People and the planet

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EXCELLENCE IN SCIENCE

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People and the planet
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Cover image: *Earth's city lights* shows how human-made lights highlight particularly developed or populated areas of the Earth's surface. The brightest areas of the Earth are the most urbanized, but not necessarily the most populated. (Compare western Europe with China and India.) Cities tend to grow along coastlines and transportation networks. Even without an underlying map, the outlines of many continents are still visible. The United States interstate highway system appears as a lattice connecting the brighter dots of city centers. In Russia, the Trans-Siberian railroad is a thin line stretching from Moscow through the center of Asia to Vladivostok. The Nile River, from the Aswan Dam to the Mediterranean Sea, is another bright thread through an otherwise dark region.Data courtesy Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC. Original version available at visibleearth.nasa.gov

Contents

President's foreword
Sir Paul Nurse FRS

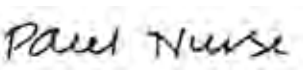
Rapid and widespread changes in the world's human population, coupled with unprecedented levels of consumption present profound challenges to human health and wellbeing, and the natural environment.

The combination of these factors is likely to have far reaching and long-lasting consequences for our finite planet and will impact on future generations as well as our own. These impacts raise serious concerns and challenge us to consider the relationship between people and the planet. It is not surprising then, that debates about population have tended to inspire controversy.

This report is offered, not as a definitive statement on these complex topics, but as an overview of the impacts of human population and consumption on the planet. It raises questions about how best to seize the opportunities that changes in population could bring – and how to avoid the most harmful impacts.

We hope this report, the Royal Society's first substantive offering on this topic, will be a springboard for further discussion and action by national and international Governments, scientific bodies, non-governmental organisations, the media and many others.

I would like to thank Sir John Sulston FRS, the Working Group and the Society's staff for making sense of such a complex set of topics. I would also like to thank the many people who contributed throughout the project, including Council's Review Panel, who have all helped to bring clarity to these enduringly important issues.



Paul Nurse
President of the Royal Society

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The members of the Working Group involved in producing this report were as listed below. The Working Group Members acted in an individual and not an organisational capacity and declared any potential conflicts of interest. The Working Group Members contributed to the project on the basis of his or her own expertise and good judgment.

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This report has been reviewed by an independent panel of experts before being approved by the Council of the Royal Society. The Review Panel members were not asked to endorse the conclusions or recommendations of the report but to act as independent referees of its technical content and presentation. Panel members acted in a personal and not an organisational capacity and were asked to declare any potential conflicts of interest. The Royal Society gratefully acknowledges the contribution of the reviewers.

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Summary

The 21st century is a critical period for people and the planet. The global population reached 7 billion during 2011 and the United Nations projections indicate that it will reach between 8 and 11 billion by 2050. Human impact on the Earth raises serious concerns, and in the richest parts of the world per capita material consumption is far above the level that can be sustained for everyone in a population of 7 billion or more. This is in stark contrast to the world's 1.3 billion poorest people, who need to consume more in order to be raised out of extreme poverty.

The highest fertility rates are now seen primarily in the least developed countries while the lowest fertility rates are seen in the more developed countries, and increasingly in Asia and Latin America. Despite a decline in fertility almost everywhere, global population is still growing at about 80 million per year, because of the demographic momentum inherent in a large cohort of young people. The global rate of population growth is already declining, but the poorest countries are neither experiencing, nor benefiting from, this decline.

Population and consumption are both important: the combination of increasing global population and increasing overall material consumption has implications for a finite planet. As both continue to rise, signs of unwanted impacts and feedback (eg climate change reducing crop yields in some areas) and of irreversible changes (eg the increased rate of species extinction) are growing alarmingly. The relationship between population, consumption and the environment is not straightforward, as the natural environment and human socioeconomic systems are complex in their own right. The Earth's capacity to meet human needs is finite, but how the limits are approached depends on lifestyle choices and associated consumption; these depend on what is used, and how, and what is regarded as essential for human wellbeing.

Demographic change is driven by economic development, social and cultural factors as well as environmental change. A transition from high to low birth and death rates has occurred in various cultures, in widely different socio-economic settings, and at different rates. Countries such as Iran and South Korea have moved through the phases of this transition much more rapidly than Europe or North America. This has brought with it challenges different from those that were experienced by the more developed countries as they reached the late stages of the transition.

Population is not only about the growing numbers of people: changes in age structure, migration, urbanisation and population decline present both opportunities and challenges to human health, wellbeing and the environment. Migrants often provide benefits to their countries of origin, through remittances, and to their host countries by helping to offset a workforce gap in ageing populations. Current and future migration will be affected by environmental change, although lack of resources may mean that the most vulnerable to these changes are the least able to migrate. Policy makers should prepare for international migration and its consequences, for integration of migrants and for protection of their human rights.

Developing countries will be building the equivalent of a city of a million people every five days from now to 2050. The continuing and rapid growth of the urban population is having a marked bearing on lifestyle and behaviour: how and what they consume, how many children they have, the type of employment they undertake. Urban planning is essential to avoid the spread of slums, which are highly deleterious to the welfare of individuals and societies.

The demographic changes and consumption patterns described above lead to three pressing challenges.

First, the world's 1.3 billion poorest people need to be raised out of extreme poverty. This is critical to reducing global inequality, and to ensuring the wellbeing of all people. It will require increased per capita consumption for this group, allowing improved nutrition and healthcare, and reduction in family size in countries with high fertility rates.

Second, in the most developed and the emerging economies unsustainable consumption must be urgently reduced. This will entail scaling back or radical transformation of damaging material consumption and emissions and the adoption of sustainable technologies, and is critical to ensuring a sustainable future for all. At present, consumption is closely linked to economic models based on growth. Improving the wellbeing of individuals so that humanity flourishes rather than survives requires moving from current economic measures to fully valuing natural capital. Decoupling economic activity from material and environmental throughputs is needed urgently for example by reusing equipment and recycling materials, reducing waste, obtaining energy from renewable sources, and by consumers paying for the wider costs of their consumption. Changes to the current socio-economic model and institutions are needed to allow both people and the planet to flourish by collaboration as well as competition during this and subsequent centuries. This requires farsighted political leadership concentrating on long term goals.

Third, global population growth needs to be slowed and stabilised, but this should by no means be coercive. A large unmet need for contraception remains in both developing and developed countries. Voluntary family planning is a key part of continuing the downward trajectory in fertility rates, which brings benefits to the individual wellbeing of men and women around the world. In the long term a stabilised population is an essential prerequisite for individuals to flourish. Education will play an important role: well educated people tend to live longer healthier lives, are more able to choose the number of children they have and are more resilient to, and capable of, change. Education goals have been repeatedly agreed by the international community, but implementation is poor.

Science and technology have a crucial role to play in meeting these three challenges by improving the understanding of causes and effects (such as stratospheric ozone depletion), and in developing ways to limit the most damaging trends (such as enhancing agricultural production with reduced environmental impact). However, attention must be paid to the socio-economic dimensions of technological deployment, as barriers will not be overcome solely by technology but in combination with changes in usage and governance.

Demographic changes and their associated environmental impacts will vary across the globe, meaning that regional and national policy makers will need to adopt their own range of solutions to deal with their specific issues. At an international level, this year's Rio+20 Conference on Sustainable Development, the discussions at the UN General Assembly revisiting the International Conference on Population and Development (ICPD+20) scheduled for 2014/2015 and the review of the Millennium Development Goals in 2015 present opportunities to reframe the relationship between people and the planet. Successfully reframing this relationship will open up a prosperous and flourishing future, for present and future generations.

Recommendations

Recommendation 1

The international community must bring the 1.3 billion people living on less than $1.25 per day out of absolute poverty, and reduce the inequality that persists in the world today. This will require focused efforts in key policy areas including economic development, education, family planning and health.

Recommendation 2

The most developed and the emerging economies must stabilise and then reduce material consumption levels through: dramatic improvements in resource use efficiency, including: reducing waste; investment in sustainable resources, technologies and infrastructures; and systematically decoupling economic activity from environmental impact.

Recommendation 3

Reproductive health and voluntary family planning programmes urgently require political leadership and financial commitment, both nationally and internationally. This is needed to continue the downward trajectory of fertility rates, especially in countries where the unmet need for contraception is high.

Recommendation 4

Population and the environment should not be considered as two separate issues. Demographic changes, and the influences on them, should be factored into economic and environmental debate and planning at international meetings, such as the Rio+20 Conference on Sustainable Development and subsequent meetings.

Recommendation 5

Governments should realise the potential of urbanisation to reduce material consumption and environmental impact through efficiency measures. The well planned provision of water supply, waste disposal, power and other services will avoid slum conditions and increase the welfare of inhabitants.

Recommendation 6

In order to meet previously agreed goals for universal education, policy makers in countries with low school attendance need to work with international funders and organisations, such as UNESCO, UNFPA, UNICEF, IMF, World Bank and Education for All. **Financial and non-financial barriers must be overcome to achieve high-quality primary and secondary education for all the world's young, ensuring equal opportunities for girls and boys.**

Recommendation 7

Natural and social scientists need to increase their **research efforts on the interactions between consumption, demographic change and environmental impact.** They have a unique and vital role in developing a fuller picture of the problems, the uncertainties found in all such analyses, the efficacy of potential solutions, and providing an open, trusted source of information for policy makers and the public.

Recommendation 8

National Governments should accelerate the development of comprehensive wealth measures. This should include reforms to the system of national accounts, and improvement in natural asset accounting.

Recommendation 9

Collaboration between National Governments is needed to **develop socio-economic systems and institutions that are not dependent on continued material consumption growth.** This will inform the development and implementation of policies that allow both people and the planet to flourish.

