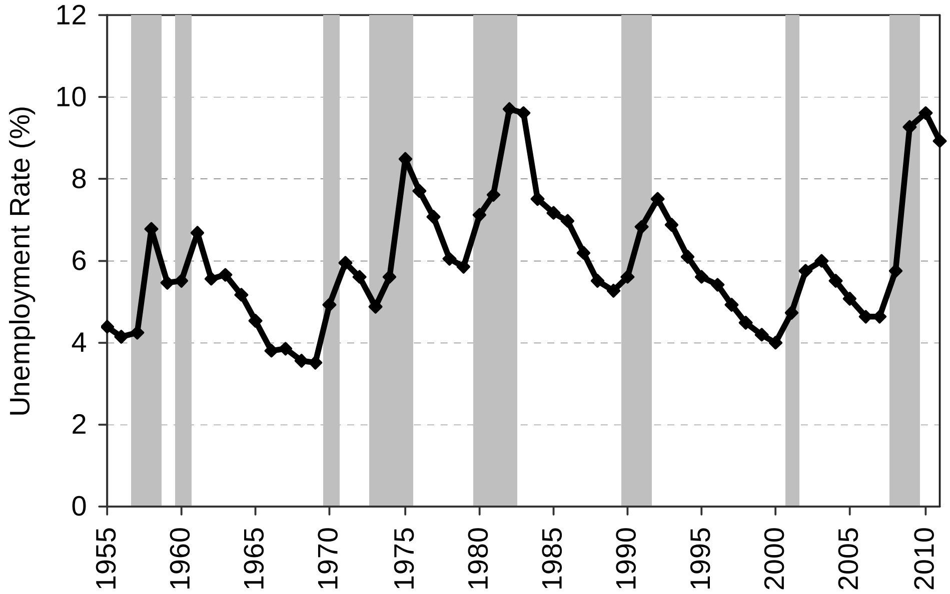

Figure 8.1: Unemployment rate in the United States (black line), compared to periods of recession (grey bars) for the period 1955–2011. Source: own calculations; unemployment data are from OECD (2012), recession data are from NBER (2012).

The relationship found by Okun, which is really more of a rule-of-thumb than a law, may be verified by regressing the change in the unemployment rate from one year to the next against the percentage change in GDP. The results of this regression for the United States, computed using data for the last 50 years, show a strong relationship between change in real GDP and the unemployment rate (Figure 8.2a). A 1% decline in real GDP is accompanied by a 0.37% increase in unemployment. A similar, albeit weaker, relationship also exists between unemployment and biophysical quantities such as energy use. For example, a 1% decline in energy use is accompanied by a 0.20% increase in unemployment (Figure 8.2b).

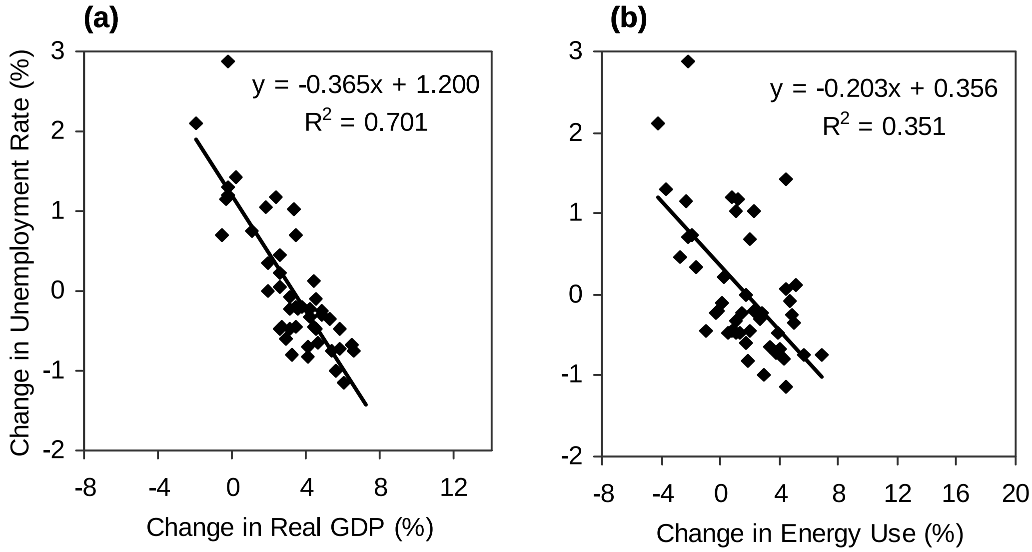

Figure 8.2: Relationship between the change in the unemployment rate and (a) change in real GDP, and (b) change in energy use, for the United States over the period 1960–2008. Source: own calculations; unemployment data are from OECD (2012), GDP data are from BEA (2012), and energy data are from IEA (2010).

These data suggest that, in the United States at least, economic growth and unemployment are tightly coupled. This is not the case in all countries, however. Lee (2000) investigates the robustness of Okun's law across 16 OECD countries, and while he finds that a relationship exists for most countries surveyed, the relationship is far from uniform. In Germany, for example, the effect of a 1% decrease in real GDP is a 0.22% decrease in unemployment (compared to 0.37% in the U.S.), while in France it is only a 0.17% decrease (Khemraj et al., 2006). In Japan, there is almost no relationship between the rate of GDP growth and unemployment. As Figure 8.3a shows, a 1% decrease in real GDP in Japan is associated with only a 0.03% change in the unemployment rate. In fact, it's questionable whether the relationship is meaningful at all in the Japanese case, as the GDP data only explain 19% of the variance in the unemployment data. The relationship between the rate of change of energy use and unemployment is even weaker (Figure 8.3b).

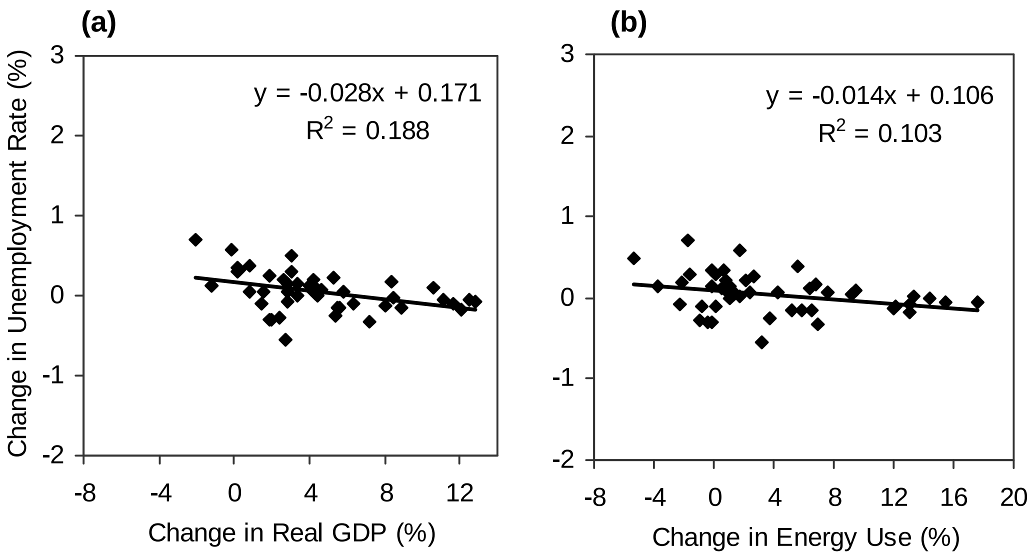

Figure 8.3: Relationship between the change in the unemployment rate and (a) change in real GDP, and (b) change in energy use, for Japan over the period 1960–2008. Source: own calculations; unemployment data are from OECD (2012), GDP data are from World Bank (2011a), and energy data are from IEA (2010).

While the time series analysis used to illustrate Okun's Law is very different from the cross-national analysis performed in this thesis, both suggest that the unemployment rate is not a simple product of economic or biophysical factors. While the level of unemployment is no doubt influenced by economic factors such as GDP growth and labour productivity, particularly in the short term, societies appear to be able to decouple the level of unemployment from these factors to some degree. Some countries, such as Germany, already use the sorts of policies advocated for a SSE to prevent unemployment from rising (e.g. working time reduction; see Crimmann et al., 2010). Others, such as Japan, may simply have different cultural values that discourage businesses from laying off workers during an economic downturn (The Economist, 2006). Interestingly, it would seem that subjective measures such as life satisfaction and happiness are easier to predict across a wide range of countries than objective indicators like the unemployment rate. All in all, these findings may give some support to Blake Alcott's claim that "Ultimately society, not the economy, determines how many people are out of work" (O'Neill et al., 2010, p. 80).

8.3. *Sufficiency*

One of the more striking findings from the empirical analysis is the high ecological footprint associated with a high level of social performance. To reach the "sufficiency" levels chosen for the six social indicators analysed requires a per capita footprint that is between three and four times a fair earthshare on average. At face value, these findings imply that for all seven billion people on Earth to lead a good life within ecological limits would require the resources of more than three planets. Or, alternatively, to manage within global ecological capacity, world population would need to decrease by a factor of more than three.

There are, of course, reasons why we might not want to attach too much weight to these findings. While the sufficiency analysis considers six separate social indicators, it relies on a single measure of environmental sustainability (the ecological footprint). As discussed in Section 3.3.3, although the ecological footprint is widely used, it has also been widely criticised as a measure of sustainability. One of the footprint's strengths is that it is an aggregated indicator with a single sustainability threshold, but this is also one of its weaknesses, as the footprint provides no information on when specific ecological limits relating to key ecosystem services might be reached (Wiedmann and Barrett, 2010). The carbon footprint dominates the global ecological footprint, and if it were not included in the calculation, the footprint would not indicate global ecological overshoot. This leads Wiedmann and Barrett (2010) to suggest that, at the global level at least, the footprint tells us nothing more than that human activity is causing climate change.

Viewed from another angle, though, the fact that climate change is occurring lends some credibility to the ecological footprint calculation. Ecological footprint studies suggest that many national economies are using biotic resources faster than they can be regenerated, and producing CO_2 faster than it be assimilated. The combined result is a state of global "ecological overshoot" (Wackernagel et al., 2002; Ewing et al., 2010a). Large-scale studies such as the Millennium Ecosystem Assessment (2005), the reports of the Intergovernmental Panel on Climate Change (e.g. IPCC, 2007), and the planetary boundaries analysis of Rockström et al. (2009b) convey a similar message. It would be more worrying if ecological footprint studies did not mirror the results of these more rigorous approaches.

Nevertheless, we should probably hope that the ecological footprint calculations are wildly inaccurate, and that the true sustainability threshold is much higher than the footprint indicates. If the footprint calculation is correct, then societies need to improve the efficiency with which they translate resource use into human well-being by a factor of three or four for all people on Earth to lead good lives within the ecological capacity of the planet.

As discussed in Section 5.8, other approaches besides the ecological footprint could be used to assess the scale of national economies in relation to a sustainability threshold. One approach would be to compare national CO_2 emissions to a globally equitable carbon budget. Based largely on the work of Meinshausen et al. (2009), the German Advisory Council on Global Change (WGBU, 2009) has estimated that if the probability of exceeding 2 degrees of warming is to be limited to 33% (still quite high), then annual CO_2 emissions from the burning of fossil fuels would need to be constrained to around 2.7 tonnes per person over the period from 2010 to 2050. This estimate is an average annual value for the period based on a cumulative global emissions budget. For the budget to be met, emissions in most countries would need to decline steadily over the period, so that annual emissions in all countries converged to around 1 tonne per person in 2050 (WGBU, 2009).

To complement the ecological footprint calculation, I have repeated the sufficiency analysis conducted in Section 7.3.2 using CO_2 emissions as an indicator of biophysical scale, and the 2.7-tonne target as a sustainability threshold.[33] The data used are from Peters et al. (2011), and represent CO_2 emissions associated with final consumption. Although these data are only available for about half as many countries as the ecological footprint data, they are arguably more scientific, and also account for trade in a more sophisticated manner.

The findings of the CO_2 analysis are very similar to the findings of the ecological footprint analysis. There is a clear relationship between CO_2 emissions and six of the individual social indicators (Figure 8.4), as well as the Social Performance Index (Figure 8.5). The best-fit model is the same in all cases, with the

[33] One could argue that the sustainability threshold should really be 1 tonne, since this is the endpoint of the required transition. However, I choose to use the average value required over the transition period(2.7 tonnes), which is a more conservative estimate.

exception of the voice and accountability indicator, where the linear model predicts more of the variance than the semi-logarithmic model.

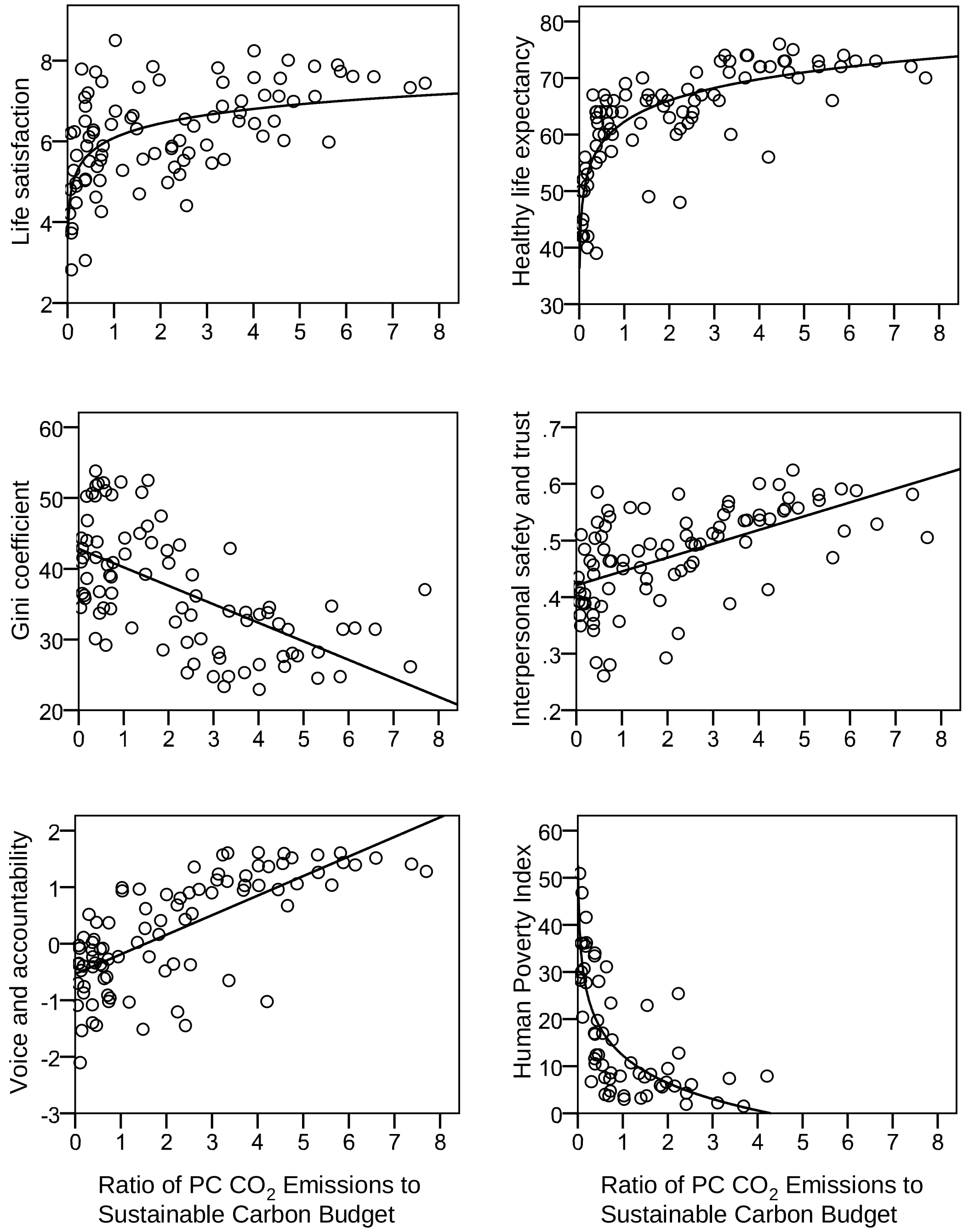

Figure 8.4: Relationship between biophysical scale (as measured by the ratio of per capita CO_2 emissions to an annual carbon budget of 2.7 tonnes per person) and the six most strongly correlated social indicators. Note: Regression lines show the best-fit model (either linear or semi-logarithmic), as determined using OLS regression.

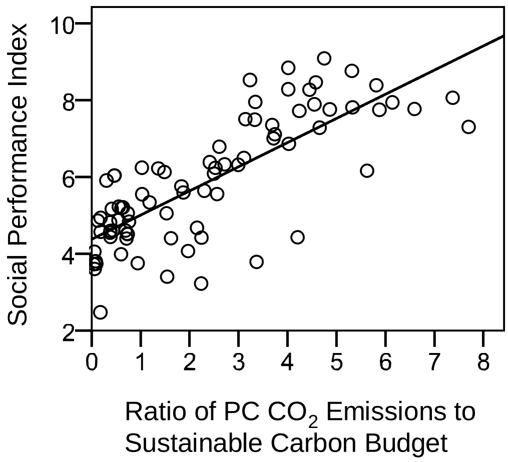

Figure 8.5: Relationship between biophysical scale (as measured by the ratio of per capita CO_2 emissions to an annual carbon budget of 2.7 tonnes per person) and the Social Performance Index. $N = 82$.

Using the equation for the best-fit curve in each of the plots, it is possible to calculate the level of per capita CO_2 emissions associated with the target scores for a "good life". The results of this calculation are even more troubling than the results of the ecological footprint calculation (compare Table 8.2 to Table 7.28). While the per capita ecological footprint associated with a good life is generally between three and four times a fair earthshare, the level of per capita CO_2 emissions associated with a good life is over four times the sustainable carbon budget for all of the indicators, with the notable exception of the Human Poverty Index (where it is lower). These findings once again suggest that if all seven billion people on Earth are to lead a good life within ecological limits, then we need to become far more efficient at translating resource use into human well-being.

Table 8.2: Regression models and sufficiency analysis for the six social indicators as a function of per capita CO_2 emissions.

Indicator	Best-fit Model	N	R^2	b_0	b_1	Target	Ratio at Target
Life satisfaction	Log	88	.318	6.09	0.52	7.0	5.9
Healthy life expectancy	Log	90	.629	62.24	5.44	70	4.2
Gini coefficient	Linear	87	.370	42.82	-2.62	30.0	4.9
Interpersonal safety and trust	Linear	89	.335	.421	.024	.550	5.4
Voice and accountability	Linear	90	.507	-0.535	.346	.90	4.1
Human Poverty Index	Log	59	.587	12.30	-8.45	5.0	2.4
Social Performance Index	Linear	82	.607	4.374	.640	7.0	4.1

Note: N is the number of data points used in each regression, R^2 is the coefficient of determination for the best-fit model, and b_o and b_1 are the coefficients of the best-fit curve.

Fortunately, Steinberger and Roberts (2010) show that there is good reason to expect the environmental efficiency with which societies deliver well-being to improve over time. The authors investigate the relationship between four social indicators (life expectancy, literacy, income, and HDI) and two resource use indicators (energy use and CO_2 emissions) over a 30-year time period. Based on a rigorous regression analysis, they find evidence of a threshold beyond which additional energy use or CO_2 emissions do not result in significantly higher social performance—a result also found for four of the six social indicators analysed against the ecological footprint in this thesis (life satisfaction, healthy life expectancy, voice and accountability, and poverty). Most importantly, however, Steinberger and Roberts show that this threshold is decreasing over time. For example, while the energy use associated with a relatively long life (~70 years) was around 100 GJ per person in 1975, this fell to 40 GJ by 2005 (a 60% efficiency improvement over 30 years; ibid., p. 430).

The authors also show that if resources were equally distributed, current global energy use and carbon emissions would be more than sufficient to achieve a high level of human development for all people. This is a very important finding, and the authors make a strong case for industrialised nations to reduce their resource use so that poorer nations may increase theirs to the threshold values associated with a high level of human development (ibid., p. 432).

What Steinberger and Roberts do not address, however, is whether the threshold values that they calculate are environmentally sustainable. It is all good and well for nations to converge to a level of energy use and CO_2 emissions that guarantees a high level of human development, but if this level is beyond what ecosystems can support in the long term, then we still have a problem. The simple sufficiency analysis conducted in this thesis suggests that the level of resource use needed to achieve a high level of human well-being for all people is well beyond global ecosystem capacity. Global CO_2 emissions must be reduced substantially if dangerous climate change is to be avoided. The same is almost certainly true for other biophysical flows. In short, it is not enough to redistribute existing resource use to achieve a high level of human development for all. Some form of global degrowth is required to achieve environmental sustainability as well, and this could have important consequences for human well-being.

The more hopeful news that emerges from the sufficiency analysis is that there is at least one country in the world that achieves (or comes very close to achieving) the target values for each social indicator at a per capita ecological footprint that is within a fair earthshare (see Table 7.29). Thus, while reducing resource use by a factor of three or four and maintaining a high level of human well-being may seem like a daunting task, it is clearly not an impossible one. It does, however, mean making today's best performing countries the standard for the global economy.

Finally, it is worth pointing out that for three of the indicators (unemployment, inflation, and working hours), the regression models used in the sufficiency analysis explained very little of the variance in the data. These results imply that the goals of low unemployment, stable prices, and reduced working hours may be achievable with little environmental cost. The finding of a linear relationship between per capita ecological footprint and the indicators of inequality and social capital is more troubling. It suggests that performance on these social goals continues to increase steadily with resource use, far beyond what is sustainable. The amount of variance explained by the linear regressions is relatively low, however, suggesting that there are much more efficient ways to achieve low inequality and high social capital than by increasing the biophysical scale of the economy.

8.4. Efficiency

The efficiency with which the ultimate means (i.e. natural resources) may be converted into the ultimate end (i.e. human well-being) is an important statistic for a steady state economy. Indicators such as the Happy Planet Index (Marks et al., 2006; Abdallah et al., 2009) attempt to measure this quantity by dividing the product of life satisfaction and life expectancy (a combined subjective/objective measure of well-being) by per capita ecological footprint (a measure of resource use). While the resulting statistic provides valuable information on how efficiently different countries convert natural resources into human well-being, it leaves what happens in between as something of a black box. The Ends–Means Spectrum used in this thesis, and the indicators that populate it, provide a framework for investigating what happens within this box.

Both Layard (2005) and Daly (1977) have suggested that if a single ultimate end were adopted for the economy, it could be used as an ordering principle to rank or prioritise the intermediate ends of the economy. In Section 6.1, I proposed extending this idea and prioritising intermediate ends based on how efficiently each intermediate end translates the ultimate means (materials and energy) into the ultimate end (human well-being).

The results of the empirical analysis show that there are some intermediate ends (such as healthy life expectancy, voice/accountability, poverty, and working hours) that are highly correlated with well-being, while there are others (such as inequality, unemployment, and inflation) that show little or no correlation with well-being (Table 7.15). At the same time, there are some intermediate ends (such as healthy life expectancy, voice/accountability, and poverty) that are highly correlated with resource use, while there are others (such as unemployment and inflation) that show little or no correlation with resource use (Table 7.27).

The best intermediate ends to pursue in a steady state economy would be those that are strongly correlated with human well-being, but only weakly correlated with resource use. Ideally, we would like to have some kind of measure of the efficiency with which each intermediate end converts natural resource use into well-being. This would allow intermediate ends to be ranked against one another. An efficiency measure of this sort could be calculated by taking the ratio of the change in well-being associated with a given change in resource use, in response to the pursuit of a particular intermediate end. As an equation, the efficiency ratio e_i for a given intermediate end i could be expressed as:

$$e_i = \left.\frac{\Delta UE}{\Delta UM}\right|_i = \frac{\Delta UE}{\Delta IE_i}\frac{\Delta IE_i}{\Delta UM} \tag{8.1}$$

where ΔUE is the change in the ultimate end (human well-being), ΔUM is the change in the ultimate means (resource use), and ΔIE_i is the change in the intermediate end i. To calculate this quantity would involve performing two regressions, the first to determine the relationship between the ultimate means and the given intermediate end, and the second to determine the relationship between the given intermediate end and the ultimate end.

To help illustrate the proposed method, I show two stylised regressions (Figure 8.6). The function that best fits the data in each regression could differ from one intermediate end to the next, and the most appropriate function would need to be determined as part of the regression analysis. Within the figure I show a function with diminishing returns for the relationship between the ultimate means and the intermediate end (such a relationship exists between per capita ecological footprint and healthy life expectancy), and a linear function for the relationship between the intermediate end and the ultimate end (such a relationship exists between healthy life expectancy and life satisfaction).

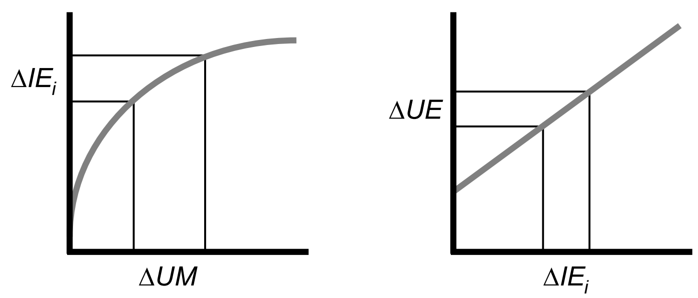

Figure 8.6: Regressions required to calculate an indicator of the efficiency with which ultimate means are translated into the ultimate end by a given intermediate end.

The efficiency indicator that would be generated using the proposed method is essentially an elasticity measure, namely the well-being elasticity of resource use for a given intermediate end. Importantly, it is a measure that permits non-linear relationships between variables (which exist in practice, as Figure 7.12 shows). Due to these nonlinearities, the results obtained using this method could potentially suggest pursuing different intermediate ends depending on a country's level of resource use. For example, at low levels of resource use well-being might be generated most efficiently by improving life expectancy, while at high levels of resource use it might be generated more efficiently by reducing inequality.

Performing the detailed regressions necessary to calculate the elasticity functions for each intermediate end, and applying them to individual countries based on their level of resource use, is beyond the scope of this thesis. Nevertheless, the method that I have outlined could potentially be used to produce policy recommendations about which intermediate ends to prioritise in order to achieve a socially sustainable steady state economy.

8.5. Revisiting the Definition of a Steady State Economy

The definition of a steady state economy adopted in this thesis, and the indicators chosen to measure how close countries are to this definition, reflect a particular interpretation of a biophysically stable and environmentally sustainable economy. The countries that are classified as "biophysically stable" in the empirical analysis are countries where environmental pressure is estimated to be relatively constant over a ten-year time period. The approach relies on the rates of change of several different aggregate indicators, which overlap with one another to various degrees, and which certainly do not capture all aspects that might be important to a steady state economy (e.g. hidden flows). The approach taken is something of a probabilistic one. It assumes that a larger number of biophysical indicators showing stability equates to a greater likelihood of actual biophysical stability.

Stability, in this sense, is really short-term stability. It simply means that stocks and flows change little over a ten-year time period. It does not imply long-term stability in the sense of "environmental sustainability". For the latter to occur, the scale of resource use must also be within ecological limits. Both biophysical stability and sustainable scale are required for a steady state economy.

The countries that are classified as achieving "optimal scale" in the analysis are countries where per capita ecological footprint is close to a fair earthshare. These are countries where people are consuming resources at a level that could theoretically be extended to all people on the planet, without exceeding ecological limits. While conceptually appealing, there are problems with this approach to optimal scale. For one thing, it relies too heavily on a single indicator (the ecological footprint), which has been widely criticised. For another, it effectively allocates all ecological resources to human beings, without setting aside any for other species.

In Chapter 4, I suggested that two types of rate-of-change indicators should be monitored in a steady state economy: one to measure the rate of change of total (renewable plus non-renewable) resource use and the other to measure the rate of change of non-renewable resource use. The goal in a SSE would be to stabilise total resource use, while reducing non-renewable resource use. Unfortunately it was not possible to construct indicators of non-renewable resource use that could be compared to total resource use because data were not available for enough countries. However, this remains an important area for future work. It is worth pointing out, though, that if indicators of the rate of change of non-renewable resource use were calculated, they would muddy the assessment of how close economies are to a SSE to some extent. Instead of having two overarching criteria (stable stocks/flows and sustainable scale), there would be a third: declining flows of non-renewable resources. While the latter is a rate-of-change measure, it is not a measure of short-term stability like the other rate-of-change measures. It would be more appropriate to describe it as a measure of long-term sustainability (like scale), although clearly it is not the same type of indicator as scale either. Due to the variety of fundamentally different types of indicators required to assess how close an economy is to a SSE, some sort of multi-criteria approach probably remains the best option for measuring progress towards such an economy.

Another of the issues raised early on in this thesis was whether constant stocks should be included as a part of the definition of a steady state economy, or whether the definition should simply specify constant flows. In Section 4.1, I argued in favour of measuring the rate of change of stocks in addition to the rate of change of flows. I decided to include stocks in the analysis for a number of reasons, the main one being that although we might assume that the environmental pressure exerted by an increase in stocks would be adequately captured by flow indicators, this assumption has yet to be tested. Thus it would seem premature to leave stocks out of a system of accounts for a steady state economy.

The results of the empirical analysis provide some insight into whether stocks should indeed be included. In general, the correlation between the rate of change of stocks and the rate of change of flows is rather low (see Table 7.9). This suggests that there may indeed be value in continuing to measure what is happening to stocks, since different information is clearly being captured by these indicators. However, the relatively strong correlation between population growth and livestock growth suggests that measuring both of these indicators may be unnecessary. The same is also true for energy use and CO_2 emissions, whose rates of change are even more highly correlated. The Biophysical Accounts could potentially be simplified by leaving out the rates of change of both livestock and CO_2 emissions.

That said, there are reasons why we might want to continue to include these quantities in the accounts. Although CO_2 emissions may be highly correlated with energy use at present, efforts to decarbonise the energy supply could change this relationship over time. CO_2 emissions also have a clear link to a global environmental problem (climate change), and could be compared to national carbon budgets to create an indicator of sustainable scale (as explored in a preliminary way in Section 8.3).

Although livestock numbers might seem to be a less important statistic to track, a study by Goodland and Anhang (2009) suggests that domesticated animals have been vastly underestimated as a source of greenhouse gas emissions. The study estimates that domesticated animals account for over 50% of all human-caused greenhouse gas emissions, and suggests that replacing livestock products with other alternatives could be a more effective strategy to mitigate climate change than replacing fossil fuels with renewable energy. If the study is correct, then livestock numbers might be a more important indicator to track in the accounts than, for example, CO_2 emissions from fossil fuels.

It is much harder to say whether the rate of change of built capital is an indicator that should be maintained in the Biophysical Accounts. It is difficult to know whether the proxy used for this indicator, the rate of change of night-time lighting, even measures built capital, since there are no built capital data that can be used as a reference. This situation may change soon, however, as at least one researcher is developing a built capital time series for European countries, based on physical infrastructure data (D. Wiedenhofer, pers. comm., 2012).

Some of the results of the empirical analysis, such as the finding that the U.S. is a biophysically stable economy, and the UK is a partially degrowing one, come as a bit of a surprise (to this researcher at least). These findings might make some members of the steady state and degrowth communities question whether the indicators that I have chosen are appropriate, or even whether the definition of a steady state economy that I have adopted is strict enough.

One of the difficulties with trying to measure how close countries are to a steady state economy is that not all of the data that we would like to have are currently available. In Chapter 4, I argued in favour of using a consumption-based approach for measuring flows, and yet I use domestic material extraction as a material use indicator because a time series of total material consumption is not yet available. The energy use indicator measures apparent consumption, and is therefore closer to the mark in some ways. However, besides omitting hidden flows, it only accounts for technical energy use, and thus neglects the nutritional energy flows required by two of the stocks in the economic system (people and domesticated animals). Similar divergences exist between the "ideal indicator" for a SSE, and what I have actually measured, for all of the indicators in the accounts, with the possible exception of population growth.

As better data become available, however, it will be possible to update the accounts and see whether countries such as the U.S. and UK perform as well when more comprehensive resource use indicators are applied. The results presented in this thesis are a "first pass"—an attempt to survey a large number of countries to see which ones might be closest to a steady state economy. Armed with the results from this analysis, however, it is possible to identify individual countries for in-depth analysis using more comprehensive indicators. In fact, many of the countries that perform well on the biophysical stability indicators in this analysis are European countries, where data that measure consumption and hidden flows are already available.

8.6. Recommendations and Policy Implications

The conceptual analysis and empirical results of this thesis lead to a number of recommendations for policy-making. These fall into two broad categories: (1) recommendations for a system of accounts to replace GDP, and (2) recommendations for how to achieve a socially sustainable steady state economy.

8.6.1. A New System of National Accounts

As discussed in Section 3.3.1, there is a growing recognition that GDP is a poor measure of economic welfare, and a number of initiatives around the world are now investigating alternatives to GDP. In general, these initiatives are investigating ways to supplement GDP with additional social and environmental information, rather than replace it. However, some commentators, such as Jeroen van den Bergh (2009; 2011), argue that we would be better off if we abolished GDP altogether—even if we didn't replace it with another indicator—due to the huge information failure that would be removed by this action.

If the goal is to achieve a steady state economy, then abolishing GDP is the appropriate action to take. While GDP is correlated with both resource use and social performance, it is not a particularly good measure of either of these. As the analysis conducted in Section 7.2.4 illustrated, health is a better predictor of life satisfaction than per capita GDP.

National governments should replace GDP with two sets of accounts—biophysical and social—and these accounts should contain indicators organised along a spectrum from means to ends. Based on the conceptual and empirical analysis performed in this thesis, I would suggest that this set of indicators should satisfy the following nine criteria:

1. **The indicators should be chosen and organised based on a unifying conceptual framework.** A unifying conceptual framework is necessary to ensure that a comprehensive set of indicators is chosen, and to interpret the relationships between them. The framework should acknowledge that the economy is a subsystem of the environment, and its scope should include the full range of relations between natural resources and human well-being. Herman Daly's "Ends–Means Spectrum" (Daly, 1977) provides such a framework.
2. **The indicators should be divided into two separate accounts—biophysical and social—and these should not be mixed.** A number of existing sustainability indices include a variety of environmental and social indicators, which are *added* together to form a single index. These indices make the implicit assumption that environmental and social goals are substitutable for one another, which they are not. More society does

not compensate for less environment, or vice versa. Each of these goals must be achieved on its own terms, and therefore measured in its own units. (Even with this approach, however, issues of aggregation and substitution would remain within the two accounts.)

3. **The biophysical indicators should monitor the major stocks and flows in the economy–environment system**. The three major stocks are the size of the human population, the stock of built capital, and the stock of domesticated animals. The three major flows are the flow of materials from the environment to the economy, the flow of emissions and wastes back to the environment, and the flow of energy through the economy. Stocks and flows should be measured using aggregated indicators that account for the overall *quantity* of resources (e.g. in mass or energy units), as opposed to their quality.
4. **The biophysical indicators should show how the stock and flow variables are changing over time, and the position of each flow variable in relation to a sustainability threshold.** The main environmental objective of a steady state economy is to reduce the level of material and energy flows to within ecological limits and stabilise it there. In order to achieve this objective, it is necessary to measure rates of change over a sufficiently long time period (~5–10 years). In addition, it is also necessary to relate individual flows to the regenerative and assimilative capacity of ecosystems. This latter objective continues to represent a significant research challenge.
5. **Biophysical flows should be measured using a consumption-based approach, but complemented with territorial indicators.** A consumption-based approach assigns responsibility for resource flows to those who benefit from using the resources, and is important for creating both a fair and self-consistent accounting system. However, domestic extraction and domestic outflow indicators are also worth tracking to encourage countries to manage national resources efficiently.
6. **A distinction should be made between renewable and non-renewable resource flows**. The goal in a steady state economy should be to stabilise total resource use within ecological limits, while decreasing non-renewable resource use over time.