CHAPTER 1

Introduction

The number of people living on the planet has never been higher, their levels of consumption are unprecedented and vast changes are taking place in the environment. This report reviews the evidence for these changes, considers the likely problems they raise and finally offers possible solutions to those problems.

Given the controversies that surround the issues of population, consumption and the environment, the Royal Society felt that a close look at the debates would be both timely and appropriate. It established an international Working Group, with wide ranging expertise covering natural and social sciences, to provide an overview of the impact of human population and human consumption on the planet, and the subsequent implications for human wellbeing. The Working Group received a wealth of evidence in response to its open call for evidence, which was invaluable in assessing these issues. Details of the evidence received are given in Appendix 1.

1.1 The evidence

The human population reached 7 billion in late 2011 (UNFPA 2011). Overall, humans are older and more urban than ever before. Fertility and mortality have declined markedly in many countries and life expectancy has increased (Cohen 2005), but differences in family size, life expectancy and income vary enormously around the globe and are greater than they have ever been. The World Bank estimates that 1.3 billion people in the developing world are trapped in absolute poverty living on less than US$1.25 per day (World Bank 2012). Just under a fifth of the world's people have families averaging between 4 and 7 children and live in countries where 90% of future population growth is expected to occur. In contrast the people who now have two children or fewer (42% of the world's population), have the highest per capita incomes and consumption.

A greater number of consumers exist than ever before because of population growth. Economic development has meant that the material needs of societies have become more complex, reflecting aspirations as well as basic needs. Over the last sixty years total fish production has increased nearly fivefold (Swartz *et al.* 2010) and total world meat production fivefold (FAO 2006).

Patterns of consumption have led to big changes in the environment. The amount of carbon dioxide (CO_2) in the atmosphere has increased steadily from pre-industrial times (Keeling 1960; Keeling and Whorf 2004a). Emissions of CO_2 from energy use reached an all time high in 2010 (IEA 2011). The world has warmed by 0.8˚C from pre-industrial levels with a widespread melting of snow and ice. Since 1978 the annual average Arctic sea ice extent has shrunk by 2.7% per decade (IPCC 2007a). With high levels of CO_2 more of it is absorbed into water and the oceans are acidifying (Royal Society 2005; IAP 2009). The increase in food production has meant that more land is taken over for agriculture and fish stocks have dwindled rapidly. The loss of biodiversity has been dramatic (Convention on Biological Diversity 2010).

1.2 The challenges

The Royal Society perceives two critical issues that must be addressed quickly in order to establish a sustainable way of life for all people and avoid undermining the wellbeing of future generations. The first is the continuing expansion of the human population. The annual rate of global population growth has slowed from its peak at above 2.0% in the mid 1960s; fertility rates have fallen so that in 2010 almost 48% of world population had a total fertility of less than 2.1 children per woman (UN 2011a). However, rapid population growth continues in some parts of the world. The upward population trend will not reach its peak for another 40 years or more because present day children and the unborn have yet to have children themselves.

The second major issue facing the planet is that, taken as a whole, per capita consumption is increasing. Total consumption will continue to increase as the population gets larger, as more people on the planet means more mouths to feed and more goods to satisfy their aspirations. People depend on their natural environment for meeting many of these needs and desires, but over-consumption of material resources is eroding this natural capital. Access to sufficient food, water and fuel for everybody is already a problem (UNDP 2011).

The unprecedented growth in consumption of natural resources has provided real benefits for many. According to the 2010 UN Human Development Report (UNDP 2010), people around the world have become better educated, healthier

and wealthier over the last 20 years. However, the economic benefits from development have not been equitably distributed. Many of the adverse impacts of environmental degradation have fallen disproportionately on the poor (UN 2011c). Reducing these differences in wealth is challenging.

The problems posed by population size and overall consumption are interlinked. Lifting 1.3 billion people out of poverty will necessarily increase consumption in some regions and must be done in a way that will not totally alienate those who are already wealthy and whose consumption in certain areas needs to fall (World Bank 2012). While migration can contribute to development and to meeting the needs of ageing developed countries, it also impacts on local politics, communities and services.

1.3 The search for solutions

Concerns regarding the growth of human populations were voiced as far back as 3600 years ago (Cohen 1995). Attempts to formulate international policy on population began before World War II and continued in 1946 when the UN Economic and Social Council Population Commission was established. A World Population Plan of Action was produced following the first inter-governmental population meeting in 1974 (WPPA 1974).

Vigorous debate about the finite nature of the planet's resources started when Dennis Meadows and his colleagues at Massachusetts Institute of Technology (MIT) published their predictions of catastrophic collapse in *The Limits to Growth*. The MIT team argued that indefinite growth was impossible in a finite world (Meadows *et al*. 1972).

Critics of *Limits* accused the authors of 'Malthusian reasoning', failing to allow for the social and economic feedback mechanisms that could overcome scarcity and environmental constraints. The critics also argued that, without unprecedented redistribution, an absence of economic development would condemn millions to poverty (Simon and Kahn 1984; Beckerman 1972).

A polarised 'economic development versus environment' debate continued through the 1970s into the 1980s, arguably paving the way for the reconciliatory message of the Brundtland Report, *Our Common Future*, published in 1987. Brundtland saw environment and economic development not as separate challenges but as 'inexorably linked' (WCED 1987), and crystallised the concept of 'sustainable development' as '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs'*. This report takes this definition to mean that present generations have a duty to adjust their conduct so as to make the world capable of sustaining future people, and that no individual is more important than anyone else because of where and when they were born.

The United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro in June 1992. Agenda 21 was adopted by more than 178 Governments at that meeting. Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally involving United Nations organisations and Governments. The Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow-up of UNCED, to monitor and report on implementation of the agreements at the local, national, regional and international levels. Since then, sustainable development has itself been the subject of extensive debate and multiple (sometimes divergent) interpretations, but is widely agreed to have environmental, social and economic dimensions. (For further discussions see Elliott 1999, Holdgate 1996, Owens 2003, Owens and Cowell 2011).

Detailed consideration of the interrelationships between population, environment and poverty eradication was left to the subsequent 1994 International Conference on Population and Development (ICPD) meeting in Cairo. In the run-up to the Cairo meeting, the world's scientific academies convened a population summit to explore in greater detail the complex and interrelated issues of population growth, resource consumption, socioeconomic development, and environmental protection (Royal Society 1994). The ICPD reflected a growing awareness of the interconnectedness of population, poverty, consumption, and the environment (UN 1994). However, since the 1994 Cairo Conference the critical links between demography, environment and development have been overlooked in international sustainability debates.

The ICPD reinforced a human rights approach to family planning while also drawing attention to the continued need to slow rapid population growth. A new 20 year International Programme of Action (IPOA) recommended among other things improvements in gender equality and women's empowerment, strengthening reproductive rights and reproductive health, and integration of population issues with development and environmental strategies. Yet today at least a quarter of a billion women have no access to modern contraceptives, and a great many girls only receive primary school education. Gaining access to modern contraceptives and improved education have both been shown to help women choose the number of children they have. Improved access to voluntary family planning can help make every birth a wanted birth and eventually stabilise global population (Potts *et al*. 2009).

In 2000 at the Millennium Summit, world leaders came together to adopt the Millennium Declaration, committing their nations to a new global partnership to reduce extreme poverty and setting out the Millennium Development Goals (MDGs), a series of time-bound targets with a deadline of 2015. Issues of family planning and population were perceived as too controversial to include in the MDGs and although the UN Millennium Declaration refers to UNCED and Agenda 21 it did not mention the Cairo IPOA (see http://www.un.org/millennium/declaration/ares552e.pdf).

The 2002 World Summit on Sustainable Development's remit was to review progress in sustainable development ten years after the first Earth Summit, and to renew commitment to action towards integrating economic development, social equity and environmental protection, leading to sustainable development. The Conference saw a major shift away from environmental issues toward social and economic development. This shift, which was driven by the needs of the developing countries and strongly influenced by the MDGs, is only one example of how sustainable development has been pulled in various directions over its 20 plus year history. The 2002 Johannesburg World Summit on Sustainable Development Plan of Implementation (POI) included only one reference to the ICPD IPOA and contained no explicit acknowledgement of the importance of demographic factors in sustainable development.

1.4 The future

The UN population projections for the rest of the 21st century vary widely between 6.2 billion and 15.8 billion in 2100 (UN 2010). Demographic projections are not predictions and demography is not destiny. History has shown population growth can slow down without coercion. However, timing is of the essence. The sooner high fertility rates decline the sooner populations will peak. The policies and investments that are made in the coming decades will influence whether population moves towards the upper or lower boundary of population projected for the rest of the century.

Slowing rapid population growth, however, will not be sufficient to assure wellbeing. Over and under-consumption, by the world's richest and poorest respectively, will continue to maintain or even increase inequalities around the world as well as decreasing wellbeing for everyone. Lifting the world's poorest out of poverty is essential and it is a widely accepted view that those surviving on less than $1.25 a day have a right to a higher standard of living.

All the dimensions of population, such as the age structure, the degree of urbanisation and the extent of migration, affect the rate and type of consumption. Current levels of consumption are very much skewed to wealthier countries. A central issue is how an acceptable level of wellbeing for each person can be achieved without having a seriously adverse effect on the environment. Apart from general considerations of stewardship, this is important because human wellbeing is utterly dependent on the natural environment. The environment has many different kinds of resources, some of which are renewed quickly and can therefore be used sustainably, while others are slow to replenish or are non-renewable.

If sustainable development is to be achieved, the goals of economic development must be reappraised. Gross Domestic Product (GDP) seeks to measure the market value of all final goods and services produced within a country in a given period. GDP has come to be adopted as the primary measure of national prosperity, but it does not capture much of what is valuable in human life such as freedom, security, health and social relations. Resources on which economic activity depends are not necessarily unlimited. While some such as fresh water may replenish, they may also suffer from irreversible deterioration when overused. Because such

resources are not included as scarce assets in current economic models, they are undervalued by market prices. Nobody wishes to see a reduction in their standard of living, but wellbeing can improve without growth in GDP.

By 2050, the global population is likely to have increased by an additional 2.3 billion people and will be predominantly urban (FAO 2009). Nearly a quarter of the population will be over the age of 60. These represent major changes to the demography of the planet, and will present major social, economic and environmental challenges, and significant obstacles to achieving sustainable development goals. Degradation of the planet is a serious issue which already impacts on human wellbeing. Fish stocks can recover if no-fish zones are properly enforced. Pollution of the atmosphere can be reduced by the use of renewable sources of energy that do not generate carbon dioxide. All of this requires concerted action by the governments of the world and the signs are that some politicians at least are starting to think ahead.

1.5 About this report

In the next Chapter the basic demographic concepts are introduced to show the diversity of demographic change occurring across the world and the opportunities and challenges that these changes bring. Chapter 3 summarises recent trends in the consumption of natural resources. Chapter 4 describes how human consumption drives environmental change, and how that behaviour is bringing the global population closer to environmental limits. Chapter 5 outlines different pathways towards a more sustainable future, and Chapter 6 contains conclusions and recommendations.

The context for the population debate has changed: the 21st century is a unique combination of demographic diversity, global environmental change and globalisation. Countries around the world will experience novel economic, social and environmental challenges as a consequence of growing consumption and the demographic changes that are now underway. How decision makers respond to these challenges will influence the overall size of the human population and the rate at which the environment is degraded, with the potential to forestall a downward economic, socio-political and environmental spiral. Over the next few years new goals and targets will be set to guide global sustainable development activities. An opportunity exists now to reframe the debate before these targets are set. With the Rio+20 meeting in 2012, the ICPD+20 scheduled for discussion at the UN General Assembly in 2014/2015, and the review of the Millennium Development Goals in 2015, the opportunity exists for the reinvigoration of discussions about the inter-linked issues of population size, equity, human wellbeing and sustainable development.

A diverse world

2.1 Introduction

The size of the world population increased rapidly during the 19th and 20th centuries from approximately 1 billion in 1825 to 7 billion in 2011. According to the 2010 medium projection of the United Nations, by 2050 the world will have 9.3 billion people[1]. At a time when so many people remain impoverished and natural resources are becoming increasingly scarce, continued population growth is cause for concern. However, population growth is only part of the story. Differences in population composition, in particular age composition, density (especially the growth in people living in towns and cities) and distribution, as affected by migration, are also important considerations. The early 21st century represents a period of unprecedented demographic change. From 2000, the number of people aged 60 years or more outnumbered the very young (0-4 years) for the first time in human history, from 2003 the median woman (though not the average woman) had and will probably continue to have less than two children, and in 2007 the number of urban dwellers outnumbered rural dwellers (Cohen 2005). The 21st century is also a period of unprecedented demographic diversity across the world. For example, the European region is already widely urbanised, is rapidly ageing and could experience a decline in population by 2050 (under the UN medium population projection). In contrast, the population across Africa is growing rapidly and is projected to more than double by 2050. Many of the countries within this region have predominantly young populations with a high proportion under the age of 25, and urbanisation levels are currently low relative to other parts of the world although the rates of urbanisation are high.

These trends in demography and their diversity reflect trends in social, economic and environmental inequalities. Population matters because relative rates of increase, differences in age structure, and migration influence inequality between countries. Economic and social inequalities within countries influence fertility and mortality rates with impacts on population size and structure and therefore the society, economy and environment. Furthermore, population matters because population numbers can sometimes overwhelm the capacity of the environment to support people's needs.

The objective of this Chapter is to introduce demographic concepts, review major demographic trends and drivers, and highlight the challenges and opportunities presented by these trends.

Unless otherwise stated, projections cited in this report refer to the UN 2010 medium fertility variant. The Least[1], Less[2] and More[3] Developed Country groupings are those of the United Nations (2011).

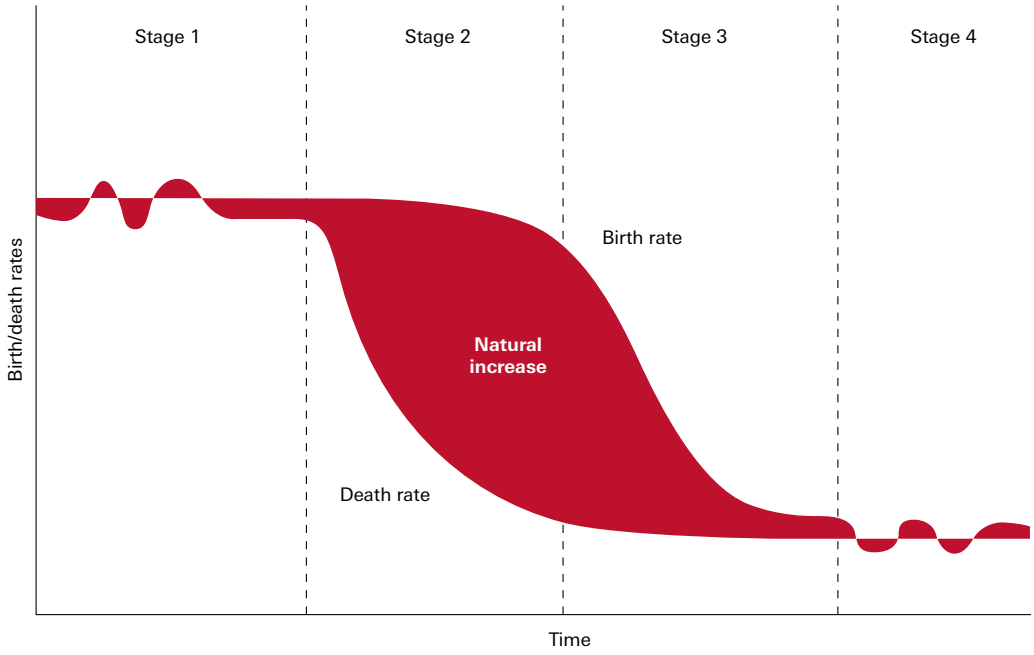
2.2 Demography – a basic introduction

Discussions of population are often framed in terms of population size and population growth. However demographic change is a dynamic process that arises from changes in mortality, fertility and migration, and the effects of these changes are not limited to population size or growth rate. Changes in these variables also influence the age structure and distribution of the population. When population growth is rapid there tends to be a higher proportion of young people and a smaller proportion of old in the population. As mortality and fertility rates decline the proportion of old people in the population increases. This process is known as the demographic transition; or the changes that occur as a country moves from high mortality and high fertility to low mortality and low fertility. During this transition, population growth and movement occur. People migrate from place to place within countries, from rural to urban areas or internationally.

The demographic transition concept (see Figure 2.1) is useful for understanding the drivers and consequences of population change. The transition is classically considered to be driven by improvements in wealth, education and health care (Notestein 1945;

1 This figure could be between 8.1 (low variant) and 10.6 billion (high variant) depending heavily on the population policies for the next few years.
2 Any country defined as 'Least Developed' by the United Nations General Assembly in its resolutions (59/209, 59/210, 60/33, 62/97, 64/L.55). This is based on low performance in three criteria: per capita gross national income (GNI), human assets and economic vulnerability to external shocks. (See Appendix 2).
3 Any country which is not 'Least Developed', but is in a 'Less developed region', comprising all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia.
4 Any country which falls into a 'developed region', comprising Europe, Northern America, Australia / New Zealand and Japan

Figure 2.1 The demographic transition
Note: Natural increase is produced from the excess of births over deaths.



Data Source: Population Reference Bureau 2006

David 1967). The shift from the first stage of the transition (a state of high mortality and high fertility) to the second stage of the transition is signalled by a decline in mortality that most improves infant and child survival and so increases the proportion of children in the population. A sharp increase in the size and density of the population follows as more people survive. There is therefore a high **youth dependency ratio**. Many Least Developed Countries currently show these features.

After a time lag, which may vary significantly in length between countries, fertility declines and the youth dependency ratio begins to fall but, as a legacy of past high fertility, the working age population continues to grow. The ratio of workers to less productive ages increases. This is the third stage of the transition. The number of births per thousand (crude birth rates) and population growth remain high for several decades because of the disproportionately large number of women in the reproductive ages, a feature termed **demographic momentum**. At this stage, population growth may still be high despite declining fertility. This phase is still underway in many Less Developed Countries and some Least Developed Countries.

Box 2.1 Demographic terms and definitions

Total fertility rate (TFR)
The average number of children a hypothetical cohort of women would have at the end of their reproductive period if they were subject during their whole lives to the fertility rates of a given period and if they were not subject to mortality. It is expressed as children per woman.

Replacement fertility
Replacement level fertility is the average number of children born to a woman so that a population exactly replaces itself from one generation to the next (Craig 1994). In More Developed Countries, this is roughly total fertility rate of 2.1 children per woman, but the global variation is substantial, ranging from less than 2.1 to 3.5, due principally to variation in mortality rates (Espenshade 2001). This report assumes a replacement level fertility of 2.1 children per woman.

Youth dependency ratio
The youth dependency ratio is the number of persons 0 to 14 years per one hundred persons 15 to 64 years.