7. **The social indicators should monitor both the functioning of the socio-economic system, and how effectively it delivers well-being.** The distinction between intermediate ends and the ultimate end is particularly important here. I suggest that human well-being represents a reasonable ultimate end for the economy, while health, equity, the elimination of poverty, increased social capital, participatory democracy, decreased working time, low unemployment, and stable prices represent reasonable intermediate ends. That said, the social objectives of the economy should be chosen democratically, based on a participatory process.
8. **Human well-being should be measured using an index that combines a small number of subjective measures from the evaluative, hedonic, and eudaimonic approaches.** To capture whether people are both "feeling good" and "doing well" requires a combination of indicators from these three different approaches to human well-being.
9. **All indicators should have targets.** As Donella Meadows writes, "An environmental indicator becomes a sustainability indicator (or unsustainability indicator) with the addition of *time*, *limit*, or *target*" (Meadows 1998, p. 12). Unfortunately, the vast majority of "sustainability indicators" that exist at the moment lack clear targets. In a steady state economy, the general objective would be to achieve a sufficiently high score on the social indicators, while stabilising the biophysical indicators within ecological limits.

While the above indicator criteria were developed with the goal of measuring progress towards a socially sustainable steady state economy in mind, they could be applied more widely. All countries could benefit from implementing a national accounting system that follows these criteria, regardless of their macroeconomic goal.

8.6.2. Achieving a Steady State Economy

Within this thesis, I have developed a set of indicators that aim to satisfy the above recommendations, and I have applied these to ~180 countries over a ten-year time period. The results of my empirical analysis suggest that some countries are closer to the goal of a steady state economy than others, and that there are important relationships between stability, scale, and social performance. Building on the policy proposals discussed in Section 2.4, these results lead to a number of recommendations for how best to achieve a socially sustainable steady state economy:

1. **Make achieving a steady state economy an explicit goal.** Although a number of countries in the world have achieved biophysical stability over a ten-year time period, this situation seems unlikely to last unless these countries make achieving a steady state economy their explicit goal. Having already achieved biophysical stability, however, it should be easier for these countries to now embrace the idea of maintaining it.
2. **Enact policies to improve social performance at the same time as policies to stabilise resource use.** Countries with stable stocks and flows have higher life satisfaction, longer healthy life expectancies, stronger democracies and less poverty than those with either increasing or decreasing stocks and flows. It is difficult to know whether greater stability leads to better social performance, or whether better social performance leads to greater stability. Nevertheless, stability and high social performance appear to be compatible goals, and thus policies designed to achieve both of these goals concurrently may have a better chance of success.
3. **Place more emphasis on sustainable scale.** Although achieving biophysical stability is an important accomplishment, it is not enough on its own. Countries must also ensure that biophysical flows are within ecological limits. Advocates of a steady state economy must recognise that degrowth is necessary in many countries before a steady state economy can be established.
4. **Manage degrowth carefully.** Degrowth in wealthy nations is almost certainly required if these nations are to achieve a steady state economy. However, social performance is in general lower in countries where biophysical scale is smaller. Moreover, while the number of countries currently experiencing degrowth is limited, it appears that social performance in these countries is also lower than in biophysically stable economies. For these reasons it is important to monitor social indicators carefully in any nation pursuing the degrowth transition to a steady state

economy, and enact policies designed to maintain (or improve) social performance if needed.

5. **Stabilise population.** A stable population is required, not just for environmental sustainability, but potentially for social sustainability as well. The results of the empirical analysis suggest that social performance is higher in countries with a stable population than in those with either an increasing or decreasing population. In wealthy nations, population may be stabilised by balancing immigration with emigration, and promoting incentives to limit family size to two or fewer children. In poorer countries, the best strategy is probably to provide education, access to birth control, and equal rights for women.
6. **Strengthen democratic institutions.** A deepening of democracy is one of the key goals of the degrowth movement. The results of the empirical analysis suggest that greater voice and accountability and biophysical stability go hand in hand. Democratic institutions may be strengthened by adopting proportional representation systems, limiting financial contributions to political parties, ensuring freedom of the press, and reducing corruption. New technologies may also be employed to allow for "direct democracy", and thus put important decisions directly to the people.
7. **Reconsider the causes of unemployment.** One of the strongest criticisms of a steady state economy is that it will result in job losses. However, the empirical analysis suggests that, when nations are compared, there is no correlation between either biophysical or economic growth rates and the level of unemployment. This finding challenges conventional economic thought, and should be investigated further before being extended too far. Nevertheless, it lends support to Blake Alcott's argument that, "Ultimately society, not the economy, determines how many people are out of work" (O'Neill et al., 2010, p. 80).
8. **Begin the transition to a steady state economy now.** A variety of global environmental indicators suggest that humanity is currently using resources faster than they can be regenerated, and producing wastes faster than they can be assimilated. With this in mind, the continued pursuit of economic growth in wealthy nations appears to be highly irresponsible. On the one hand it is reducing the ecological space available to poor na-

tions, where growth is still needed to alleviate poverty, and on the other hand it is failing to improve people's lives. If humanity is to have any hope of achieving a sustainable future, then wealthy nations must begin the transition to a steady state economy now.

8.7. Summary

One of the most important findings of this thesis is that the stationary is not "dull" as suggested by Adam Smith, but is in fact more cheerful and hearty than either the "progressive" or "declining" state. Whether biophysical stability leads to higher social performance, or higher social performance encourages biophysical stability is difficult to know, but the principle message remains: the two goals are compatible, which is good news for achieving a socially sustainable steady state economy.

Accompanying this good news, though, there is also some bad news. Greater social performance is associated, not just with biophysical stability, but also with higher levels of resource use. Moreover, the level of resource use associated with a sufficiently high score on the social indicators is too high to be extended to all people on the planet (assuming the sustainability thresholds associated with the ecological footprint and global CO_2 emissions budget are correct). If global inequalities are to be eliminated, then we either need to become far more efficient at translating natural resources into human well-being, or global population has to decline dramatically. An efficiency indicator calculated by taking the ratio of the change in well-being associated with a given change in resource use could be helpful for prioritising the intermediate ends of the economy, and thus allow us to achieve high human well-being at less environmental cost.

A steady state economy is best thought of as an economy where environmental pressure is stabilised, and where resource use is kept within ecological limits. Degrowth may be required before a steady state economy can be established in many nations. Both constant stocks and constant flows are an important part of the definition of a steady state economy, and for the time being at least, it seems reasonable to track both of these in any system of accounts designed to measure progress towards a steady state economy.

The empirical results of this thesis are based on the best data that are currently available for a large number of countries, but represent an inevitable trade-off between accuracy and coverage. Therefore, the results should not be viewed as a definitive assessment of which economies are closest to a steady state economy, but rather as a helpful "first pass", to be complemented by more in-depth analyses in the future.

Nevertheless, a number of important recommendations emerge from both the theoretical explorations and empirical findings of the thesis. These recommendations include replacing GDP with two sets of accounts (biophysical and social) that organise indicators along a continuum from means to ends, and enacting social and environmental policies in concert to achieve a steady state economy.

9. Conclusion

No one tries to predict what he will do tomorrow. Instead he decides what he will do tomorrow, and, subject to contingencies beyond his control, he carries out his decision.

— Herman Daly [34]

This chapter concludes the thesis. Following a brief review of the study (Section 9.1), I discuss the main theoretical and empirical contributions of the thesis (Section 9.2), as well as its limitations (Section 9.3). These lead me to make a number of suggestions for future research that could be carried out (Section 9.4). Finally, the thesis draws to a close with some reflections on the main findings and the thesis process itself (Section 9.5).

9.1. A Brief Review of the Study

This study took as its starting point the idea that continued economic growth is not sustainable due to biophysical limits, and no longer desirable (in wealthy countries at least) because it is failing to improve people's lives. After briefly surveying the environmental and social critiques of economic growth that have given rise to the call for a steady state economy (Chapter 1), the study identified two main research questions: (1) how can progress towards a steady state economy be measured at the national level, and (2) what is the relationship between a country's proximity to a steady state economy and its social performance?

To answer these questions, the study first reviewed the literature defining the concept of a steady state economy, and compared and contrasted this concept with the related idea of degrowth (Chapter 2). The review of definitions was followed by an exploration of the proposals that have been made for how to achieve a steady state economy. These proposals were drawn from the existing literature, as well as from a report that I co-authored based on the first Steady State Economy Conference (see O'Neill et al., 2010). The policy proposals include ideas for how to limit resource use and waste production, stabilise population, reduce inequality, secure full employment, reform the monetary system, rethink

[34] Daly (1977, p. 137)

business and investment, address global relationships, dismantle the culture of consumerism, and change the way we measure progress.

Following the general exploration of policies for a steady state economy, the study examined the arguments for and against using quantitative indicators to measure progress, and analysed four existing indicator approaches that could be used to measure progress towards a socially sustainable steady state economy (Chapter 3). These approaches include (1) Gross Domestic Product, (2) the Index of Sustainable Economic Welfare, (3) biophysical and social indicators, and (4) a composite indicator. The analysis concluded that separate biophysical and social indicators represent the best approach, but that a unifying framework based on ends and means is required to choose appropriate indicators and interpret the relationships between them.

Prior to selecting individual indicators, the study explored some of the ways that specific aspects of Herman Daly's definition of a steady state economy could be interpreted (Chapter 4). Aspects that were discussed include the relative importance of the definition's three main components (stocks, flows, and scale), the issue of aggregation, the treatment of renewable and non-renewable resources, the issue of trade, the inclusion of hidden flows, and the role of the stock of natural capital. This exploration led to a list of criteria that biophysical indicators for a steady state economy should aim to satisfy.

Based on Daly's definition and these criteria, the study proposed a set of seven abstract biophysical indicators (Chapter 5). These include the rate of change of three stocks (human population, built capital, and domesticated animals), the rate of change of three flows (material use, energy use, and material outflows), and the scale of resource use in comparison to the capacity of ecosystem sources and sinks. The study discussed how each of these abstract indicators could be measured in practice, and one or more measurable proxies was chosen for each based on the best data currently available for a large number of countries.

The selection of biophysical indicators was followed by an exploration of how to measure the social performance of a steady state economy (Chapter 6). Based largely on the declaration from the first international degrowth conference, the study identified eight intermediate ends to work towards in a steady state economy, and a single ultimate end to help prioritise these. The ultimate end is human well-being, and the intermediate ends are health, equity, the elimination of poverty, increased social capital, participatory democracy, decreased working time, low unemployment, and stable prices. The study explored five different approaches to defining and measuring human well-being, and proposed that well-being should be measured using a small number of subjective indicators from three of these approaches (evaluative, hedonic, and eudaimonic). It also discussed how each intermediate end is described in the degrowth and steady state literatures, how it contributes to the ultimate end of human well-being, how it relates to resource use, and what approaches exist to measure progress towards it. A measurable proxy for each of the social objectives was then selected based on the best data currently available for a large number of countries.

Following the selection of biophysical and social indicators, these indicators were used to conduct an empirical analysis that considered ~180 countries over a ten-year time period from 1997 to 2007 (Chapter 7). The analysis investigated how close different countries are to both biophysical stability and optimal scale, and examined the relationship between their proximity to these objectives and social performance. The empirical analysis indicated that most countries in the world are biophysical growth economies, although there are around 20 countries that achieve relatively stable stocks and flows over the analysis period. Both biophysical stability and biophysical scale were found to be statistically significant predictors of social performance. The findings suggest that while a biophysically stable economy may be socially sustainable, the level of resource use required may be too high to be extended to all people without exceeding global ecological limits.

Finally, the study discussed the implications of the overall results, questioning Adam Smith's claim that "the stationary is dull" (Chapter 8). It explored the implications of individual indicator results such as the relationship between population stability and high social performance, the relationship between strong democracies and overall biophysical stability, and the lack of any relationship between growth rates and the level of unemployment. It also discussed the finding that a potentially unsustainable level of resource use is needed to achieve social sufficiency, and proposed a new measure of efficiency that could be used as a way of prioritising intermediate ends. Lastly, the study made recommendations in two broad areas: (1) for a new system of national accounts to replace GDP, and (2) for how to achieve a socially sustainable steady state economy.

9.2. *Theoretical and Empirical Contributions*

This thesis makes a number of important theoretical and empirical contributions to knowledge. The theoretical contributions include the following:

- The study offers a strong critique of existing indicator approaches, and proposes a novel system of indicators to measure progress towards a socially sustainable steady state economy. An important feature of this system is that the indicators are split into two separate accounts (biophysical and social), and organised according to a unifying conceptual framework based on ends and means.
- The study translates Herman Daly's abstract definition of a steady state economy into a more precise and operational definition at the national level, which lends itself to measurement. This definition accounts for trade, chooses a way of aggregating stocks and flows, includes the stock of domesticated animals, and specifies the role of renewable and non-renewable resources.
- The study moves beyond the purely biophysical definition of a steady state economy to describe what would *not* be held steady in such an economy. In other words, it describes the social goals that might be pursued and monitored in a steady state economy. These include eight intermediate ends (health, equity, the elimination of poverty, increased social capital, participatory democracy, decreased working time, low unemployment, and stable prices), and a single ultimate end to help prioritise these (human well-being).
- The study offers three novel methods for assessing how close different economies are to the stability and optimal scale objectives of a steady state economy. These include a "multi-criteria approach", which categorises countries based on their performance on seven rate-of-change indicators; a Biophysical Stability Index, which calculates stability as the average of the same seven rate-of-change indicators; and a "pathway approach", which places countries into one of four quadrants based on their performance on three separate indicators.

- Finally, the study draws together and integrates knowledge from a number of different areas of inquiry, including steady state economics, degrowth, material and energy flow accounting, and subjective well-being. More specifically, the study provides a common information system to measure what is meant by both degrowth and a steady state economy. In doing so it builds on Kerschner's (2010) work showing the complementary nature of the two ideas. The strength of the steady state concept is its focus on the biophysical resources that the economy depends on, which the study relates to key quantities in material and energy flow accounting. The strength of degrowth is its focus on social objectives, which the study relates to key ideas in the emerging field of subjective well-being.

In addition to the above theoretical contributions, the thesis also makes a number of important empirical contributions. These include:

- The study shows which economies are growing, which are degrowing, and which are stable, based on the rates of change of seven biophysical indicators. The results reveal that the vast majority of countries in the world are biophysical growth economies, although a number of countries achieve stable levels of stocks and flows over the analysis period (e.g. Denmark, France, Japan, Poland, Romania, and the U.S., among others). However, the scale of resource use in these countries is probably too high to be sustainable, implying the need for degrowth before these countries can achieve a steady state economy.
- The study shows that there are no countries in the world that achieve overall biophysical stability at the scale of a fair earthshare. However, a small number of countries come relatively close, including Colombia, Cuba, Kyrgyzstan, Romania, and South Africa.
- The study provides a composite indicator to measure progress towards the main social objectives of the degrowth movement, as articulated in the Paris Declaration. The index reveals that the countries with the highest social performance are almost exclusively wealthy European nations, with Switzerland, Denmark, and Iceland topping the list.
- The study compares the social performance of countries that are closer to, and further away from, the idea of steady state economy. The results reveal

that countries with stable biophysical stocks and flows perform better on a number of social indicators than countries with either growing or degrowing stocks and flows. This is encouraging news for achieving a steady state economy. However, the results also reveal that social performance is higher in countries with greater resource use, and a high level of social performance is only attained at a level of resource use that is well beyond a fair earthshare. Taken together, these findings suggest that while a biophysically stable economy may be socially sustainable, it could be difficult to extend the required level of resource use to all people on the planet without surpassing ecological limits.

- The study suggests a number of important relationships between individual biophysical and social indicators. These include a relationship between a stable population and high social performance, a relationship between strong democracies and overall biophysical stability, and *no* relationship between biophysical/economic growth rates and the level of unemployment. The latter finding is particularly interesting, as it runs contrary to conventional economic thought.
- Finally, the study provides the first measure of the rate of change of built capital at the national level. Due to a lack of any comparable data, however, the accuracy of this measure has yet to be determined.

9.3. Limitations

This thesis translates Herman Daly's definition of a steady state economy into a concrete and operational set of indicators, and measures how close economies are to steady state economy using these indicators. There are limitations to both the methods applied, and to the particular data used in the analysis. Perhaps the most important limitation relates to the concept of indicators themselves. As discussed in Section 3.1, indicators are only partial reflections of reality, based on uncertain and imperfect models. They are not the "real system", and this must be kept in mind when interpreting the results of any indictor analysis, including this one. That said, we need indicators. They are an important simplification of reality that allow us to function in a complex world.

Part of the simplification offered by indicators is the aggregation of data. Good indicators allow us to distil meaning from complex datasets, but there is always the danger of going too far—of over-aggregating the data and producing an indicator devoid of real meaning. The approach that I have adopted in this thesis uses highly aggregated biophysical indicators to measure a country's proximity to a steady state economy. There is no question that adding together flows of biomass, minerals, and fossil fuels to arrive at an indicator of the overall quantity of resource use ignores important information about the differences in the quality of each of these flows. However, it also provides us with new information about the overall environmental pressure exerted by different economies, which is something missing from traditional economic analyses, and a key part of the definition of a steady state economy.

In many cases, it was not possible to measure exactly what we would like to measure in order to determine how close countries are to a steady state economy. For example, the indicator chosen to measure biophysical scale (i.e. the ratio of per capita ecological footprint to a fair earthshare), represents a compromise. The footprint was chosen because it relates resource use to a clear sustainability threshold, and such a threshold is needed in order to identify whether the optimal scale criteria associated with a steady state economy is being met. However, the ecological footprint has been widely criticised as a measure of sustainability, and the threshold that it indicates may be of questionable utility.

Similar compromises were also made when choosing the social indicators. For example, in Section 6.2.6, I concluded that the ultimate end of human well-being should be measured using a single index that combines a small number of subjective measures from the hedonic, evaluative, and eudaimonic approaches to well-being. However, no such index is available for a large number of countries, which forced me to use a simpler measure of well-being (i.e. life satisfaction).

There are also limits to the methods developed and used in the thesis. For example, the pathway approach developed in Section 7.1.3represents a conceptually appealing way of visualising how close economies are to a steady state economy. However, actually applying this approach leads to some tough questions about exactly which indicators to use, and how to aggregate them. I chose to use only three indicators in the pathway approach, which made the results easier to interpret, but meant discarding valuable information from the Biophysical Accounts. The result is that the pathway approach, in its present incarnation at least, is useful for illustrating the path that economies must take to reach a steady state economy, but is not as useful for showing how close economies are to biophysical stability as the multi-criteria approach or BSI.

Another aspect of the study which may, or may not, be viewed as a limitation is that there is no single index showing how close economies are to a steady state economy. I have created an index of biophysical stability (the BSI) and an "index" of biophysical scale (the ratio of per capita ecological footprint to a fair earthshare), but I choose not to aggregate these two together into a single indicator. The primary reason for this choice is that the two quantities are so fundamentally different that it is difficult to defend any scheme that merges them. Creating a "Steady State Economy Index" (as it might be called), would involve aggregating the level of a biophysical flow with its rate of change, and I am not sure this would be meaningful information.

Finally, it is worth drawing some attention to the fact that the empirical results of this thesis are the product of a cross-national analysis (and not, for example, a time series analysis). Although the results suggest certain general relationships between resource use and social performance based on international comparisons, there is no guarantee that these relationships would hold within individual countries, or over time. For example, although people in countries with stable biophysical stocks and flows tend to live longer lives than people in countries with growing or degrowing stocks and flows, this does not necessarily mean that stabilising resource use within a particular country would improve health outcomes.

9.4. Suggestions for Future Work

Taken together, the findings and limitations of this study suggest a number of avenues for future research. Perhaps the most important area where further research is required is in the quantification of biophysical limits. These remain very difficult to estimate. Within this thesis the ecological footprint is used as the indicator of biophysical scale, but other approaches could be pursued as well such as embodied HANPP and/or carbon budgets. The planetary boundaries approach devised by Rockström et al. (2009a; 2009b) may also hold promise. But even if we are able to accurately quantify planetary limits, there is still the tricky question of how to translate these into "ecological budgets" at the national level. This is another area where more work is required.

The empirical results identify a number of countries with biophysically stable economies. However, this identification is based on a relatively short time period (ten years) and, in some cases, fairly crude data. It would be useful to do an in-depth analysis of the small number of countries identified as having biophysically stable economies to determine (a) whether this assessment still holds when more detailed data and/or a longer time series are used, and (b) whether there are certain conditions, institutions, and policies common to these countries, which help to explain their success.

One of the more interesting empirical findings of this study is the lack of any statistically significant relationship between growth (whether economic or biophysical) and the unemployment rate, when nations are compared. This is a finding that should be investigated further using panel data that include unemployment, GDP, and resource use for a wide range of countries. Currently, such a study would be limited by the availability of internationally comparable unemployment statistics. Therefore, further efforts should be made to standardise unemployment data between countries, particularly those that are not part of the OECD. Similar efforts are required to develop an indicator of absolute poverty that can be applied across a wide range of countries.

Perhaps the largest indicator challenge, however, is to develop a single measure of human well-being that combines a small number of subjective measures from the hedonic, evaluative, and eudaimonic approaches. The search for such a measure has been referred to as "the single most important challenge faced by quality-of-life research" (Stiglitz et al. 2009, p. 59). If human well-being is to be viewed as the ultimate end of the economic system, then a more comprehensive way of accounting for it than simply using life satisfaction (as I have done) needs to be developed.

Finally, it would be interesting to follow the lead of Steinberger and Roberts (2010) and investigate whether the sufficiency thresholds for social indicators such as life satisfaction, voice/accountability, interpersonal safety/trust, and poverty have changed over time. Steinberger and Roberts find that the carbon and energy efficiency with which societies achieve high life expectancy, literacy, and income has improved over time, but whether their findings would hold for other social indicators (or with respect to the ecological footprint) has yet to be investigated.

9.5. Final Reflections

This study took as its starting point the assumption that economic growth in wealthy nations cannot continue, and that a steady state economy is required to achieve ecological sustainability. The research was motivated by a simple idea—that while there may not be any true steady state economies at present, some countries are probably closer to this goal than others, and it may be possible to learn something about how to achieve a true steady state economy by identifying and analysing the environmental and social conditions in these countries.

While some of the empirical findings of the study are not surprising, such as the result that the vast majority of people in the world live in biophysical growth economies, others are more remarkable. These include the finding that biophysically stable economies perform better on a number of social indicators than growing economies. This finding gives me hope that it is possible to achieve an economy that is both ecologically and socially sustainable at the same time.

The thesis process itself was, at times, a trying one. In many ways I felt that I was engaging in a rather risky enterprise, trying to develop a new system of accounts for a different type of economy, and hoping that the indicators contained within these accounts would also contribute to a better understanding of complex economic systems. It was not always obvious that this would be the case, but in the end I think the study's contribution, and my own personal development as a researcher, have been substantial.

Given my background in the natural sciences, I started this project thinking that my main contribution needed to be empirical. Over time, though, I came to understand and embrace other ways of advancing knowledge. In the end, my work took much more of a theoretical turn than I would initially have expected, and I now believe that the conceptual contributions of the thesis are at least as important as the empirical ones.

The overarching goal of this research was to contribute to the development of a new "macro-economics for sustainability". A new economics is needed because the old one simply isn't working, for people or planet. Creating a new economic model feels a bit like assembling a massive jigsaw puzzle, but without the benefit of the picture on the box. I hope that this study has helped to put a few more pieces in place.

Appendix I: Abbreviations

ANOVA	Analysis of Variance
BEA	Bureau of Economic Analysis
BSI	Biophysical Stability Index
CO_2	Carbon Dioxide
DEC	Domestic Energy Consumption
DEE	Domestic Energy Extraction
DEI	Direct Energy Input
DMC	Domestic Material Consumption
DME	Domestic Material Extraction
DMI	Direct Material Input
DMO	Direct Material Output
DPO	Domestic Processed Output
DPSIR	Driving forces, Pressures, States, Impacts, and Responses
DRM	Day Reconstruction Method
EEA	European Environment Agency
EF	Ecological Footprint
EFA	Energy Flow Accounting
EIA	Energy Information Administration
EKC	Environmental Kuznets Curve
EMC	Environmentally-weighted Material Consumption
ET	Energy Throughput
EU	European Union
EWEB	Environmentally Efficient Well-being
FAO	Food and Agriculture Organization
FES	Fair Earthshare
GAS	Gross Additions to Stock
GDP	Gross Domestic Product
GFN	Global Footprint Network
GNP	Gross National Product
GPI	Genuine Progress Indicator
HANPP	Human Appropriation of Net Primary Production
HDI	Human Development Index

HPI	Happy Planet Index
HPI-1	Human Poverty Index (for developing countries)
HPI-2	Human Poverty Index (for OECD countries)
I_E	Energy Imports
IE	Intermediate End
IEA	International Energy Agency
ILO	International Labour Organization
I_M	Material Imports
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISD	Indices of Social Development
ISEW	Index of Sustainable Economic Welfare
ISS	Institute of Social Studies
MEFA	Material and Energy Flow Accounting
MFA	Material Flow Accounting
MIPS	Material Input Per Service Unit
MPI	Multidimensional Poverty Index
MT	Material Throughput
NAS	Net Additions to Stock
NBER	National Bureau of Economic Research
NGDC	National Geophysical Data Center
OLS	Ordinary Least Squares
PC	Per Capita
PPP	Purchasing Power Parity
RFS	Removals From Stock
SE	Standard Error
SERI	Sustainable Europe Research Institute
SPI	Social Performance Index
SSE	Steady State Economy
SWB	Subjective Well-being
SWIID	Standardized World Income Inequality Database
TEC	Total Energy Consumption
TMC	Total Material Consumption
TMR	Total Material Requirement

TPES	Total Primary Energy Supply
UE	Ultimate End
UM	Ultimate Means
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNMP	United Nations Millennium Project
WCED	World Commission on Environment and Development
WHO	World Health Organization
WRI	World Resources Institute
WTO	World Trade Organization
WVS	World Values Survey
X_E	Energy Exports
X_M	Material Exports

Appendix II: Data Adjustments

The calculation of the compound annual rate of change for the indicators in the Biophysical Accounts, and the accompanying standard errors, revealed a number of countries with high standard error values that I investigated further by visually examining the trends. In general the high standard errors were caused by a high amount of scatter in the data. In one case, however (the ecological footprint in Samoa), the high standard error appeared to be caused by a single spurious data point in 2006 (Figure A.1) . Further investigation revealed that this high value was caused by an unusually high value for fish imports in the year (an order of magnitude greater than other years). Suspecting an error in the data, I have therefore replaced the ecological footprint for Samoa in 2006 with an average of the values in 2005 and 2007. The result is that the rate of change of the ecological footprint for Samoa, which was originally calculated as 4.19 ± 2.82, becomes 0.52 ± 0.98).

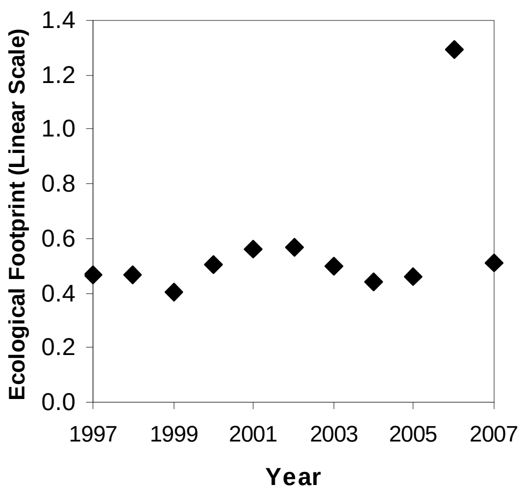

Figure A.1: Ecological footprint in Samoa for the period 1997–2007 (before correction).

A similar problem occurs with the livestock data in Mozambique (Figure A.2). There is a spike in the year 1999 which appears to be due to a spurious entry for the number of Turkeys in that year (85 billion!) Data in the surrounding years suggest that the value should actually be 85 million. Correcting the data changes the livestock growth rate from -0.33 ± 2.42 to 1.79 ± 0.57.

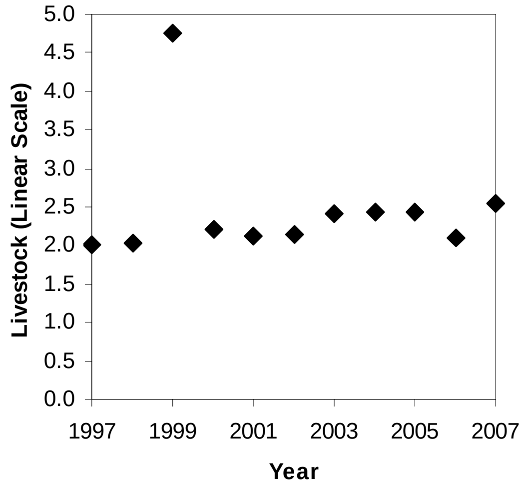

Figure A.2: Livestock in Mozambique for the period 1997–2007 (before correction).

Appendix III: Additional Data

In order to improve the readability of the thesis, some of the data used in Chapter 7 are not presented within the chapter text, but are instead included here. Table A.1 provides the "raw" rate-of-change data for the seven stocks and flow indicators in the Biophysical Accounts, and accompanying standard errors. Table A.2 provides the complementary *per capita* rate-of-change data, and their standard errors. Finally, Table A.3 provides total and per capita GDP growth rates, as well per capita GDP levels.

Table A.1: The Biophysical Accounts: rate-of-change indicators with standard errors.

Country	Change in Stocks (% per year)			Change in Flows (% per year)			
	Population	Livestock	Lights	Materials	Energy	CO_2	EF
Afghanistan	3.25 ±0.11	0.18 ±0.70	.. ..	0.84 ±0.67	-4.44 ±1.24	-4.19 ±2.67	2.16 ±0.51
Albania	0.18 ±0.04	-1.44 ±0.21	6.20 ±0.97	6.09 ±0.34	3.88 ±0.79	10.55 ±1.90	5.49 ±0.52
Algeria	1.49 ±0.00	1.71 ±0.20	2.39 ±0.51	3.27 ±0.26	2.67 ±0.52	3.57 ±0.58	4.18 ±0.43
Angola	2.94 ±0.03	1.38 ±0.47	6.50 ±0.71	5.79 ±0.56	8.27 ±0.70	13.24 ±1.73	3.80 ±0.39
Antigua & Barbuda	1.74 ±0.08	0.98 ±0.15	.. ..	3.52 ±0.22	3.12 ±0.41	2.96 ±0.27	1.85 ±0.51
Argentina	1.00 ±0.02	0.44 ±0.16	1.21 ±0.32	1.43 ±0.36	2.44 ±0.45	2.67 ±0.58	-0.63 ±0.49
Armenia	-0.17 ±0.05	2.90 ±0.33	5.77 ±1.38	5.15 ±0.28	3.98 ±0.32	3.98 ±0.98	3.20 ±0.69
Australia	1.21 ±0.01	-0.75 ±0.17	0.00 ±0.22	2.29 ±0.13	2.08 ±0.09	1.14 ±0.36	0.74 ±0.94
Austria	0.46 ±0.03	-1.31 ±0.09	0.36 ±0.75	1.33 ±0.35	1.42 ±0.14	1.76 ±0.30	1.46 ±0.27
Azerbaijan	0.82 ±0.02	3.78 ±0.10	2.68 ±0.71	8.64 ±1.40	1.48 ±0.82	1.39 ±0.47	3.13 ±0.34
Bahamas	1.36 ±0.02	-0.30 ±1.76	.. ..	0.84 ±0.49	3.43 ±0.83	2.30 ±0.36	-3.56 ±2.08
Bahrain	2.27 ±0.01	0.02 ±0.63	.. ..	1.95 ±0.10	4.41 ±0.33	1.95 ±0.92	8.16 ±0.73
Bangladesh	1.71 ±0.02	1.48 ±0.10	-0.35 ±1.31	3.03 ±0.11	7.40 ±0.19	6.60 ±0.41	2.73 ±0.33
Barbados	0.01 ±0.05	-2.60 ±0.55	.. ..	-1.15 ±0.29	-1.13 ±1.09	2.77 ±0.63	2.25 ±0.51
Belarus	-0.48 ±0.00	-1.90 ±0.33	-2.36 ±1.42	2.94 ±0.67	1.61 ±0.69	1.33 ±0.36	-0.51 ±0.95
Belgium	0.40 ±0.02	-2.10 ±0.26	-2.00 ±0.44	0.05 ±0.12	0.45 ±0.13	-1.22 ±0.23	0.93 ±0.17
Belize	2.37 ±0.03	3.01 ±0.47	.. ..	2.41 ±0.48	9.65 ±1.18	-2.03 ±2.52	-2.15 ±2.35
Benin	3.30 ±0.02	3.18 ±0.19	1.74 ±0.62	2.27 ±0.83	11.30 ±0.40	12.36 ±0.77	3.00 ±1.31
Bhutan	2.82 ±0.05	0.32 ±0.25	.. ..	2.41 ±0.16	9.50 ±1.82	4.55 ±0.61	1.75 ±0.25
Bolivia	2.00 ±0.01	2.64 ±0.05	1.91 ±0.42	2.58 ±0.35	6.49 ±0.66	2.86 ±1.12	1.96 ±0.17
Bosnia & Herz.	1.02 ±0.22	3.46 ±0.38	1.82 ±1.24	5.02 ±0.59	5.33 ±0.52	6.73 ±0.91	1.29 ±1.15
Botswana	1.47 ±0.05	-1.42 ±0.67	5.55 ±0.41	2.73 ±0.81	3.08 ±0.66	3.58 ±0.59	0.32 ±1.69
Brazil	1.34 ±0.02	2.79 ±0.26	0.59 ±0.48	3.66 ±0.20	2.28 ±0.20	1.30 ±0.21	0.81 ±0.26
Brunei Darussalam	2.16 ±0.03	9.90 ±1.18	.. ..	2.14 ±0.34	12.48 ±1.26	1.30 ±1.14	-3.17 ±1.16
Bulgaria	-0.70 ±0.01	-2.61 ±0.48	1.81 ±1.38	1.23 ±0.23	0.42 ±0.52	0.13 ±0.71	2.23 ±0.84
Burkina Faso	3.25 ±0.03	4.53 ±0.03	3.89 ±0.46	3.79 ±0.26	2.24 ±0.37	5.69 ±0.74	1.67 ±0.98
Burundi	2.35 ±0.13	4.88 ±0.55	0.65 ±1.70	3.42 ±0.62	-0.54 ±0.50	-6.91 ±1.30	2.18 ±0.83
Cambodia	1.77 ±0.04	1.81 ±0.29	6.25 ±0.81	2.86 ±0.48	9.05 ±0.27	8.78 ±0.37	3.22 ±0.32
Cameroon	2.36 ±0.01	1.97 ±0.40	-0.09 ±0.54	1.41 ±0.21	1.87 ±0.38	5.08 ±1.13	2.30 ±0.25
Canada	1.00 ±0.01	1.40 ±0.18	-2.10 ±0.71	0.51 ±0.14	1.30 ±0.16	1.68 ±0.31	1.36 ±0.51
Cape Verde	1.71 ±0.02	3.28 ±0.48	.. ..	-4.04 ±1.76	11.04 ±1.92	8.67 ±0.49	-1.32 ±1.75
Central African Rep.	1.93 ±0.03	2.82 ±0.11	.. ..	1.54 ±0.10	1.55 ±0.40	-0.47 ±0.42	-0.15 ±0.15
Chad	3.48 ±0.03	2.85 ±0.09	4.66 ±0.75	2.48 ±0.09	3.10 ±0.59	16.83 ±1.98	2.78 ±0.37
Chile	1.14 ±0.02	0.61 ±0.28	2.25 ±0.46	3.92 ±0.41	2.96 ±0.64	1.86 ±0.65	2.59 ±0.43
China	0.73 ±0.01	0.49 ±0.23	4.99 ±0.37	5.87 ±0.48	9.12 ±1.03	7.75 ±0.94	3.46 ±0.51
Colombia	1.62 ±0.01	0.52 ±0.23	-1.48 ±0.33	2.03 ±0.24	0.79 ±0.36	-0.35 ±0.67	0.62 ±0.32
Comoros	2.25 ±0.01	-0.40 ±0.44	.. ..	0.36 ±0.23	4.51 ±0.46	6.06 ±0.25	7.52 ±0.78
Congo	2.20 ±0.04	3.27 ±0.23	4.66 ±0.68	1.26 ±0.46	8.67 ±1.49	3.72 ±3.85	2.99 ±0.32
Congo (Dem. Rep.)	2.89 ±0.04	-2.05 ±0.43	1.79 ±0.44	2.23 ±0.35	0.86 ±0.91	0.17 ±1.92	0.72 ±0.06
Costa Rica	2.00 ±0.06	-1.92 ±0.52	0.70 ±0.57	1.26 ±0.27	4.51 ±0.29	4.72 ±0.25	0.93 ±0.60
Cote d'Ivoire	2.31 ±0.04	1.09 ±0.37	1.84 ±0.74	1.08 ±0.21	1.10 ±0.92	-0.51 ±1.22	0.28 ±0.38
Croatia	-0.40 ±0.05	0.98 ±0.27	2.10 ±0.83	2.44 ±0.31	1.27 ±0.22	2.17 ±0.29	1.65 ±0.40
Cuba	0.20 ±0.01	-0.99 ±0.22	2.38 ±1.20	-1.50 ±0.58	-1.70 ±0.92	0.56 ±0.24	0.88 ±0.45
Cyprus	1.25 ±0.02	0.75 ±0.46	1.85 ±0.22	5.10 ±0.40	2.92 ±0.25	2.47 ±0.27	3.89 ±0.47
Czech Republic	-0.05 ±0.03	-3.23 ±0.31	-1.47 ±1.11	1.15 ±0.26	1.49 ±0.33	-0.20 ±0.38	1.50 ±0.43
Denmark	0.32 ±0.01	0.08 ±0.15	-1.76 ±1.16	0.82 ±0.46	-0.60 ±0.26	-0.76 ±0.66	0.01 ±0.31
Djibouti	2.24 ±0.10	0.53 ±0.17	.. ..	0.94 ±0.23	-0.13 ±0.33	1.56 ±0.68	3.69 ±0.58
Dominica	-0.20 ±0.01	0.04 ±0.02	.. ..	0.07 ±0.36	3.66 ±0.85	4.47 ±0.81	-1.17 ±0.63
Dominican Rep.	1.56 ±0.01	1.75 ±0.82	0.25 ±1.03	3.05 ±0.53	4.77 ±0.58	1.09 ±0.40	1.36 ±0.38
Ecuador	1.23 ±0.02	-0.68 ±0.21	2.47 ±0.28	1.66 ±0.51	3.15 ±0.41	4.43 ±0.44	0.28 ±0.63
Egypt	1.91 ±0.00	2.78 ±0.09	3.09 ±0.06	2.82 ±0.17	4.72 ±0.35	4.71 ±0.70	1.99 ±0.36
El Salvador	0.43 ±0.02	2.75 ±0.39	1.29 ±0.59	0.71 ±0.37	3.43 ±0.31	1.55 ±0.20	2.96 ±0.42
Eritrea	3.84 ±0.06	0.48 ±0.50	.. ..	-1.70 ±0.48	-4.39 ±1.52	1.22 ±1.09	0.29 ±0.90
Estonia	-0.41 ±0.04	-2.00 ±0.49	-1.02 ±0.84	-0.26 ±3.35	1.53 ±0.66	1.03 ±0.77	2.11 ±0.91
Ethiopia	2.67 ±0.01	3.68 ±0.48	7.80 ±0.36	3.57 ±0.33	9.24 ±0.64	2.87 ±1.03	2.17 ±0.26
Fiji	0.68 ±0.01	-0.56 ±0.15	.. ..	-1.00 ±0.50	9.91 ±0.87	9.82 ±1.86	-0.37 ±1.30
Finland	0.27 ±0.01	-1.31 ±0.14	-2.31 ±0.89	2.06 ±0.53	1.23 ±0.22	1.44 ±0.80	2.62 ±0.41
France	0.58 ±0.02	-0.87 ±0.12	-0.13 ±0.25	0.31 ±0.27	0.85 ±0.12	-0.08 ±0.31	0.53 ±0.29
Gabon	2.17 ±0.04	0.16 ±0.11	2.06 ±0.64	-0.68 ±0.86	-0.36 ±0.71	-1.19 ±3.04	6.28 ±2.79
Gambia	3.28 ±0.05	2.48 ±0.56	4.28 ±1.71	5.11 ±0.83	4.93 ±0.53	5.21 ±0.45	0.82 ±2.23
Georgia	-1.21 ±0.00	0.97 ±0.58	9.01 ±1.49	6.60 ±0.70	-0.51 ±0.92	1.78 ±1.64	-15.11 ±6.20