Old-age dependency ratio
The old-age dependency ratio is the number of persons 65 years and over per one hundred persons 15 to 64 years.

Total dependency ratio
The total dependency ratio is the number of persons under age 15 plus persons aged 65 or older per one hundred persons 15 to 64. It is the sum of the youth dependency ratio and the old-age dependency ratio.

Demographic dividend
Occurs when there is a higher proportion of workers to dependents within a population, and therefore a potential for added productivity which can produce a bonus of economic growth, assuming that the correct policies are in place to take advantage of this.

Demographic deficit
Occurs when there is a higher proportion of dependents to workers in the population, potentially leading to reduced productivity and restricted economic growth.

Demographic momentum
The tendency for population growth to continue beyond the time that replacement-level fertility has been achieved because of the relatively high concentration of people in the childbearing years.

Demographic inertia
The tendency for current population parameters, such as growth rate, to continue for a period of time; there is often a delayed population response to gradual changes in birth and mortality rates. A common example of demographic inertia occurs when a well-below replacement level of fertility becomes established over several cohorts.

As the fourth stage of the transition is reached inevitably the **profile of the population ages**, as fertility declines, as mortality declines, and as more individuals survive to increasingly older ages (see Box 2.2). The age-structure of the population will depend upon all three of these factors. Most of the More Developed Countries have reached this fourth stage. There is some indication that during the late stages of the demographic transition, **demographic inertia** may set in whereby a well-below replacement level of fertility becomes established over several cohorts, potentially leading to a decline in population numbers were populations not maintained by in-migration. Such societies also experience a shift towards a higher **old-age dependency ratio**.

While the classic demographic transition theory assumed that the ultimate destination was a stable population with replacement level fertility, fertility in many countries has fallen well below replacement, with many people postponing the birth of their first child and changes in the pattern of marriage and parenthood being observed. This unexpected development has been dubbed the second demographic transition (Leeson 2009; Reher 2011; Lesthaeghe and Neidert 2006).

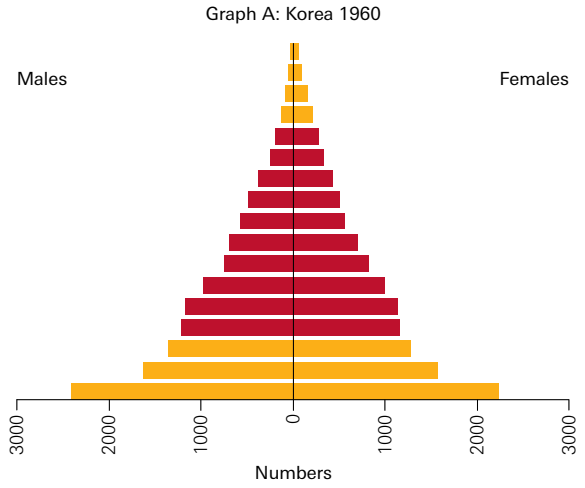
The drivers behind the second demographic transition are complex and not well understood. Some economists, for example, argue that the basic causes of the second demographic transition are rooted in technological advances and changes in the market which have altered the costs and rewards of marriage and child rearing (Lundberg and Pollak 2007; Kohler *et al*. 2006). Others argue that postponed fertility is a response to economic certainty, reinforced however, by changes in society which enlarges women's opportunities for economic activity. Others suggest that ideational changes which accompany increased affluence are the main reason, leading to a focus on individual autonomy and self-realisation (Lesthaeghe 2010).

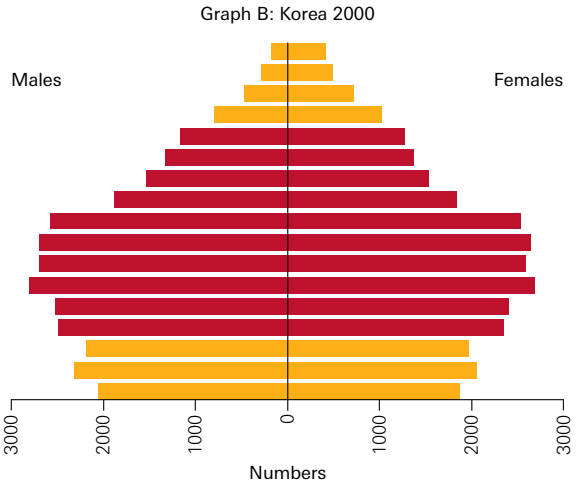
The greatest difference between the demographic transition processes in the Least, Less and More, Developed Countries has been the speed of mortality and fertility decline. Mortality has declined more rapidly relative to fertility decline in most of the Less and Least Developed Countries, compared to the relative rates of decline in mortality and fertility in the More Developed Countries, and as a result the populations of the Less and Least Developed Countries are growing much more rapidly today than More Developed Countries did at the comparable stage of the transition. Mortality decline in the Less and Least Developed Countries is currently heavily concentrated in infancy and early childhood leading to a higher proportion of women of reproductive age alive in the population. This has a pronounced multiplier effect on population growth: population growth is much more rapid in these countries (Rayner and Malone 1998).

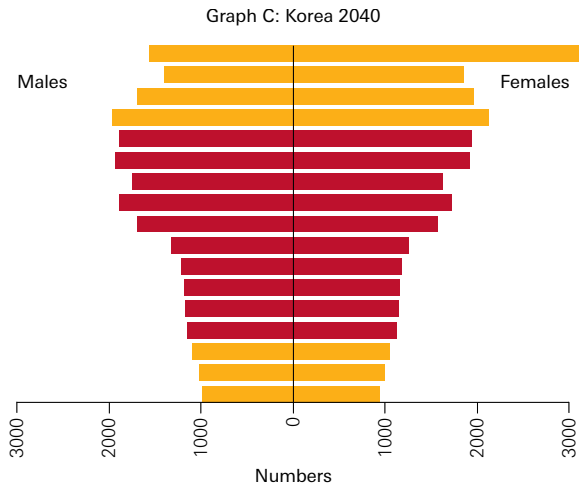
The drivers of the demographic transition may differ between countries and the time taken to complete the transition may vary significantly. Some demographers believe that all countries in the world are in different but converging stages of this process, others believe that the completion of the transition is not an inevitable end point for all. The global population comprises many populations at different stages of the transition. For example, some of the Least Developed Countries are still in the very early stages of the transition, eg many of the sub-Saharan African countries are currently growing rapidly because mortality has declined but fertility remains high. The majority of Less Developed Countries eg in Asia and Latin America, now have declining fertility and slowing rates of population growth. Many of the More Developed Countries are in stage four of the transition and have fertility rates at or below replacement. For example, Japan is experiencing population decline due to continuing low fertility. Some of the European countries would be experiencing decline were it not for net in-migration.

Box 2.2 The demographic transition in South Korea

The shift in age structure experienced as countries move through the transition is well illustrated by the example of South Korea. By 1960, mortality had already declined but fertility remained high at about six births per woman and the population was growing at 2.8% per year. At that time, 42% of the total population were aged under 15 years but only 3% were aged 65 or more. South Korea instituted a comprehensive voluntary family planning programme, and by 2000 the number of births per woman was about 1.4 and the population growth rate had abated to 0.6% per year. Between 1960 and 2000 the number of working-age adults (15-64 years) per 100 dependents rose from 120 to 250. Between 2000 and 2040 it is projected that the proportion of Korea's population aged 65 or more will rise from 7.4% to 30.5% and the ratio of workers to dependents will fall from 250 to 137 per 100 dependents. All of the More Developed Countries now face similar challenges as the population ages.



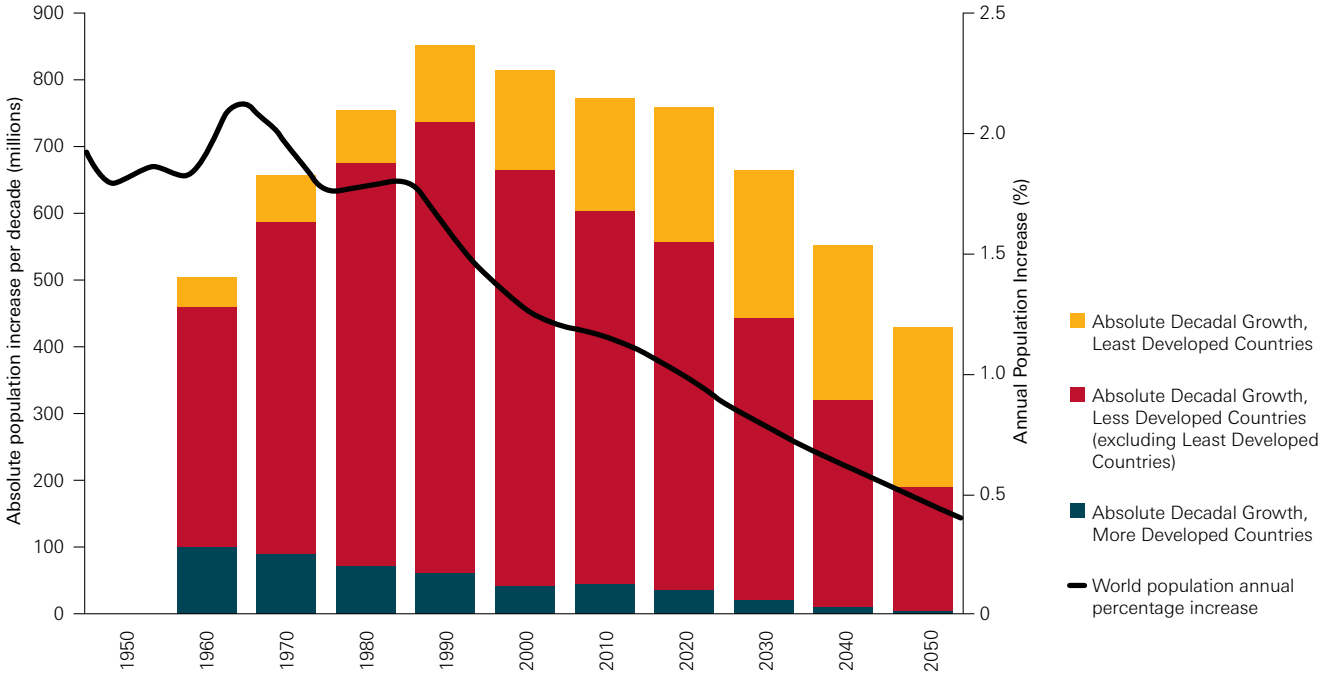




Source: Cleland *et al.* 2006

The vertical axis shows 5 year age cohorts from 0 to 80; the top bar is 80+. Red bars are working age cohorts, from 15 to 65. Horizontal axis shows population numbers in 1000s.

Figure 2.2 A figure of absolute population growth to illustrate the difference between absolute growth versus percentage growth. The line shows percent growth, the bars show absolute growth (per decade).



Source: UNPD 2011

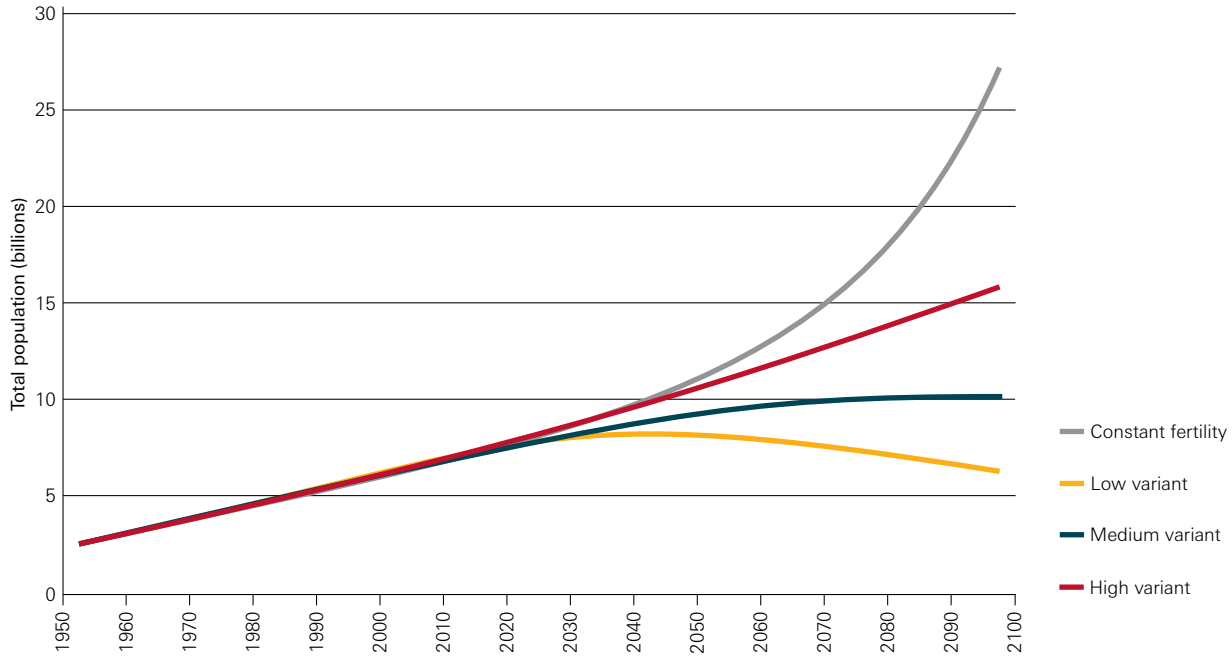
2.3 Recent population trends

2.3.1 Population size

According to UN observations, the global population increased rapidly over the 19th and 20th centuries, and by late 2011 the world population had reached the 7 billion mark. While the average annual rate of population change peaked in the 1960s at 2% and now stands at 1.1% per year, the absolute rate of growth peaked at 89 million per annum in 1988 and now stands at 78 million (see Figure 2.2).

Globally, mortality and fertility have been in general decline since the 1950s as incomes have increased, standards of living have improved, and more people have had better access to education and health care, including reproductive health care. Developments in technology and communication have also played an important role. It is expected that these trends will continue and that mortality and fertility will carry on declining over the next century. The rate at which these declines occur will determine whether the global population is closer to the low or high variant for 2050, as projected by the UN Population Division. Changes in fertility, not mortality, are likely to have the greatest impact on future population size, growth and age structure. Under the UN medium fertility variant the population is expected to reach 9.3 billion by 2050, but an increase or decrease in TFR by 0.5 will determine whether the world reaches 8.1 or 10.6 billion (see Figure 2.3). The case of Ghana illustrates the importance that decisions about childbearing made today, and in the future, have on determining the future size of the population. In 2010 the population of Ghana was a little above 20 million with a fertility rate of 4 births per woman. If fertility declines dramatically and reaches replacement level

Figure 2.3 Global population numbers for the low, medium and high variants, and what happens if fertility rates remain constant, up until 2100.



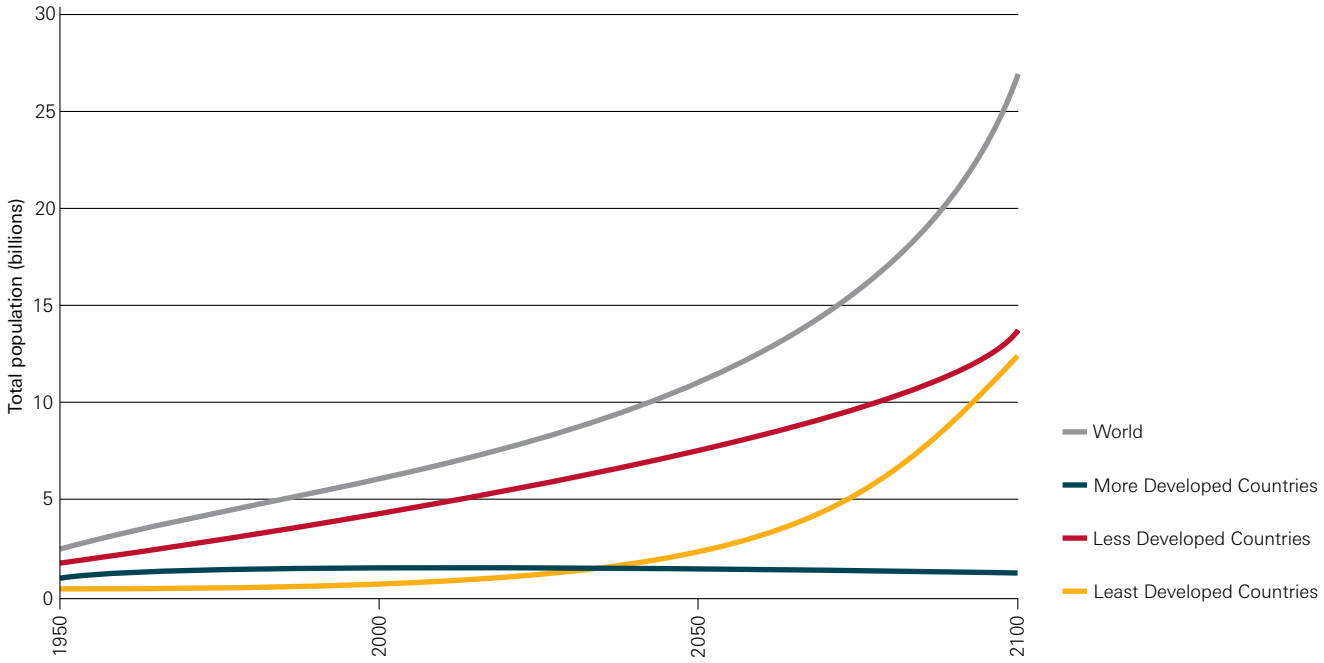
Source: UNPD 2011

by 2020, the population would nevertheless continue to grow for a further 40 years until it stabilises at 40 million. If replacement level fertility were achieved by 2040, the population would stabilise at 50 million and if this achievement were delayed further to 2060, the population would reach 65 million before stabilising.

As with all projections there is uncertainty associated with the UN figures. The projections depend on the assumption that the countries that currently have high fertility will repeat the experience of countries that have seen a marked fall in family size. However, this assumption is by no means certain. For example, the pace of fertility decline in sub-Saharan Africa has proceeded more slowly than some commentators expected, probably due to a combination of lack of investment in female education, family planning and cultural reasons which are difficult to disaggregate. The projected size of the population looks very different if the fertility levels experienced in each country between 2005-2010 were maintained until 2100 (see Figure 2.3, constant fertility, and Figure 2.4 constant fertility by development group). The annual rate of population change would keep on increasing, leading to a significantly larger global population. Figure 2.5 shows the medium projection by development group.