Country	Change in Stocks (% per year)			Change in Flows (% per year)			
	Population	Livestock	Lights	Materials	Energy	CO_2	EF
Germany	0.06 ±0.01	-1.11 ±0.09	-1.74 ±0.46	-2.38 ±0.24	0.14 ±0.13	-1.02 ±0.21	0.03 ±0.22
Ghana	2.34 ±0.02	2.69 ±0.08	-0.12 ±0.68	3.47 ±0.32	2.70 ±1.03	3.86 ±0.77	3.22 ±0.57
Greece	0.26 ±0.01	-0.10 ±0.08	2.33 ±0.43	1.57 ±0.20	2.09 ±0.17	1.54 ±0.18	2.57 ±0.49
Grenada	0.22 ±0.02	0.78 ±0.30	.. ..	2.49 ±0.41	4.16 ±1.67	2.09 ±0.30	0.65 ±0.86
Guatemala	2.47 ±0.01	2.72 ±0.15	3.98 ±0.93	2.86 ±0.35	4.84 ±0.23	4.85 ±0.45	3.43 ±0.32
Guinea	1.97 ±0.01	5.67 ±0.03	0.30 ±1.41	3.55 ±0.36	1.70 ±0.40	1.01 ±0.10	3.92 ±0.41
Guinea-Bissau	2.40 ±0.02	1.56 ±0.16	-1.97 ±2.73	1.10 ±0.10	2.55 ±0.26	1.42 ±1.45	0.47 ±0.39
Guyana	0.11 ±0.02	3.12 ±0.76	-1.98 ±0.54	-4.27 ±1.00	2.07 ±1.02	-1.06 ±0.26	-1.29 ±1.01
Haiti	1.74 ±0.02	1.31 ±0.34	-3.09 ±1.22	0.99 ±0.18	2.88 ±0.28	6.53 ±0.68	1.25 ±0.41
Honduras	2.06 ±0.01	4.00 ±0.73	5.12 ±0.49	3.69 ±0.42	5.90 ±0.29	7.37 ±0.50	2.73 ±0.33
Hungary	-0.26 ±0.00	-0.92 ±0.35	-1.43 ±1.23	1.81 ±1.06	0.99 ±0.22	-0.70 ±0.27	0.03 ±0.95
Iceland	1.12 ±0.07	-0.79 ±0.25	5.86 ±2.44	1.34 ±0.53	5.69 ±0.66	0.97 ±0.16	-0.47 ±3.37
India	1.65 ±0.02	-0.17 ±0.01	0.71 ±0.51	2.71 ±0.23	4.54 ±0.32	4.15 ±0.22	1.59 ±0.30
Indonesia	1.33 ±0.01	1.47 ±0.62	0.88 ±0.40	3.94 ±0.29	4.24 ±0.41	5.02 ±0.84	0.78 ±0.22
Iran	1.19 ±0.02	0.81 ±0.23	4.33 ±0.40	3.85 ±0.24	6.39 ±0.24	5.43 ±0.20	4.53 ±0.19
Iraq	2.80 ±0.06	0.85 ±0.37	3.90 ±0.78	-0.13 ±1.83	1.47 ±0.42	4.26 ±0.41	4.17 ±0.62
Ireland	1.78 ±0.06	0.16 ±0.19	1.95 ±0.47	4.54 ±0.77	3.14 ±0.35	1.62 ±0.33	2.45 ±0.42
Israel	1.99 ±0.03	1.15 ±0.38	0.09 ±0.09	2.44 ±0.14	2.23 ±0.39	0.28 ±0.32	2.91 ±0.28
Italy	0.42 ±0.04	-1.14 ±0.34	0.62 ±0.18	0.07 ±0.26	1.08 ±0.15	0.74 ±0.14	1.12 ±0.14
Jamaica	0.75 ±0.02	-2.29 ±1.09	-0.93 ±0.38	1.51 ±0.28	1.80 ±0.38	2.23 ±0.75	1.70 ±0.53
Japan	0.11 ±0.01	-0.72 ±0.10	-0.96 ±0.23	-0.03 ±0.01	0.49 ±0.10	0.15 ±0.17	-0.26 ±0.18
Jordan	2.67 ±0.08	0.76 ±0.74	2.46 ±0.39	3.26 ±0.21	4.80 ±0.40	4.71 ±0.35	4.33 ±0.59
Kazakhstan	0.03 ±0.13	2.38 ±1.10	3.19 ±0.86	5.57 ±0.42	3.67 ±0.41	6.01 ±0.68	19.56 ±2.74
Kenya	2.65 ±0.00	1.54 ±0.34	-0.95 ±0.67	1.41 ±0.23	4.53 ±0.56	2.38 ±1.10	1.55 ±0.38
Kiribati	1.80 ±0.01	4.69 ±0.58	.. ..	1.84 ±0.63	7.24 ±0.59	-0.71 ±1.08	-0.34 ±3.45
Korea, North	0.64 ±0.03	3.61 ±0.95	0.48 ±0.97	1.82 ±0.25	0.99 ±0.54	-3.92 ±3.22	1.09 ±0.54
Korea, South	0.54 ±0.02	1.03 ±0.48	0.19 ±0.18	2.41 ±0.25	3.29 ±0.23	2.29 ±0.55	2.85 ±0.71
Kuwait	4.39 ±0.24	3.54 ±0.47	1.82 ±0.81	3.43 ±0.67	3.85 ±0.42	3.83 ±0.59	3.89 ±1.45
Kyrgyzstan	1.18 ±0.04	1.49 ±0.12	-0.96 ±1.15	0.78 ±0.53	-0.92 ±0.57	1.27 ±1.31	0.18 ±1.07
Laos	1.83 ±0.04	1.97 ±0.57	5.02 ±0.69	2.29 ±0.25	6.09 ±1.15	7.51 ±0.78	1.63 ±0.30
Latvia	-0.71 ±0.02	-1.80 ±0.70	-0.79 ±0.86	7.93 ±3.50	2.02 ±0.49	0.04 ±0.91	4.82 ±0.71
Lebanon	1.46 ±0.03	1.53 ±0.17	-1.15 ±0.86	1.06 ±0.23	-1.57 ±0.68	-0.49 ±0.88	0.26 ±0.28
Lesotho	1.23 ±0.06	1.51 ±1.07	3.61 ±0.69	1.18 ±0.76	5.12 ±1.75	2.92 ±0.35	-2.45 ±0.58
Liberia	4.52 ±0.32	2.39 ±0.28	12.84 ±2.57	3.83 ±0.84	5.06 ±0.38	7.96 ±0.65	4.79 ±0.46
Libya	2.06 ±0.00	2.29 ±0.88	5.40 ±0.42	2.68 ±0.63	3.06 ±0.49	1.78 ±0.28	3.71 ±0.48
Lithuania	-0.58 ±0.02	-1.61 ±0.84	-0.55 ±1.21	3.46 ±0.40	0.77 ±0.84	-0.08 ±0.90	1.99 ±0.68
Luxembourg	1.23 ±0.01	-1.06 ±0.34	-1.46 ±0.86	0.15 ±0.08	4.45 ±0.35	4.83 ±0.54	2.14 ±0.87
Macedonia	0.27 ±0.02	-2.64 ±0.37	0.16 ±1.17	-1.22 ±0.85	-0.64 ±0.75	-0.57 ±0.48	5.69 ±1.79
Madagascar	2.92 ±0.02	-1.13 ±0.96	-1.87 ±0.85	1.03 ±1.01	7.14 ±1.04	1.61 ±1.08	3.00 ±1.22
Malawi	3.01 ±0.04	3.08 ±0.44	0.66 ±0.71	3.40 ±0.75	4.44 ±0.24	2.54 ±0.93	2.70 ±0.73
Malaysia	2.03 ±0.04	3.81 ±0.40	2.42 ±0.34	2.23 ±0.58	3.86 ±0.46	6.06 ±0.68	5.24 ±2.03
Mali	2.30 ±0.03	4.66 ±0.19	6.33 ±0.46	4.06 ±0.34	2.29 ±0.29	1.01 ±0.13	3.39 ±0.46
Malta	0.63 ±0.01	0.07 ±0.53	.. ..	1.67 ±0.49	0.44 ±0.73	0.69 ±1.23	-0.37 ±1.10
Mauritania	2.75 ±0.02	2.66 ±0.38	1.49 ±0.42	1.67 ±0.13	-1.87 ±0.62	1.06 ±2.81	3.03 ±0.59
Mauritius	0.96 ±0.02	2.39 ±0.45	0.74 ±0.25	1.00 ±0.62	5.55 ±0.79	6.39 ±0.46	9.29 ±1.27
Mexico	1.22 ±0.04	0.51 ±0.07	0.80 ±0.39	1.36 ±0.09	2.25 ±0.24	2.04 ±0.20	1.43 ±0.52
Moldova	-1.58 ±0.03	-3.29 ±0.77	-2.94 ±1.41	-0.65 ±1.16	0.37 ±1.17	-1.80 ±2.01	-1.50 ±1.40
Mongolia	1.27 ±0.01	-2.68 ±1.44	2.83 ±0.89	-0.78 ±0.69	3.50 ±0.53	2.89 ±0.49	-0.93 ±1.02
Morocco	1.17 ±0.01	1.26 ±0.26	5.73 ±0.37	2.34 ±0.27	2.57 ±0.24	4.12 ±0.26	2.45 ±0.65
Mozambique	2.64 ±0.01	1.79 ±0.57	5.54 ±0.19	2.66 ±0.27	19.20 ±3.20	8.31 ±0.66	1.13 ±0.40
Myanmar	0.83 ±0.03	2.95 ±0.05	-3.19 ±0.90	5.10 ±0.27	8.64 ±0.68	6.58 ±1.22	6.14 ±0.16
Namibia	2.04 ±0.03	1.58 ±0.72	1.61 ±0.58	1.97 ±0.58	7.93 ±0.53	5.42 ±0.68	5.84 ±1.78
Nauru	0.10 ±0.02	0.15 ±0.09	.. ..	.. ..	0.88 ±0.13	0.48 ±0.13	-0.54 ±0.40
Nepal	2.22 ±0.03	1.07 ±0.06	2.76 ±0.99	1.73 ±0.05	5.27 ±0.91	1.98 ±1.14	1.04 ±0.03
Netherlands	0.51 ±0.01	-1.92 ±0.34	-1.79 ±0.34	0.24 ±0.47	1.51 ±0.14	-0.08 ±0.33	1.14 ±0.42
New Zealand	1.12 ±0.02	-0.05 ±0.11	-0.64 ±0.32	1.02 ±0.18	1.02 ±0.21	0.78 ±0.30	-0.19 ±0.53
Nicaragua	1.42 ±0.03	2.55 ±0.36	1.36 ±1.04	2.25 ±0.21	4.02 ±0.19	3.02 ±0.41	0.82 ±0.49
Niger	3.54 ±0.03	4.33 ±0.01	0.98 ±0.62	2.67 ±0.37	1.77 ±0.24	-1.66 ±1.03	3.68 ±1.23
Nigeria	2.45 ±0.00	2.14 ±0.06	0.32 ±0.33	2.42 ±0.24	2.85 ±0.48	10.63 ±2.02	2.61 ±0.20
Norway	0.67 ±0.02	-0.42 ±0.09	-0.05 ±1.29	0.71 ±0.21	0.49 ±0.35	3.05 ±0.65	2.19 ±0.87
Oman	1.79 ±0.02	2.70 ±0.23	5.75 ±0.44	2.59 ±0.72	7.16 ±1.00	9.96 ±0.76	8.24 ±1.05

Country	Change in Stocks (% per year)			Change in Flows (% per year)			
	Population	Livestock	Lights	Materials	Energy	CO_2	EF
Pakistan	2.34 ±0.03	3.03 ±0.25	1.45 ±0.21	2.75 ±0.23	3.67 ±0.49	5.18 ±0.26	1.93 ±0.51
Panama	1.85 ±0.02	1.65 ±0.29	1.93 ±0.78	2.62 ±0.19	1.46 ±0.39	1.49 ±0.70	5.33 ±0.48
Papua New Guinea	2.60 ±0.02	1.87 ±0.27	-1.99 ±0.64	0.98 ±1.01	5.94 ±0.87	6.02 ±1.38	1.89 ±1.01
Paraguay	2.01 ±0.02	0.24 ±0.28	-0.41 ±0.47	0.97 ±0.16	0.37 ±0.37	-0.70 ±0.60	-1.48 ±0.58
Peru	1.40 ±0.03	1.93 ±0.11	1.51 ±0.26	5.44 ±0.28	3.04 ±0.24	3.66 ±1.02	0.83 ±0.56
Philippines	1.96 ±0.01	1.43 ±0.13	-0.13 ±0.71	1.89 ±0.37	1.71 ±0.29	-0.56 ±0.48	0.07 ±0.76
Poland	-0.12 ±0.00	-0.21 ±0.52	1.10 ±1.22	0.59 ±0.34	-0.40 ±0.54	-0.64 ±0.44	0.50 ±0.38
Portugal	0.56 ±0.01	-0.08 ±0.13	3.63 ±0.15	3.23 ±0.47	1.60 ±0.37	0.43 ±0.62	-0.47 ±0.33
Qatar	7.29 ±0.55	-3.37 ±0.95	1.55 ±0.54	8.39 ±0.40	4.73 ±1.49	6.21 ±2.01	6.37 ±2.31
Romania	-0.46 ±0.00	-1.05 ±0.66	0.53 ±1.30	0.39 ±0.65	-0.55 ±0.63	-0.85 ±0.79	0.57 ±1.01
Russia	-0.44 ±0.01	-3.46 ±0.37	-1.43 ±0.58	3.43 ±0.24	1.60 ±0.14	0.78 ±0.20	1.12 ±0.48
Rwanda	3.87 ±0.47	8.28 ±0.39	-1.13 ±1.02	4.48 ±0.38	-0.17 ±0.40	0.75 ±0.16	1.86 ±0.81
St. Kitts & Nevis	1.31 ±0.00	2.12 ±0.31	.. ..	-1.74 ±0.79	7.50 ±1.65	11.52 ±1.56	1.05 ±0.50
St. Lucia	1.07 ±0.02	0.55 ±0.56	.. ..	0.83 ±0.34	7.46 ±1.34	1.93 ±0.36	0.99 ±0.52
St. Vincent & Gren.	0.11 ±0.01	-1.58 ±0.41	.. ..	2.01 ±0.36	3.20 ±0.43	3.48 ±0.54	7.22 ±2.19
Samoa	0.38 ±0.06	1.83 ±0.25	.. ..	0.87 ±0.08	2.47 ±0.26	2.15 ±0.12	0.53 ±0.98
Sao Tome & Prin.	1.73 ±0.01	3.11 ±0.24	.. ..	3.56 ±0.09	3.85 ±0.68	5.83 ±0.36	2.10 ±0.37
Saudi Arabia	2.56 ±0.03	1.27 ±0.36	3.35 ±0.22	2.42 ±0.40	4.81 ±0.42	6.95 ±0.66	10.57 ±1.01
Senegal	2.66 ±0.00	1.38 ±0.12	4.55 ±0.32	1.66 ±0.19	5.62 ±0.31	5.14 ±0.84	-1.20 ±0.80
Serbia	-0.48 ±0.02	-4.14 ±0.59	1.32 ±0.84	-3.32 ±0.93	0.84 ±0.78	1.81 ±1.14	.. ..
Seychelles	0.59 ±0.07	-5.69 ±0.73	.. ..	2.46 ±0.22	7.58 ±1.04	5.17 ±1.12	26.59 ±2.58
Sierra Leone	3.31 ±0.13	3.24 ±1.03	9.12 ±1.98	4.17 ±0.80	4.06 ±0.38	9.82 ±1.44	1.16 ±0.40
Singapore	1.67 ±0.10	4.07 ±1.58	-0.06 ±0.03	2.68 ±0.11	4.53 ±0.44	-1.21 ±0.94	1.68 ±1.26
Slovakia	0.04 ±0.00	-3.94 ±0.54	-3.78 ±1.01	1.81 ±0.80	0.49 ±0.26	-0.89 ±0.38	2.08 ±0.93
Slovenia	0.17 ±0.00	-0.50 ±0.35	-0.46 ±0.79	6.28 ±1.08	1.01 ±0.12	-0.17 ±0.26	2.88 ±0.26
Solomon Islands	2.67 ±0.01	0.92 ±0.13	.. ..	3.10 ±1.29	2.17 ±0.30	1.76 ±0.21	7.29 ±1.83
Somalia	2.55 ±0.04	0.51 ±0.19	6.90 ±1.57	0.70 ±0.26	3.65 ±0.57	3.06 ±0.56	2.21 ±0.22
South Africa	1.39 ±0.02	-0.26 ±0.08	0.90 ±0.20	0.99 ±0.14	2.27 ±0.31	1.53 ±0.44	-0.36 ±0.43
Spain	1.16 ±0.06	1.28 ±0.16	1.31 ±0.18	3.63 ±0.50	3.69 ±0.25	3.27 ±0.14	1.87 ±0.22
Sri Lanka	0.75 ±0.02	-1.58 ±1.15	3.03 ±1.03	1.57 ±0.41	3.13 ±0.25	5.06 ±0.62	0.70 ±0.28
Sudan	2.18 ±0.02	2.21 ±0.17	6.58 ±0.28	2.41 ±0.17	12.22 ±1.07	10.54 ±1.00	2.00 ±0.45
Suriname	1.34 ±0.02	-3.00 ±0.76	2.20 ±0.51	2.92 ±0.47	0.74 ±0.60	1.43 ±0.18	8.80 ±2.66
Swaziland	1.12 ±0.08	-0.38 ±0.56	4.22 ±0.79	1.21 ±0.31	1.60 ±1.16	-2.06 ±0.33	1.35 ±1.19
Sweden	0.37 ±0.03	-1.44 ±0.14	-3.24 ±0.54	3.58 ±0.57	-0.56 ±0.28	-0.62 ±0.47	1.46 ±1.27
Switzerland	0.61 ±0.02	-0.15 ±0.08	-0.11 ±0.88	0.40 ±0.12	0.09 ±0.24	-0.36 ±0.33	1.39 ±0.30
Syria	2.93 ±0.06	3.92 ±0.94	2.07 ±0.25	0.99 ±0.31	1.39 ±0.35	2.09 ±0.69	3.07 ±0.55
Tajikistan	1.21 ±0.02	3.46 ±0.49	0.98 ±0.92	1.92 ±0.65	2.73 ±0.24	2.81 ±1.13	4.08 ±0.56
Tanzania	2.69 ±0.02	2.50 ±0.51	0.10 ±0.66	3.01 ±0.38	7.97 ±0.37	9.47 ±0.94	1.75 ±0.22
Thailand	1.00 ±0.03	0.33 ±0.60	1.36 ±0.18	2.95 ±0.38	5.20 ±0.48	4.29 ±0.49	2.53 ±0.40
Timor-Leste	2.87 ±0.35	1.19 ±0.69	.. ..	3.01 ±0.54	.. ..	.. ..	1.25 ±0.47
Togo	2.85 ±0.06	4.24 ±0.20	-2.24 ±0.88	1.67 ±0.56	13.35 ±1.54	1.37 ±1.16	1.86 ±0.38
Tonga	0.56 ±0.03	0.44 ±0.10	.. ..	0.35 ±0.10	2.52 ±1.30	5.42 ±0.66	-0.54 ±0.63
Trinidad & Tobago	0.37 ±0.01	6.40 ±1.15	3.73 ±0.82	8.68 ±0.42	8.66 ±0.64	6.68 ±0.35	4.02 ±1.81
Tunisia	0.93 ±0.01	1.35 ±0.29	2.75 ±0.45	2.57 ±0.22	2.12 ±0.56	3.36 ±0.23	3.00 ±0.71
Turkey	1.42 ±0.02	-0.88 ±0.40	2.14 ±0.93	2.87 ±0.65	4.05 ±0.57	3.23 ±0.66	2.53 ±0.79
Turkmenistan	1.42 ±0.01	9.35 ±0.67	3.10 ±0.71	9.52 ±0.96	14.41 ±1.17	4.70 ±0.84	5.53 ±0.63
Uganda	3.24 ±0.01	2.95 ±0.06	-1.19 ±1.34	2.39 ±0.15	4.56 ±0.52	9.50 ±0.84	3.28 ±0.25
Ukraine	-0.83 ±0.02	-6.14 ±0.51	-2.49 ±0.88	2.53 ±0.42	0.76 ±0.37	0.15 ±0.35	0.87 ±0.59
United Arab Emir.	4.85 ±0.15	4.41 ±0.21	3.37 ±0.39	2.77 ±0.34	4.39 ±0.44	6.43 ±2.27	6.71 ±0.43
United Kingdom	0.43 ±0.01	-1.81 ±0.24	-1.44 ±0.34	-2.37 ±0.14	-0.05 ±0.14	-0.09 ±0.14	1.22 ±0.14
United States	1.06 ±0.02	0.15 ±0.10	-0.95 ±0.43	0.51 ±0.10	0.64 ±0.10	0.64 ±0.10	0.98 ±0.18
Uruguay	0.15 ±0.03	0.91 ±0.29	-2.51 ±0.59	2.64 ±0.95	0.06 ±0.79	0.96 ±1.31	-0.21 ±0.32
Uzbekistan	1.25 ±0.02	3.76 ±0.34	-1.05 ±0.65	2.17 ±0.15	2.19 ±0.25	0.41 ±0.53	1.71 ±0.30
Vanuatu	2.50 ±0.06	0.82 ±0.77	.. ..	0.60 ±0.48	5.42 ±0.59	1.33 ±0.46	-12.22 ±1.83
Venezuela	1.85 ±0.01	1.56 ±0.13	0.15 ±0.40	0.11 ±0.42	1.29 ±0.41	1.01 ±0.97	1.66 ±0.42
Vietnam	1.35 ±0.01	4.03 ±0.12	7.99 ±0.74	7.70 ±0.83	9.58 ±0.20	10.98 ±0.74	5.39 ±0.18
Yemen	2.95 ±0.01	3.61 ±0.22	6.89 ±0.65	1.99 ±0.34	5.71 ±0.48	5.18 ±0.72	3.42 ±0.20
Zambia	2.43 ±0.03	1.06 ±0.29	0.02 ±0.40	4.33 ±0.93	2.45 ±0.41	2.15 ±1.18	-0.17 ±1.48
Zimbabwe	0.22 ±0.08	-1.03 ±0.61	-3.88 ±1.07	-2.01 ±0.31	-1.96 ±0.55	-4.69 ±0.65	-0.87 ±0.34
World	*1.28 ±0.01*	*0.82 ±0.04*	*0.17 ±0.26*	*2.35 ±0.14*	*2.61 ±0.17*	*2.68 ±0.26*	*1.90 ±0.15*

Note: Data show annual percentage rates of change, as well as standard errors, for the seven stock and flows indicators, calculated over the ten-year analysis period (1997–2007).

Table A.2: The Biophysical Accounts: *per capita* rate-of-change indicators with standard errors.

Country	Change in PC Stocks (%/year)		Change in PC Flows (% per year)			
	Livestock	Lights	Materials	Energy	CO_2	EF
Afghanistan	-2.98 ±0.68	.. ..	-2.42 ±0.64	-7.06 ±1.17	-7.21 ±2.59	-1.06 ±0.51
Albania	-1.62 ±0.23	6.01 ±1.00	5.83 ±0.33	4.72 ±0.80	10.35 ±1.93	5.30 ±0.55
Algeria	0.23 ±0.20	0.90 ±0.51	1.76 ±0.26	1.27 ±0.54	2.06 ±0.58	2.66 ±0.43
Angola	-1.52 ±0.49	3.46 ±0.71	2.75 ±0.49	5.89 ±0.70	10.00 ±1.72	0.84 ±0.40
Antigua & Barbuda	-0.75 ±0.21	.. ..	1.68 ±0.25	1.53 ±0.44	1.19 ±0.33	0.07 ±0.50
Argentina	-0.55 ±0.17	0.20 ±0.31	0.42 ±0.36	1.41 ±0.45	1.66 ±0.59	-1.62 ±0.49
Armenia	3.07 ±0.29	5.95 ±1.35	5.51 ±0.24	4.31 ±0.32	4.16 ±0.94	3.37 ±0.65
Australia	-1.94 ±0.17	-1.20 ±0.22	1.08 ±0.13	0.87 ±0.09	-0.07 ±0.36	-0.46 ±0.94
Austria	-1.75 ±0.09	-0.10 ±0.77	0.99 ±0.34	1.24 ±0.14	1.30 ±0.29	1.00 ±0.25
Azerbaijan	2.94 ±0.11	1.84 ±0.71	7.92 ±1.36	0.93 ±0.83	0.57 ±0.48	2.30 ±0.35
Bahamas	-1.64 ±1.77	.. ..	-0.54 ±0.51	2.38 ±0.85	0.92 ±0.37	-4.86 ±2.08
Bahrain	-2.19 ±0.63	.. ..	-0.28 ±0.10	2.66 ±0.35	-0.31 ±0.92	5.75 ±0.73
Bangladesh	-0.23 ±0.12	-2.03 ±1.29	1.13 ±0.12	5.56 ±0.19	4.81 ±0.41	1.00 ±0.33
Barbados	-2.60 ±0.51	.. ..	-0.90 ±0.52	-1.57 ±1.09	2.76 ±0.67	2.23 ±0.50
Belarus	-1.43 ±0.33	-1.89 ±1.42	3.45 ±0.68	2.03 ±0.70	1.81 ±0.36	-0.03 ±0.95
Belgium	-2.56 ±0.24	-2.39 ±0.44	-0.33 ±0.12	0.26 ±0.13	-1.61 ±0.24	0.55 ±0.18
Belize	0.62 ±0.46	.. ..	-0.16 ±0.45	6.91 ±1.17	-4.30 ±2.51	-4.41 ±2.33
Benin	-0.12 ±0.19	-1.51 ±0.62	-0.58 ±0.88	7.77 ±0.40	8.77 ±0.76	-0.29 ±1.30
Bhutan	-2.43 ±0.27	.. ..	-0.28 ±0.15	7.78 ±1.84	1.68 ±0.61	-1.05 ±0.29
Bolivia	0.62 ±0.06	-0.09 ±0.43	0.56 ±0.36	4.35 ±0.66	0.84 ±1.13	-0.04 ±0.17
Bosnia & Herz.	2.42 ±0.39	0.79 ±1.10	4.01 ±0.76	3.11 ±0.42	5.66 ±0.77	0.27 ±1.00
Botswana	-2.85 ±0.66	4.02 ±0.38	1.34 ±0.82	1.07 ±0.65	2.07 ±0.56	-1.13 ±1.66
Brazil	1.43 ±0.25	-0.74 ±0.50	2.25 ±0.22	0.86 ±0.21	-0.04 ±0.22	-0.52 ±0.26
Brunei Darussalam	7.58 ±1.16	.. ..	-0.13 ±0.31	10.12 ±1.29	-0.84 ±1.15	-5.22 ±1.18
Bulgaria	-1.93 ±0.48	2.52 ±1.39	1.93 ±0.23	1.40 ±0.52	0.83 ±0.70	2.94 ±0.83
Burkina Faso	1.23 ±0.04	0.61 ±0.46	0.63 ±0.25	-1.25 ±0.37	2.36 ±0.72	-1.53 ±0.98
Burundi	2.47 ±0.44	-1.66 ±1.68	0.78 ±0.55	-3.91 ±0.54	-9.05 ±1.26	-0.16 ±0.79
Cambodia	0.04 ±0.32	4.40 ±0.80	1.03 ±0.51	7.39 ±0.27	6.89 ±0.39	1.42 ±0.34
Cameroon	-0.39 ±0.40	-2.39 ±0.54	-0.91 ±0.21	-0.49 ±0.39	2.66 ±1.14	-0.06 ±0.25
Canada	0.40 ±0.18	-3.07 ±0.71	-0.47 ±0.14	0.46 ±0.17	0.67 ±0.31	0.36 ±0.51
Cape Verde	1.54 ±0.49	.. ..	-5.94 ±1.80	9.00 ±1.92	6.84 ±0.47	-2.98 ±1.74
Central African Rep.	0.88 ±0.12	.. ..	-0.14 ±0.06	-0.45 ±0.39	-2.35 ±0.41	-2.03 ±0.17
Chad	-0.61 ±0.11	1.14 ±0.76	-1.01 ±0.06	-0.12 ±0.62	12.90 ±1.96	-0.68 ±0.36
Chile	-0.53 ±0.27	1.10 ±0.45	2.73 ±0.40	1.83 ±0.63	0.71 ±0.66	1.43 ±0.44
China	-0.24 ±0.22	4.23 ±0.38	5.04 ±0.48	8.51 ±1.04	6.97 ±0.95	2.71 ±0.52
Colombia	-1.08 ±0.24	-3.04 ±0.33	0.66 ±0.33	-0.45 ±0.34	-1.93 ±0.68	-0.98 ±0.32
Comoros	-2.58 ±0.44	.. ..	-2.23 ±0.23	1.46 ±0.46	3.73 ±0.25	4.92 ±0.78
Congo	1.05 ±0.21	2.41 ±0.70	-0.90 ±0.43	5.36 ±1.54	1.49 ±3.81	0.77 ±0.33
Congo (Dem. Rep.)	-4.80 ±0.39	-1.07 ±0.44	-0.58 ±0.28	-2.16 ±0.90	-2.64 ±1.89	-2.11 ±0.06
Costa Rica	-3.84 ±0.57	-1.27 ±0.53	-0.74 ±0.30	2.70 ±0.25	2.67 ±0.28	-1.05 ±0.60
Cote d'Ivoire	-1.19 ±0.36	-0.45 ±0.71	-1.00 ±0.22	-1.21 ±0.92	-2.75 ±1.24	-1.98 ±0.38
Croatia	1.39 ±0.28	2.51 ±0.84	2.61 ±0.31	1.06 ±0.23	2.58 ±0.30	2.06 ±0.39
Cuba	-1.18 ±0.23	2.18 ±1.19	-1.69 ±0.58	-2.09 ±0.91	0.36 ±0.24	0.69 ±0.45
Cyprus	-0.49 ±0.45	0.59 ±0.22	3.78 ±0.38	1.11 ±0.26	1.20 ±0.27	2.60 ±0.48
Czech Republic	-3.18 ±0.29	-1.42 ±1.13	1.20 ±0.25	1.55 ±0.32	-0.15 ±0.37	1.55 ±0.42
Denmark	-0.24 ±0.15	-2.08 ±1.16	0.50 ±0.46	-0.95 ±0.26	-1.08 ±0.67	-0.31 ±0.31
Djibouti	-1.68 ±0.09	.. ..	-1.27 ±0.16	-1.22 ±0.48	-0.66 ±0.76	1.41 ±0.59
Dominica	0.25 ±0.02	.. ..	0.21 ±0.36	3.27 ±0.84	4.68 ±0.80	-0.94 ±0.65
Dominican Rep.	0.19 ±0.83	-1.28 ±1.02	1.38 ±0.53	3.12 ±0.56	-0.46 ±0.40	-0.20 ±0.38
Ecuador	-1.89 ±0.22	1.22 ±0.27	0.42 ±0.53	1.31 ±0.39	3.16 ±0.43	-0.94 ±0.64
Egypt	0.86 ±0.09	1.16 ±0.06	0.70 ±0.18	2.50 ±0.35	2.75 ±0.70	0.08 ±0.36
El Salvador	2.31 ±0.40	0.86 ±0.58	-0.31 ±0.59	2.87 ±0.28	1.12 ±0.20	2.52 ±0.42
Eritrea	-3.24 ±0.53	.. ..	-5.37 ±0.47	-7.64 ±1.48	-2.52 ±1.09	-3.43 ±0.89
Estonia	-1.59 ±0.46	-0.60 ±0.81	0.16 ±3.37	2.25 ±0.65	1.45 ±0.74	2.53 ±0.92
Ethiopia	0.99 ±0.48	5.00 ±0.36	1.15 ±0.36	5.92 ±0.66	0.19 ±1.03	-0.48 ±0.26
Fiji	-1.23 ±0.15	.. ..	-1.67 ±0.50	9.04 ±0.88	9.09 ±1.86	-1.04 ±1.30
Finland	-1.57 ±0.13	-2.57 ±0.89	1.78 ±0.53	1.02 ±0.22	1.17 ±0.80	2.35 ±0.41
France	-1.43 ±0.12	-0.70 ±0.25	-0.23 ±0.27	0.29 ±0.13	-0.65 ±0.31	-0.05 ±0.29
Gabon	-1.96 ±0.09	-0.10 ±0.63	-2.77 ±0.83	-2.89 ±0.77	-3.29 ±3.07	4.02 ±2.80
Gambia	-0.78 ±0.58	0.96 ±1.74	2.10 ±0.78	1.73 ±0.55	1.87 ±0.43	-2.38 ±2.20
Georgia	2.21 ±0.59	10.35 ±1.49	7.79 ±0.70	-0.03 ±0.90	3.03 ±1.64	-14.06 ±6.19