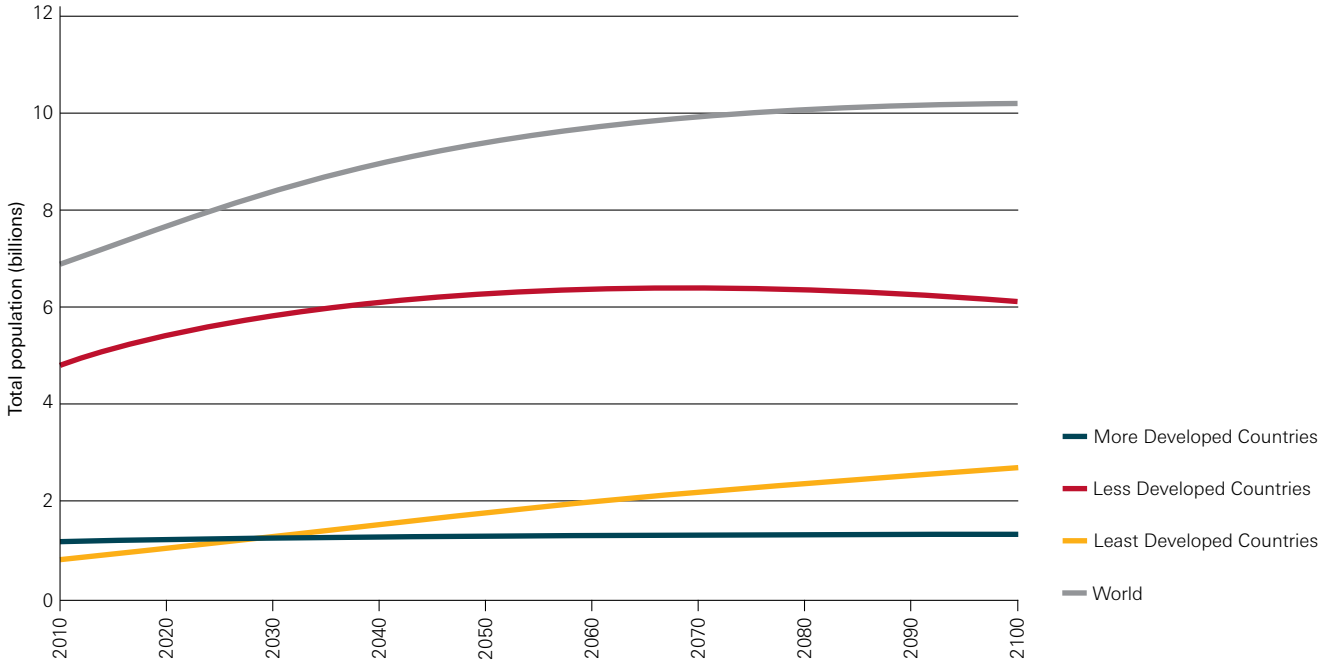
The age structure and composition of a population are the result of the three demographic components (mortality, fertility and migration). The next sections in this report summarise some of the current trends in these components around the world, and also looks at trends in urbanisation and ageing.

Figure 2.4 UN constant fertility. These populations would result if the current fertility of the three regions were maintained indefinitely. The plots up to 2010 show the actual populations.



Source: UNPD 2011

Figure 2.5 UN medium projections of total population size.
The More Developed Countries have been below replacement fertility for three decades, and are relatively stable. The average TFR of the Less Developed Countries (excluding Least) has fallen to 2.3; they are still growing rapidly due to demographic momentum, but with a small further decline in fertility will stabilise by the middle of the century. The Least Developed Countries are experiencing continued rapid growth at an average TFR of 4.1, and most of them need a substantial decline in fertility to reach stability.



Source: UNPD 2011

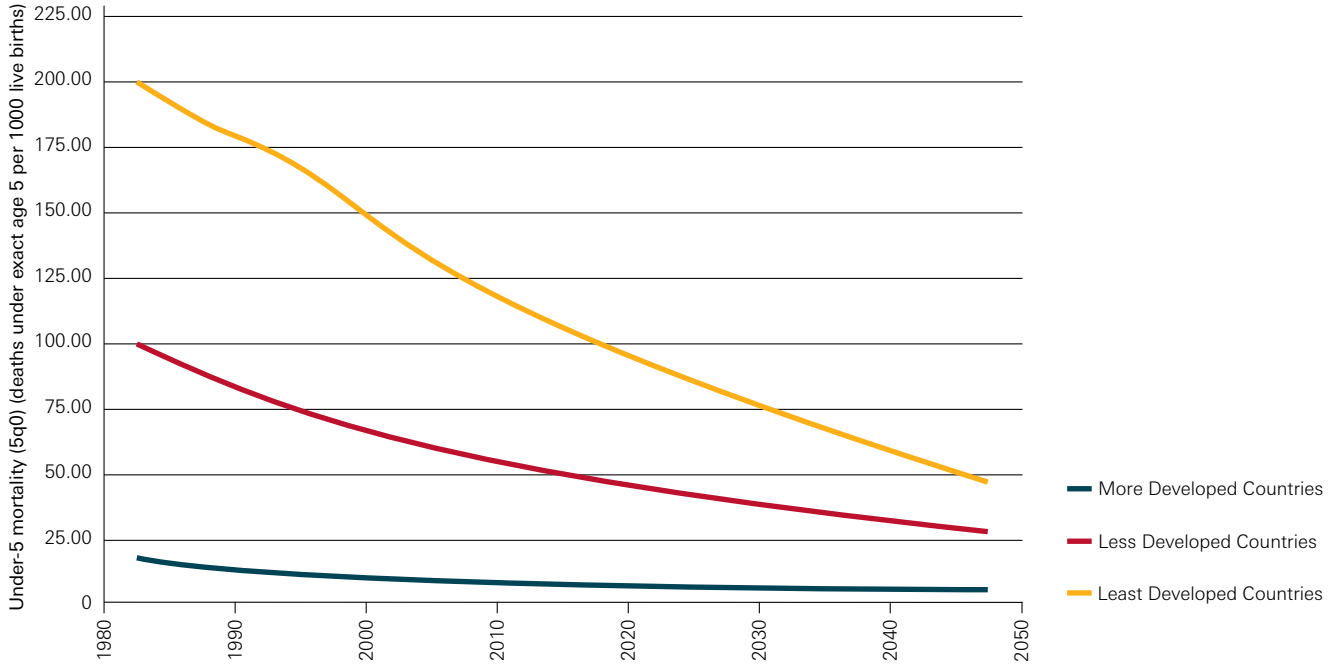
2.3.2 Mortality trends

In the More Developed Countries mortality first started to decline after 1750 and this decline accelerated in the late 19th and early 20th century, due to medical advances. More recently mortality rates among those over 65, and more recently still among those over 85, have fallen rapidly and continuously. In the Less Developed Countries improved survival typically started in the 1920s or 1930s and accelerated after the World War II, with dramatic improvements in child survival. Since 1950, infant mortality rates have declined everywhere, although at varying rates between the Least, Less and More Developed Countries (see Figure 2.6). In the Least Developed Countries mortality rates have declined rapidly but are still high.

The maternal mortality ratio (deaths of women while pregnant or within 42 days of a delivery or abortion) remains extremely high for the Least Developed Countries at an average of 597 per 100,000 live births (2008), and is 1,400 per 100,000 live births in Afghanistan (2008). In the Less Developed Countries it was 293 deaths per 100,000 live births in 2008. In the More Developed Countries, the maternal mortality ratio is 18 per 100,000 per live births. It is 5 or below is some countries, such as Greece, Ireland and Denmark (UNFPA 2011).

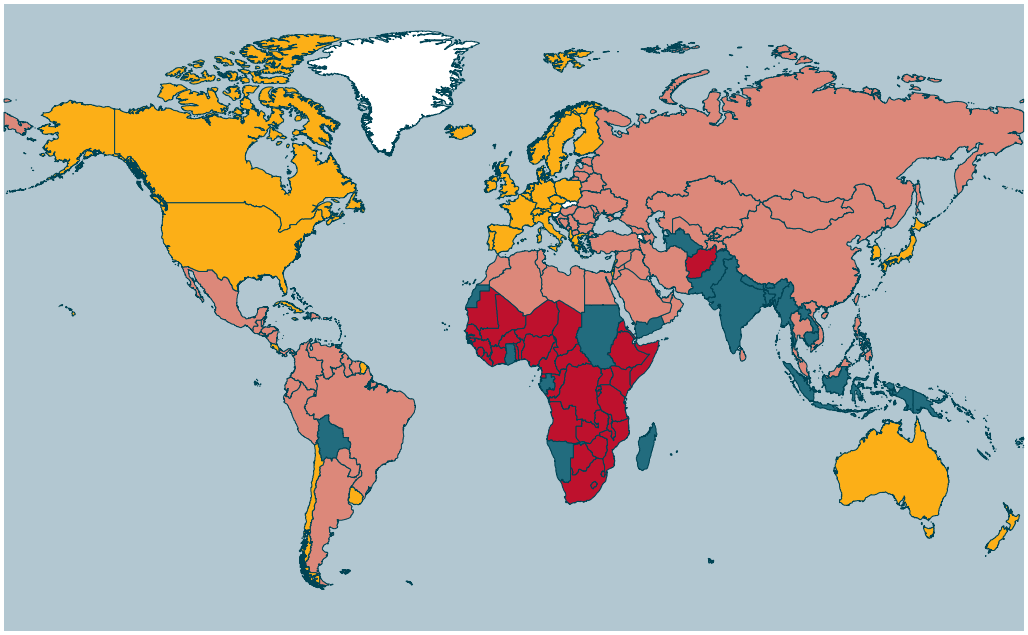
Life expectancy at birth in the Less Developed Countries (excluding the Least Developed Countries) is now 70 years or more. This has increased from 42 and 43 for males and females respectively in 1950, to 67 and 71 in 2010, and is projected to increase to 73 and 78 by 2050, and 79 and 83 in 2100, respectively. In the Least Developed Countries the same trend is expected, although life expectancy is currently well below that of the other country groupings and currently stands at 57 and 60 for males and females, respectively. In the More Developed Countries life expectancy at birth is now at 75 for males and 81 for females, and is projected to increase to 80 and 86 by 2050 and 85 and 90 by 2100 (see Figure 2.7).