Country	Change in PC Stocks (%/year)		Change in PC Flows (% per year)			
	Livestock	Lights	Materials	Energy	CO_2	EF
Germany	-1.17 ±0.10	-1.80 ±0.46	-2.44 ±0.24	0.08 ±0.13	-1.08 ±0.21	-0.03 ±0.22
Ghana	0.34 ±0.10	-2.41 ±0.67	1.30 ±0.35	0.47 ±1.03	1.48 ±0.78	0.86 ±0.59
Greece	-0.35 ±0.07	2.07 ±0.41	1.30 ±0.18	1.88 ±0.17	1.28 ±0.17	2.31 ±0.49
Grenada	0.55 ±0.30	.. ..	1.80 ±0.47	3.55 ±1.68	1.87 ±0.30	0.41 ±0.84
Guatemala	0.24 ±0.15	1.47 ±0.94	0.38 ±0.35	2.87 ±0.22	2.32 ±0.46	0.94 ±0.33
Guinea	3.63 ±0.03	-1.64 ±1.41	1.47 ±0.40	-0.33 ±0.43	-0.94 ±0.11	1.92 ±0.41
Guinea-Bissau	-0.82 ±0.17	-4.27 ±2.72	-1.46 ±0.25	0.45 ±0.25	-0.95 ±1.43	-1.88 ±0.39
Guyana	3.01 ±0.75	-2.10 ±0.53	-4.47 ±1.00	2.15 ±0.95	-1.17 ±0.26	-1.40 ±1.00
Haiti	-0.42 ±0.33	-4.75 ±1.22	-0.72 ±0.18	1.02 ±0.27	4.71 ±0.68	-0.48 ±0.43
Honduras	1.91 ±0.74	3.00 ±0.48	1.61 ±0.42	3.31 ±0.31	5.20 ±0.50	0.65 ±0.34
Hungary	-0.66 ±0.35	-1.17 ±1.23	2.07 ±1.05	1.18 ±0.22	-0.44 ±0.27	0.30 ±0.95
Iceland	-1.90 ±0.19	4.68 ±2.42	0.23 ±0.54	4.54 ±0.66	-0.15 ±0.14	-1.57 ±3.39
India	-1.78 ±0.03	-0.93 ±0.51	1.06 ±0.26	2.85 ±0.33	2.46 ±0.23	-0.06 ±0.31
Indonesia	0.15 ±0.62	-0.44 ±0.40	2.72 ±0.30	2.87 ±0.43	3.64 ±0.84	-0.54 ±0.23
Iran	-0.38 ±0.24	3.10 ±0.40	2.69 ±0.22	5.21 ±0.25	4.18 ±0.21	3.30 ±0.20
Iraq	-1.90 ±0.39	1.06 ±0.75	-2.48 ±1.81	-1.34 ±0.42	1.41 ±0.41	1.33 ±0.61
Ireland	-1.59 ±0.23	0.16 ±0.49	2.81 ±0.82	1.30 ±0.41	-0.17 ±0.39	0.65 ±0.44
Israel	-0.82 ±0.39	-1.86 ±0.09	0.44 ±0.15	0.12 ±0.35	-1.68 ±0.33	0.91 ±0.27
Italy	-1.55 ±0.32	0.20 ±0.20	-0.24 ±0.26	0.95 ±0.14	0.32 ±0.16	0.70 ±0.15
Jamaica	-3.02 ±1.08	-1.67 ±0.37	0.82 ±0.30	0.85 ±0.39	1.47 ±0.77	0.94 ±0.53
Japan	-0.84 ±0.11	-1.08 ±0.23	-0.16 ±0.02	0.36 ±0.10	0.04 ±0.17	-0.37 ±0.18
Jordan	-1.86 ±0.68	-0.20 ±0.32	0.50 ±0.19	1.89 ±0.43	1.99 ±0.32	1.61 ±0.56
Kazakhstan	2.34 ±0.98	3.16 ±0.80	5.52 ±0.48	3.70 ±0.44	5.98 ±0.59	19.52 ±2.82
Kenya	-1.07 ±0.34	-3.50 ±0.67	-1.23 ±0.23	1.83 ±0.54	-0.25 ±1.10	-1.06 ±0.38
Kiribati	2.85 ±0.57	.. ..	-0.03 ±0.63	5.38 ±0.59	-2.47 ±1.09	-2.07 ±3.45
Korea, North	2.96 ±0.92	-0.16 ±0.95	1.17 ±0.25	0.38 ±0.54	-4.53 ±3.24	0.45 ±0.51
Korea, South	0.49 ±0.50	-0.35 ±0.19	1.92 ±0.24	2.75 ±0.22	1.74 ±0.54	2.29 ±0.71
Kuwait	-0.82 ±0.37	-2.46 ±0.92	-0.92 ±0.87	0.32 ±0.43	-0.54 ±0.71	-0.48 ±1.55
Kyrgyzstan	0.30 ±0.11	-2.12 ±1.18	-0.38 ±0.51	-2.12 ±0.56	0.09 ±1.34	-0.99 ±1.04
Laos	0.14 ±0.60	3.13 ±0.70	0.38 ±0.27	4.28 ±1.11	5.58 ±0.75	-0.20 ±0.27
Latvia	-1.10 ±0.68	-0.08 ±0.86	8.68 ±3.51	2.78 ±0.48	0.75 ±0.89	5.57 ±0.72
Lebanon	0.06 ±0.16	-2.57 ±0.85	-0.24 ±0.21	-2.02 ±0.64	-1.92 ±0.85	-1.19 ±0.25
Lesotho	0.27 ±1.03	2.35 ±0.64	-0.01 ±0.72	4.96 ±1.71	2.28 ±0.34	-3.64 ±0.54
Liberia	-2.04 ±0.50	7.96 ±2.58	0.35 ±0.55	1.31 ±0.50	3.29 ±0.76	0.26 ±0.22
Libya	0.22 ±0.88	3.27 ±0.42	0.61 ±0.63	0.63 ±0.48	-0.27 ±0.28	1.61 ±0.48
Lithuania	-1.03 ±0.84	0.04 ±1.21	4.04 ±0.39	1.03 ±0.86	0.51 ±0.90	2.59 ±0.67
Luxembourg	-2.23 ±0.34	-2.66 ±0.85	-0.92 ±0.11	3.07 ±0.34	3.56 ±0.54	1.18 ±0.91
Macedonia	-2.90 ±0.39	-0.11 ±1.15	-1.52 ±0.85	-0.98 ±0.76	-0.84 ±0.47	5.40 ±1.81
Madagascar	-3.93 ±0.97	-4.65 ±0.83	-1.56 ±1.14	3.95 ±1.04	-1.27 ±1.08	0.08 ±1.23
Malawi	0.08 ±0.44	-2.28 ±0.68	0.49 ±0.72	1.65 ±0.24	-0.45 ±0.90	-0.29 ±0.71
Malaysia	1.74 ±0.42	0.38 ±0.33	0.18 ±0.60	1.49 ±0.42	3.95 ±0.70	3.14 ±2.05
Mali	2.31 ±0.16	3.94 ±0.47	1.03 ±0.35	-0.40 ±0.29	-1.26 ±0.14	1.07 ±0.45
Malta	-0.56 ±0.53	.. ..	1.01 ±0.50	-0.03 ±0.73	0.06 ±1.22	-0.99 ±1.10
Mauritania	-0.09 ±0.37	-1.23 ±0.43	-1.21 ±0.13	-4.33 ±0.61	-1.65 ±2.81	0.27 ±0.58
Mauritius	1.42 ±0.46	-0.21 ±0.24	0.03 ±0.62	4.54 ±0.78	5.38 ±0.45	8.25 ±1.26
Mexico	-0.70 ±0.09	-0.41 ±0.37	0.26 ±0.09	0.99 ±0.24	0.81 ±0.23	0.21 ±0.51
Moldova	-1.74 ±0.78	-1.38 ±1.43	0.80 ±1.14	0.58 ±1.17	-0.23 ±2.03	0.08 ±1.42
Mongolia	-3.91 ±1.44	1.54 ±0.90	-1.57 ±0.69	1.97 ±0.54	1.60 ±0.49	-2.17 ±1.02
Morocco	0.09 ±0.25	4.50 ±0.38	1.08 ±0.28	1.29 ±0.23	2.91 ±0.26	1.27 ±0.65
Mozambique	-0.83 ±0.56	2.82 ±0.19	0.13 ±0.30	16.61 ±3.16	5.52 ±0.66	-1.48 ±0.39
Myanmar	2.10 ±0.07	-3.99 ±0.90	4.07 ±0.26	7.24 ±0.69	5.70 ±1.24	5.26 ±0.17
Namibia	-0.44 ±0.71	-0.41 ±0.55	0.29 ±0.58	6.25 ±0.43	3.32 ±0.70	3.73 ±1.78
Nauru	0.05 ±0.08	.. ..	.. ..	1.31 ±0.23	0.37 ±0.13	-0.54 ±0.40
Nepal	-1.12 ±0.09	0.53 ±0.97	-0.42 ±0.04	3.34 ±0.87	-0.23 ±1.13	-1.15 ±0.06
Netherlands	-2.42 ±0.34	-2.29 ±0.34	-0.27 ±0.47	0.89 ±0.14	-0.59 ±0.33	0.63 ±0.42
New Zealand	-1.17 ±0.10	-1.74 ±0.32	-0.13 ±0.17	-0.05 ±0.23	-0.34 ±0.31	-1.30 ±0.54
Nicaragua	1.12 ±0.34	-0.06 ±1.02	0.82 ±0.20	1.88 ±0.19	1.58 ±0.40	-0.59 ±0.47
Niger	0.77 ±0.02	-2.47 ±0.61	-0.87 ±0.37	-1.91 ±0.24	-5.02 ±1.01	0.14 ±1.23
Nigeria	-0.30 ±0.05	-2.07 ±0.33	-0.11 ±0.25	0.60 ±0.48	7.99 ±2.01	0.16 ±0.20
Norway	-1.09 ±0.10	-0.71 ±1.29	0.05 ±0.22	0.00 ±0.34	2.36 ±0.66	1.51 ±0.86
Oman	0.90 ±0.24	3.90 ±0.45	1.21 ±0.72	4.90 ±1.02	8.03 ±0.76	6.33 ±1.06

Country	Change in PC Stocks (%/year)		Change in PC Flows (% per year)			
	Livestock	Lights	Materials	Energy	CO_2	EF
Pakistan	0.67 ±0.27	-0.87 ±0.20	0.53 ±0.22	1.44 ±0.54	2.78 ±0.28	-0.40 ±0.52
Panama	-0.20 ±0.28	0.08 ±0.78	0.74 ±0.21	-0.26 ±0.40	-0.36 ±0.71	3.41 ±0.49
Papua New Guinea	-0.70 ±0.26	-4.47 ±0.63	-1.51 ±1.00	3.35 ±0.86	3.34 ±1.37	-0.69 ±1.01
Paraguay	-1.74 ±0.29	-2.37 ±0.47	-1.03 ±0.17	-1.46 ±0.38	-2.66 ±0.61	-3.42 ±0.57
Peru	0.51 ±0.12	0.11 ±0.26	4.03 ±0.30	1.53 ±0.25	2.23 ±1.04	-0.57 ±0.56
Philippines	-0.52 ±0.13	-2.05 ±0.71	-0.23 ±0.37	-0.45 ±0.28	-2.47 ±0.47	-1.85 ±0.76
Poland	-0.09 ±0.52	1.22 ±1.22	0.71 ±0.34	-0.36 ±0.55	-0.52 ±0.43	0.62 ±0.38
Portugal	-0.63 ±0.14	3.05 ±0.15	2.66 ±0.47	1.14 ±0.36	-0.13 ±0.62	-1.03 ±0.33
Qatar	-9.93 ±0.99	-5.35 ±0.47	2.14 ±0.70	0.42 ±1.59	-1.01 ±1.59	-0.86 ±1.85
Romania	-0.60 ±0.66	1.00 ±1.30	0.86 ±0.66	-0.34 ±0.63	-0.40 ±0.79	1.03 ±1.01
Russia	-3.03 ±0.38	-0.99 ±0.58	3.90 ±0.24	2.10 ±0.14	1.22 ±0.21	1.57 ±0.48
Rwanda	4.25 ±0.61	-4.82 ±0.95	0.77 ±0.70	-2.83 ±0.40	-3.00 ±0.39	-1.94 ±1.09
St. Kitts & Nevis	0.80 ±0.31	.. ..	-3.08 ±0.81	6.44 ±1.68	10.08 ±1.55	-0.28 ±0.49
St. Lucia	-0.52 ±0.58	.. ..	-0.37 ±0.29	6.84 ±1.33	0.85 ±0.36	-0.12 ±0.52
St. Vincent & Gren.	-1.69 ±0.41	.. ..	1.87 ±0.47	3.53 ±0.43	3.36 ±0.54	7.09 ±2.20
Samoa	1.45 ±0.23	.. ..	0.23 ±0.10	1.58 ±0.26	1.76 ±0.13	0.16 ±0.95
Sao Tome & Prin.	1.35 ±0.24	.. ..	1.76 ±0.10	1.58 ±0.68	4.03 ±0.36	0.35 ±0.37
Saudi Arabia	-1.26 ±0.37	0.76 ±0.23	-0.14 ±0.41	2.61 ±0.41	4.28 ±0.64	7.80 ±1.02
Senegal	-1.24 ±0.11	1.84 ±0.32	-0.77 ±0.22	2.94 ±0.31	2.42 ±0.84	-3.76 ±0.80
Serbia	-3.68 ±0.58	1.81 ±0.85	-2.36 ±0.87	.. ..	2.30 ±1.15	.. ..
Seychelles	-6.25 ±0.70	.. ..	1.49 ±0.16	6.34 ±1.04	4.56 ±1.10	25.85 ±2.59
Sierra Leone	-0.08 ±0.94	5.62 ±1.93	0.81 ±0.89	0.78 ±0.38	6.30 ±1.43	-2.08 ±0.34
Singapore	2.36 ±1.63	-1.70 ±0.09	0.87 ±0.12	2.66 ±0.46	-2.84 ±1.01	0.01 ±1.26
Slovakia	-3.98 ±0.54	-3.82 ±1.01	1.79 ±0.80	0.38 ±0.27	-0.93 ±0.38	2.04 ±0.93
Slovenia	-0.66 ±0.35	-0.63 ±0.79	6.09 ±1.08	1.01 ±0.12	-0.33 ±0.26	2.71 ±0.26
Solomon Islands	-1.70 ±0.14	.. ..	0.43 ±1.29	-0.56 ±0.32	-0.89 ±0.22	4.50 ±1.83
Somalia	-1.99 ±0.17	4.24 ±1.53	-2.32 ±0.26	0.34 ±0.59	-0.24 ±0.58	-0.33 ±0.19
South Africa	-1.62 ±0.08	-0.48 ±0.20	-0.23 ±0.18	1.16 ±0.32	0.14 ±0.46	-1.73 ±0.44
Spain	0.13 ±0.21	0.15 ±0.21	2.36 ±0.48	2.35 ±0.32	2.09 ±0.15	0.71 ±0.25
Sri Lanka	-2.31 ±1.13	2.26 ±1.04	0.95 ±0.39	2.05 ±0.25	4.27 ±0.64	-0.06 ±0.28
Sudan	0.04 ±0.15	4.31 ±0.27	0.04 ±0.23	9.48 ±1.06	8.18 ±1.01	-0.17 ±0.46
Suriname	-4.28 ±0.77	0.86 ±0.49	1.63 ±0.56	-0.55 ±0.62	0.09 ±0.19	7.37 ±2.66
Swaziland	-1.49 ±0.62	3.07 ±0.73	-0.17 ±0.36	-0.42 ±1.12	-3.15 ±0.31	0.23 ±1.23
Sweden	-1.80 ±0.11	-3.59 ±0.54	3.24 ±0.59	-0.71 ±0.28	-0.99 ±0.48	1.08 ±1.27
Switzerland	-0.75 ±0.07	-0.71 ±0.88	-0.02 ±0.12	-0.44 ±0.25	-0.96 ±0.32	0.78 ±0.29
Syria	0.96 ±0.89	-0.84 ±0.27	-1.77 ±0.37	-1.33 ±0.42	-0.82 ±0.73	0.13 ±0.59
Tajikistan	2.23 ±0.49	-0.23 ±0.92	0.68 ±0.65	0.84 ±0.24	1.58 ±1.13	2.83 ±0.55
Tanzania	-0.19 ±0.53	-2.52 ±0.68	0.35 ±0.41	5.45 ±0.37	6.60 ±0.93	-0.91 ±0.23
Thailand	-0.66 ±0.59	0.35 ±0.19	1.90 ±0.36	4.32 ±0.49	3.25 ±0.47	1.52 ±0.38
Timor-Leste	-1.64 ±0.73	.. ..	.. ..	.. ..	.. ..	-1.58 ±0.59
Togo	1.35 ±0.14	-4.95 ±0.93	-1.16 ±0.67	10.27 ±1.53	-1.43 ±1.13	-0.96 ±0.39
Tonga	-0.12 ±0.13	.. ..	-0.09 ±0.13	0.66 ±1.28	4.84 ±0.66	-1.07 ±0.66
Trinidad & Tobago	6.00 ±1.15	3.34 ±0.82	8.29 ±0.42	8.91 ±0.64	6.29 ±0.35	3.63 ±1.81
Tunisia	0.42 ±0.28	1.80 ±0.44	1.54 ±0.26	1.04 ±0.55	2.41 ±0.23	2.05 ±0.71
Turkey	-2.27 ±0.42	0.70 ±0.93	1.54 ±0.71	2.45 ±0.59	1.78 ±0.67	1.09 ±0.80
Turkmenistan	7.82 ±0.67	1.66 ±0.72	8.02 ±0.97	12.96 ±1.16	3.23 ±0.85	4.05 ±0.64
Uganda	-0.28 ±0.07	-4.29 ±1.35	-0.74 ±0.16	1.22 ±0.55	6.06 ±0.83	0.04 ±0.26
Ukraine	-5.36 ±0.50	-1.67 ±0.89	3.38 ±0.42	1.63 ±0.36	0.99 ±0.34	1.71 ±0.58
United Arab Emir.	-0.43 ±0.18	-1.42 ±0.28	-1.99 ±0.45	-0.53 ±0.51	1.50 ±2.22	1.77 ±0.54
United Kingdom	-2.23 ±0.23	-1.87 ±0.33	-2.80 ±0.15	-0.50 ±0.15	-0.52 ±0.13	0.78 ±0.13
United States	-0.89 ±0.11	-1.98 ±0.42	-0.55 ±0.10	-0.35 ±0.10	-0.42 ±0.09	-0.07 ±0.18
Uruguay	0.76 ±0.32	-2.66 ±0.56	2.47 ±0.97	-0.51 ±0.79	0.81 ±1.32	-0.36 ±0.34
Uzbekistan	2.47 ±0.36	-2.27 ±0.65	0.78 ±0.16	0.95 ±0.24	-0.84 ±0.51	0.45 ±0.29
Vanuatu	-1.64 ±0.73	.. ..	-1.82 ±0.45	3.64 ±0.59	-1.15 ±0.42	-14.36 ±1.82
Venezuela	-0.28 ±0.11	-1.67 ±0.39	-1.71 ±0.43	-0.22 ±0.41	-0.82 ±0.95	-0.18 ±0.42
Vietnam	2.65 ±0.13	6.56 ±0.73	6.24 ±0.84	8.18 ±0.20	9.50 ±0.74	3.99 ±0.19
Yemen	0.64 ±0.22	3.83 ±0.64	-0.97 ±0.33	2.46 ±0.46	2.16 ±0.73	0.45 ±0.20
Zambia	-1.34 ±0.29	-2.35 ±0.40	2.14 ±0.95	-0.15 ±0.43	-0.27 ±1.21	-2.53 ±1.50
Zimbabwe	-1.25 ±0.56	-4.09 ±1.02	-2.53 ±0.33	-1.89 ±0.49	-4.90 ±0.64	-1.09 ±0.35
World	-0.45 ±0.04	-1.10 ±0.26	1.06 ±0.14	1.36 ±0.17	1.38 ±0.27	0.62 ±0.16