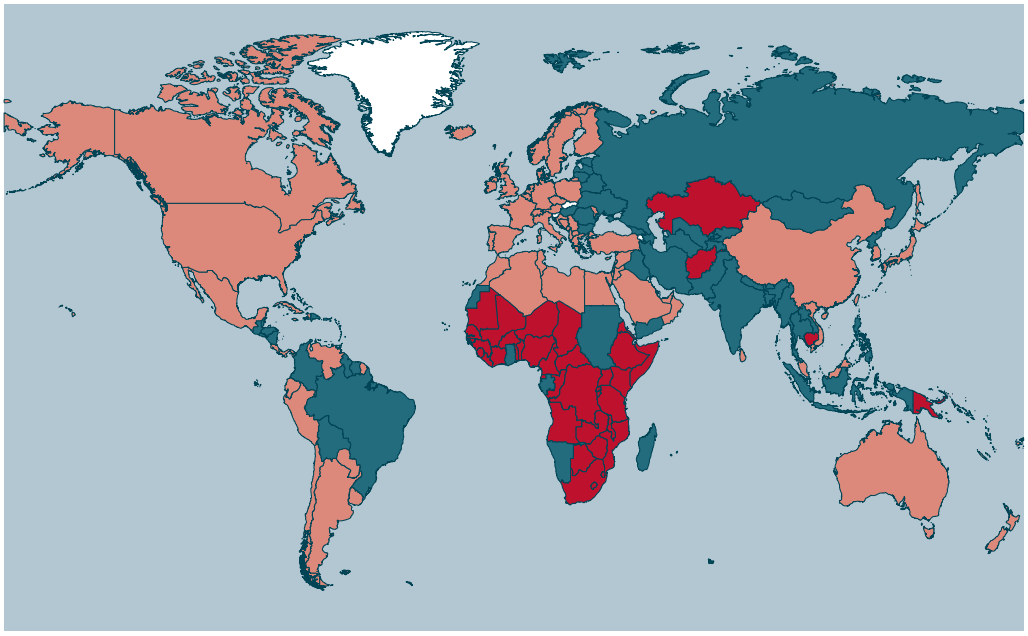
Figure 2.6 Under-5 mortality trends (estimates for 1980 – 2010 and medium projections for 2010 – 2050), calculated at 5 year intervals, plotted as midpoints of those intervals.



Source: UNPD 2011a

Figure 2.7 Female and male life expectancy at birth 2005 – 2010





Source: Harper 2012; UNPD 2011

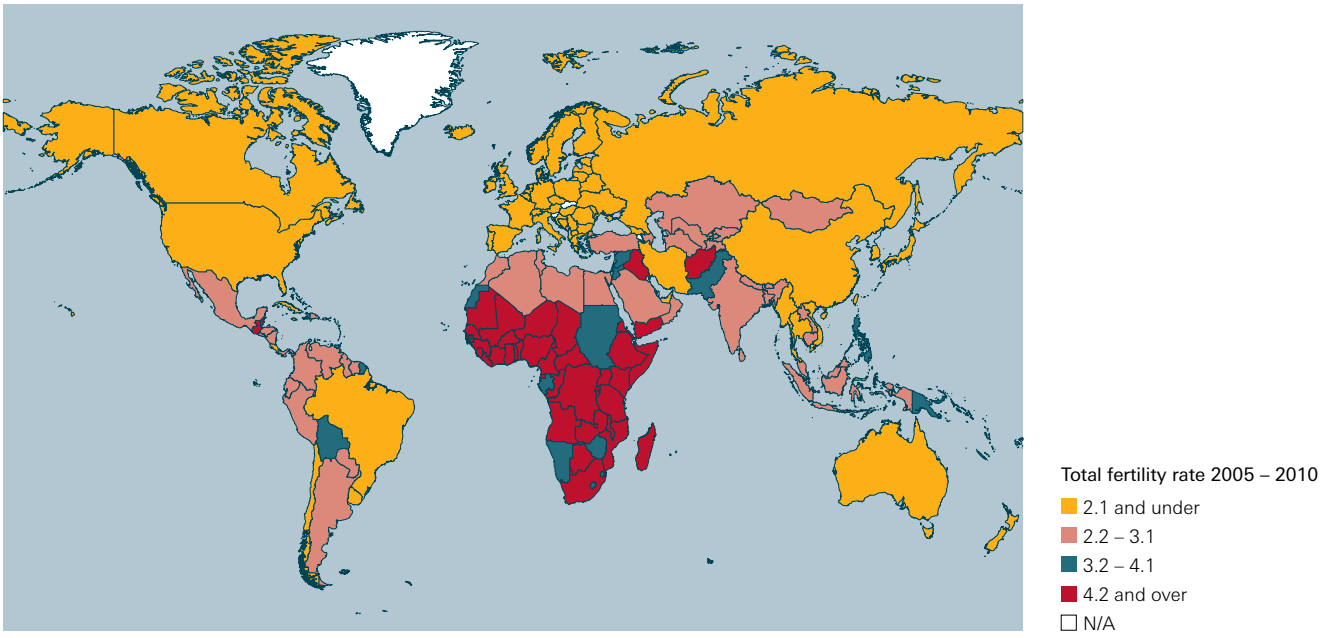
2.3.3 Fertility trends

The global trend in fertility since the 1950s has been one of general decline. However, as emphasised above, this observation obscures the variation in fertility seen around the world. Broadly speaking the world can be split into four groups: the low fertility countries that have TFRs at, below or approaching replacement - 2.1 and under; the low-medium fertility countries with TFRs of 2.2-3.1; the high medium fertility countries with fertility rates of 3.2-4.1 and the high fertility countries with TFRs of 4.2 or more (see Figure 2.8). Those below replacement are concentrated in the More Developed Countries but also in parts of Asia and Latin America. Those countries with high fertility rates are primarily Least Developed Countries, predominantly in sub-Saharan Africa but also in parts of Asia, Oceania and Latin America. High fertility rates and demographic momentum mean that their populations are projected to more than double over the next 40 years (UN 2011a).

In many of the More Developed Countries fertility rates have declined in two phases (see Figure 2.9). Fertility decline started in the late 19th century. Birth rates fell to very low levels in the 1930s but rose again after the World War II. This baby boom was most pronounced in the USA where fertility increased from 2.9 births per woman in 1946 to 3.7 in 1957. Japan is the clearest exception to this trend as birth rates declined from 4.5 in 1947 to 2.0 in 1957. The mid-1960s marked a second phase of fertility decline in the More Developed Countries, and by 1980 fertility rates had fallen below two births per woman. The Total Fertility Rate for the More Developed Countries is estimated to be 1.71 (in 2010-2015, UN 2010a).

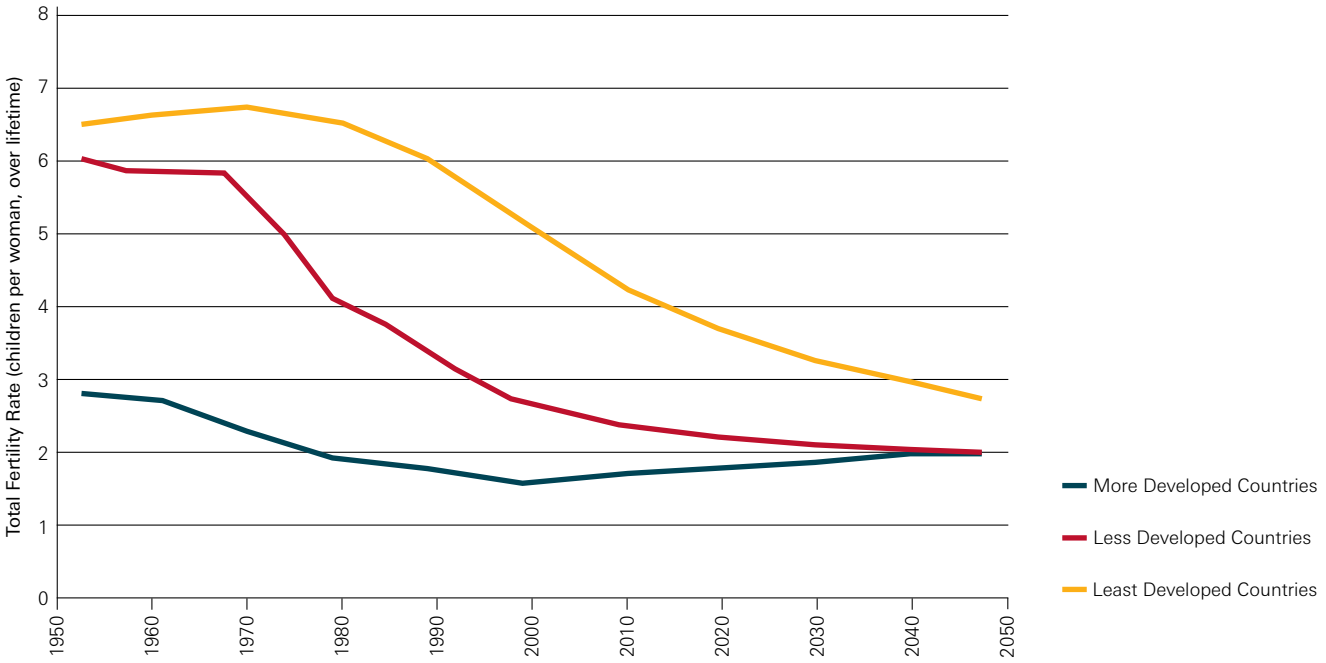
In the Less Developed Countries the decline in fertility started in the 1950s, dropping from 6 births per woman to 2.3 for the period 2010-2015. Fertility in the Least Developed Countries started to decline in the 1970s, going from 6.7 in 1965-1970 to 4.1 in 2010-2015.