Note: Data show annual *per capita* percentage rates of change, as well as standard errors, for six stock and flow indicators, calculated over the ten-year analysis period (1997–2007).

Table A.3: Annual GDP growth rates and standard errors for the 1997–2007 analysis period, and per capita GDP for 2007.

Country	Change in GDP (% per year)	Change in PC GDP (% per year)	PC GDP (PPP$)
Afghanistan	.. ..	.. ..	874
Albania	6.27 ±0.31	5.95 ±0.36	6,731
Algeria	4.15 ±0.16	2.62 ±0.16	7,305
Angola	9.73 ±0.99	6.25 ±0.98	4,982
Antigua & Barbuda	4.82 ±0.45	3.06 ±0.52	18,967
Argentina	1.93 ±0.99	0.95 ±1.00	12,545
Armenia	10.68 ±0.51	10.86 ±0.46	5,261
Australia	3.52 ±0.08	2.21 ±0.09	33,848
Austria	2.28 ±0.13	1.83 ±0.14	35,576
Azerbaijan	14.36 ±1.11	13.37 ±1.09	7,395
Bahamas	2.04 ±0.36	0.66 ±0.38	25,199
Bahrain	5.92 ±0.19	2.22 ±0.50	25,404
Bangladesh	5.55 ±0.09	3.83 ±0.13	1,291
Barbados	0.86 ±0.34	0.62 ±0.34	18,591
Belarus	7.13 ±0.35	7.59 ±0.35	10,446
Belgium	2.12 ±0.09	1.69 ±0.10	33,486
Belize	6.21 ±0.36	3.07 ±0.40	6,206
Benin	4.26 ±0.12	1.10 ±0.14	1,382
Bhutan	8.26 ±0.26	5.33 ±0.28	4,199
Bolivia	3.06 ±0.19	1.09 ±0.21	3,995
Bosnia & Herz.	6.03 ±0.32	4.97 ±0.22	7,084
Botswana	5.63 ±0.21	4.12 ±0.18	12,375
Brazil	2.83 ±0.23	1.51 ±0.25	9,196
Brunei Darussalam	2.27 ±0.13	0.11 ±0.13	48,654
Bulgaria	5.29 ±0.19	6.20 ±0.14	11,249
Burkina Faso	5.60 ±0.12	2.62 ±0.12	1,038
Burundi	2.01 ±0.22	-0.30 ±0.15	355
Cambodia	9.34 ±0.24	7.70 ±0.28	1,799
Cameroon	3.86 ±0.11	1.53 ±0.10	2,029
Canada	3.14 ±0.15	2.16 ±0.16	36,074
Cape Verde	6.08 ±0.31	4.41 ±0.33	3,165
Central African Rep.	0.48 ±0.38	-1.25 ±0.37	698
Chad	10.52 ±1.09	6.84 ±1.08	1,302
Chile	3.78 ±0.23	2.61 ±0.25	13,047
China	9.74 ±0.29	9.00 ±0.31	5,239
Colombia	3.27 ±0.43	1.63 ±0.44	8,085
Comoros	2.24 ±0.11	-0.45 ±0.11	1,015
Congo	3.68 ±0.24	1.13 ±0.25	3,345
Congo (Dem. Rep.)	1.95 ±0.82	-0.83 ±0.77	289
Costa Rica	4.88 ±0.30	2.83 ±0.33	10,261
Cote d'Ivoire	0.01 ±0.21	-1.77 ±0.21	1,649
Croatia	3.89 ±0.24	4.15 ±0.20	16,942
Cuba	5.49 ±0.46	5.22 ±0.47	..
Cyprus	3.73 ±0.12	2.09 ±0.17	25,687
Czech Republic	3.61 ±0.33	3.63 ±0.29	22,862
Denmark	1.80 ±0.11	1.48 ±0.11	34,595
Djibouti	2.73 ±0.23	0.46 ±0.32	1,952
Dominica	1.46 ±0.49	1.77 ±0.48	8,446
Dominican Rep.	4.85 ±0.37	3.27 ±0.37	7,445
Ecuador	3.82 ±0.46	2.12 ±0.46	6,862
Egypt	4.36 ±0.17	2.47 ±0.17	4,955
El Salvador	2.66 ±0.11	2.23 ±0.11	6,155
Eritrea	0.11 ±0.40	-3.60 ±0.38	560
Estonia	7.57 ±0.29	8.00 ±0.26	19,626
Ethiopia	6.17 ±0.62	3.54 ±0.64	751
Fiji	2.25 ±0.19	1.81 ±0.20	4,299
Finland	3.38 ±0.13	3.10 ±0.13	33,474
France	2.13 ±0.11	1.46 ±0.13	30,554
Gabon	0.59 ±0.43	-1.54 ±0.46	13,383
Gambia	3.61 ±0.25	0.63 ±0.26	1,169
Georgia	6.51 ±0.49	6.87 ±0.41	4,409

Country	Change in GDP (% per year)	Change in PC GDP (% per year)	PC GDP (PPP$)
Germany	1.36 ±0.13	1.31 ±0.14	33,364
Ghana	4.98 ±0.15	2.48 ±0.15	1,304
Greece	4.15 ±0.07	3.78 ±0.07	26,733
Grenada	3.76 ±0.50	3.52 ±0.51	8,117
Guatemala	3.58 ±0.12	1.09 ±0.13	4,331
Guinea	3.33 ±0.11	1.70 ±0.12	977
Guinea-Bissau	-0.20 ±0.84	-2.13 ±0.84	1,029
Guyana	0.74 ±0.15	0.44 ±0.15	2,556
Haiti	0.36 ±0.20	-1.23 ±0.20	1,052
Honduras	4.33 ±0.32	2.23 ±0.33	3,567
Hungary	4.08 ±0.21	4.33 ±0.22	17,269
Iceland	4.36 ±0.24	3.05 ±0.21	36,860
India	6.90 ±0.30	5.28 ±0.32	2,686
Indonesia	3.65 ±0.60	2.35 ±0.60	3,403
Iran	5.28 ±0.21	3.82 ±0.25	10,286
Iraq	-1.20 ±2.07	-3.84 ±2.05	3,036
Ireland	6.47 ±0.29	4.67 ±0.36	41,025
Israel	3.43 ±0.27	1.32 ±0.28	25,130
Italy	1.37 ±0.10	0.92 ±0.15	28,766
Jamaica	1.63 ±0.17	1.11 ±0.19	7,252
Japan	1.29 ±0.16	1.14 ±0.18	31,660
Jordan	5.90 ±0.30	3.41 ±0.31	4,851
Kazakhstan	9.03 ±0.44	8.86 ±0.35	10,259
Kenya	3.47 ±0.32	0.82 ±0.32	1,455
Kiribati	2.73 ±0.32	0.91 ±0.31	2,319
Korea, North	.. ..	.. ..	..
Korea, South	4.87 ±0.29	4.32 ±0.29	25,021
Kuwait	6.33 ±0.64	2.60 ±0.74	49,542
Kyrgyzstan	4.10 ±0.18	3.08 ±0.18	1,900
Laos	6.40 ±0.13	4.66 ±0.15	1,917
Latvia	7.94 ±0.33	8.68 ±0.30	16,284
Lebanon	3.10 ±0.21	1.60 ±0.21	10,160
Lesotho	3.29 ±0.11	2.10 ±0.11	1,282
Liberia	3.06 ±2.01	-0.33 ±1.77	365
Libya	.. ..	.. ..	15,071
Lithuania	6.64 ±0.40	7.25 ±0.38	17,027
Luxembourg	4.83 ±0.24	3.46 ±0.24	74,114
Macedonia	2.44 ±0.30	2.12 ±0.30	8,386
Madagascar	3.09 ±0.45	-0.01 ±0.46	913
Malawi	2.76 ±0.42	0.01 ±0.41	693
Malaysia	4.88 ±0.36	2.62 ±0.38	12,554
Mali	5.83 ±0.19	2.67 ±0.20	913
Malta	2.27 ±0.23	1.59 ±0.23	22,243
Mauritania	4.61 ±0.44	1.70 ±0.44	1,749
Mauritius	4.02 ±0.16	3.04 ±0.15	11,024
Mexico	2.95 ±0.19	1.60 ±0.19	12,905
Moldova	4.61 ±0.62	4.85 ±0.62	2,564
Mongolia	5.77 ±0.49	4.61 ±0.46	3,324
Morocco	4.51 ±0.18	3.28 ±0.19	3,802
Mozambique	7.73 ±0.17	4.97 ±0.17	743
Myanmar	.. ..	.. ..	..
Namibia	4.80 ±0.30	2.70 ±0.35	5,658
Nauru	.. ..	.. ..	..
Nepal	3.73 ±0.12	1.43 ±0.11	980
Netherlands	2.25 ±0.19	1.73 ±0.18	37,577
New Zealand	3.50 ±0.10	2.28 ±0.10	26,014
Nicaragua	3.65 ±0.15	2.21 ±0.15	2,458
Niger	3.39 ±0.23	-0.15 ±0.23	622
Nigeria	5.46 ±0.39	2.92 ±0.38	1,882
Norway	2.34 ±0.07	1.69 ±0.06	48,800
Oman	3.64 ±0.21	2.39 ±0.20	22,496

Country	Change in GDP (% per year)	Change in PC GDP (% per year)	PC GDP (PPP$)
Pakistan	4.75 ±0.28	2.69 ±0.32	2,322
Panama	4.85 ±0.45	2.93 ±0.47	10,779
Papua New Guinea	1.21 ±0.39	-1.31 ±0.40	1,956
Paraguay	1.78 ±0.43	-0.22 ±0.44	4,187
Peru	4.01 ±0.45	2.65 ±0.48	7,333
Philippines	4.34 ±0.25	2.24 ±0.27	3,303
Poland	3.82 ±0.20	3.98 ±0.19	15,655
Portugal	1.71 ±0.24	1.15 ±0.24	21,993
Qatar	.. ..	.. ..	72,814
Romania	4.43 ±0.51	5.00 ±0.52	10,761
Russia	6.28 ±0.33	6.68 ±0.34	14,016
Rwanda	7.72 ±0.16	3.65 ±0.40	917
St. Kitts & Nevis	3.34 ±0.24	0.94 ±0.34	13,474
St. Lucia	2.24 ±0.38	1.07 ±0.39	9,194
St. Vincent & Gren.	4.23 ±0.29	4.11 ±0.28	8,481
Samoa	4.54 ±0.19	4.01 ±0.18	3,979
Sao Tome & Prin.	.. ..	.. ..	1,553
Saudi Arabia	3.32 ±0.27	0.12 ±0.19	20,243
Senegal	4.49 ±0.14	1.76 ±0.14	1,706
Serbia	3.55 ±0.61	3.85 ±0.60	9,667
Seychelles	1.52 ±0.58	0.69 ±0.54	20,098
Sierra Leone	9.26 ±0.95	5.30 ±0.82	695
Singapore	5.48 ±0.41	3.87 ±0.39	49,877
Slovakia	4.58 ±0.43	4.58 ±0.42	19,356
Slovenia	4.19 ±0.13	4.03 ±0.12	26,321
Solomon Islands	-0.03 ±1.12	-2.76 ±1.11	2,322
Somalia	.. ..	.. ..	..
South Africa	3.78 ±0.20	2.12 ±0.29	9,374
Spain	3.70 ±0.09	2.34 ±0.16	28,522
Sri Lanka	4.65 ±0.28	3.61 ±0.26	3,956
Sudan	6.13 ±0.26	3.63 ±0.25	1,881
Suriname	4.15 ±0.39	2.78 ±0.40	6,546
Swaziland	3.34 ±0.20	2.26 ±0.16	4,581
Sweden	3.26 ±0.10	2.92 ±0.11	34,782
Switzerland	1.86 ±0.15	1.20 ±0.15	37,854
Syria	3.81 ±0.30	1.04 ±0.32	4,407
Tajikistan	8.72 ±0.26	7.64 ±0.28	1,674
Tanzania	6.45 ±0.18	3.66 ±0.17	1,151
Thailand	4.27 ±0.47	3.14 ±0.49	7,249
Timor-Leste	.. ..	.. ..	677
Togo	1.85 ±0.22	-0.74 ±0.29	874
Tonga	2.12 ±0.30	1.53 ±0.31	4,054
Trinidad & Tobago	7.84 ±0.31	7.44 ±0.31	23,611
Tunisia	4.78 ±0.11	3.72 ±0.11	7,102
Turkey	4.16 ±0.59	2.71 ±0.60	12,488
Turkmenistan	15.79 ±0.36	14.51 ±0.37	5,795
Uganda	6.76 ±0.22	3.43 ±0.20	1,025
Ukraine	6.42 ±0.45	7.34 ±0.44	6,547
United Arab Emir.	6.31 ±0.42	-0.44 ±0.43	42,742
United Kingdom	2.82 ±0.07	2.37 ±0.08	34,116
United States	2.87 ±0.12	1.86 ±0.11	43,660
Uruguay	0.42 ±0.70	0.26 ±0.71	10,783
Uzbekistan	5.37 ±0.28	4.09 ±0.28	2,290
Vanuatu	6.48 ±2.32	3.89 ±2.35	3,930
Venezuela	2.33 ±1.00	0.50 ±1.01	11,404
Vietnam	7.20 ±0.17	5.88 ±0.19	2,482
Yemen	4.06 ±0.07	0.96 ±0.07	2,240
Zambia	4.30 ±0.29	1.80 ±0.30	1,242
Zimbabwe	-5.80 ±0.68	-6.06 ±0.63	..
World	*3.80 ±0.13*	*2.53 ±0.14*	*9,552*

Note: All growth rates are calculated using data expressed in 2005 purchasing power parity (PPP) dollars, with the exception of growth rates for Cuba and Zimbabwe, which are calculated using constant local currency data.

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