Figure 2.8 Total fertility rate 2005 – 2010



Source: Harper 2012; UNPD 2011a

Figure 2.9 Total fertility rate estimates for 1950 – 2010 and medium projections for 2010 – 2050, calculated at 5 year intervals, plotted as midpoints of those intervals.



Source: UNPD 2011a

As the century progresses the UN medium population projections are based on the assumption that fertility in the More Developed Countries will rise to 1.97 in 2045-2050, whilst the fertility in the Less Developed Countries will fall to replacement (2.00) in 2045-50. The fertility in the Least Developed Countries is projected to fall to 2.8 by 2045-2050. Given that fertility decline in Sub-Saharan Africa has been slower than expected over the last decade these latter figures, at least, are uncertain.

2.3.4 Trends in global population age structure

One of the consequences of a global decline in mortality and fertility rates has been the ageing of the global population. In global terms the rate of ageing currently underway and the number of old people in the population are unprecedented in human history. Since 1950 the proportion of people aged 60 and above has been rising steadily as a result of a slowdown in the growth of the number of children coupled with a steady increase in the number of old people due to declines in later life mortality. In 1950 5% of the global population was aged 65 and above, in 2010 this had increased to 9% and is expected to reach 20% in 2050 under the UN medium variant (UN 2009). By 2050 there may be 1.9 billion people aged over 65. In the More Developed Countries the proportion of the population aged 60 and above is projected to increase from 20% to more than 30% by 2050. There will be twice as many older people as young and the proportion of the working age population will have declined from 62% to 52%. The proportion of the population aged 60 and above in the Less Developed Countries is projected to go from 8 to 20%, and in the Least Developed Regions from 5 to 10% (UN 2011). The Asian Pacific region will hold two-thirds of the world's 2 billion elders.

However, not all countries are at this stage of the demographic transition. Many of the Least Developed Countries have predominantly young populations and therefore high youth dependency ratios. For example, half of Niger's population is under the age of 15 (Sippel *et al*. 2011). Many of the Less Developed Countries, for example, Brazil, have populations that have moved beyond this stage of the transition into the phase when the majority of the population are of working age.

2.3.5 Migration trends

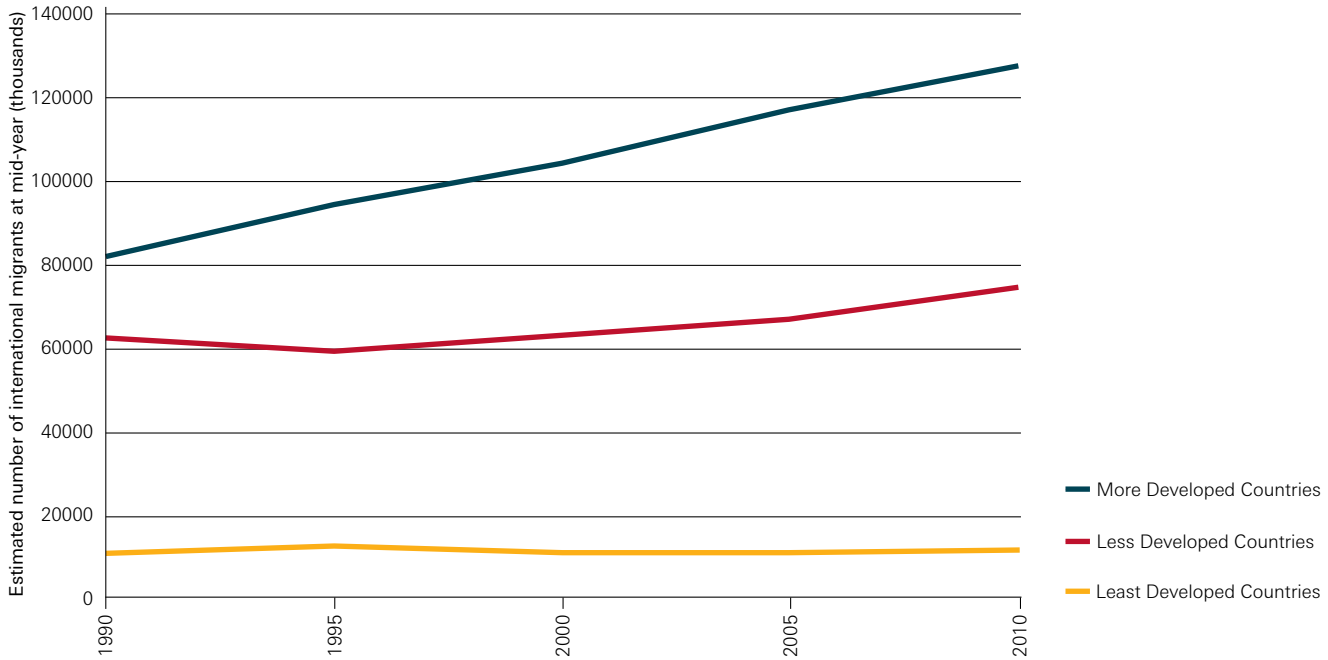
The number of international migrants is estimated to have increased from 156 million in 1990[5] to reach 214 million in 2010. This represents a 38% increase in the number of people living abroad in just two

decades. Numbers are approximately constant in the Least Developed Countries, but they have risen slightly since 1995 in the Less Developed Countries, and they have risen steeply in the More Developed Countries (see Figure 2.10). The percentage of the world's population living outside of their country of birth has increased only slightly, to 3.1% in 2010 from 2.9% in 1990. However, the More Developed Countries have seen a larger increase in the migrant share of the population from 7.2% in 1990 to 10.3% in 2010 (UNDP 2009). Part of the apparent overall increase in the number of international migrants however is a reflection of the changes in international borders when many countries became sovereign nations after 1990, such that some of their residents appear in the statistics as international migrants from another country.

Globally, 49% of those living abroad are women, but in the Less Developed Countries the number of female migrants has been historically lower (about 45% since 1990). The share of international migrants represented by women has remained relatively constant over time in most regions and at global levels. However, it is argued that one of the main changes in international migration in recent years has been the increasing number of women who are migrating on their own (Castles and Miller 2009). In the past, men were more likely to migrate, either as single young men or with the intention of bringing wives and children over at a later date. Nowadays women are increasingly migrating independently in order to look for better job opportunities (UN-INSTRAW 2007).

Refugees accounted for about 8% of total global migration in 2010 (about 16.4 million). This represents a considerable decrease from the 12% share of 1990. This number will also have been affected by countries becoming sovereign nations. This share tends to be greater in Africa and Asia (13% and 18% respectively in 2010) and smaller in Europe and Northern America (about 2% in each case in 2010). The large number of refugees in Asia (about 11 million in 2010) is in part explained by the number of refugees in Western Asia (which includes the Middle East).[6]

Figure 2.10 International migrant stock by region of the world.



Source: UN(2009a) Trends in International Migrant Stock (2008 revision)

5 Unless otherwise specified all data cited in this sub-section are from the United Nations Population Division (UN 2009b).
6 In the UNPD definition Western Asia includes Armenia, Azerbaijan, Bahrain, Cyprus, Georgia, Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Turkey, United Arab Emirates and Yemen.

Estimates of future trends in international migration are much less reliable than projections of population growth and structure. In the 2010 revision of the UNPD population estimates, the assumptions on the future of international migration were based on the policy stance of each country and previous migration trends. The result was a slightly declining level of net-migration to More Developed Regions over the next decades. It is possible that this assumption is wrong; as the population of Europe continues to age and decline, it is likely that the region will want to attract more migrants. After 2050, net migration is assumed to decline at a faster pace. However, international migration is the most dynamic component of population change in many destination countries (Cangiano 2011).

Even if lower rates of population growth in developing countries reduces the pool of potential international migrants in the future, making assumptions about the future of global migration remains a challenge. This has been accepted by the UN in the past. For instance, the 1998 revision of the World Population Prospects suggested that "international migration is the component of population dynamics most difficult to project reliably. This occurs in part because the data available on past trends are sparse and partial, and in part because the movement of people across international boundaries, which is a response to rapidly changing economic, geopolitical or security factors, is subject to a great deal of volatility" (UNPD 1999 as cited in Cohen 2003). This is a problem common to all population projections, not only the UNPD estimates.

Six broad trends have been identified in recent patterns of migration: globalization – the tendency for more countries to receive migrants from a large range of source countries; acceleration in the number of people involved; growing differentiation in the range of categories of migrant; feminisation, with increasing proportions of women as primary migrants; politicisation, in its impact on domestic politics and prominence in bilateral and international agreements; and transition, where countries of emigration become countries of immigration (Castles and Miller 2009).

New patterns of migration to African countries such as Ghana and Morocco, from within and beyond the continent, challenge perceptions that it is only for the More Developed Countries that the challenges posed by immigration have to be addressed (Jonsson 2009).

2.3.6 Urbanisation trends

Urbanisation is defined as an increasing proportion of a population living in urban areas, and is mostly due to the net movement of people from rural to urban areas (UN definition). Urbanisation should not be confused with urban growth (an absolute term, rather than a proportion) (Satterthwaite 2007), which is usually due to the fact that those living in (and migrating to) urban areas are of reproductive age.

Urbanisation appears to be a global process as all countries of the world are becoming more urbanised, ie a greater proportion of the population are living in urban areas.

Globally, the proportion of people in urban areas rose from 29% in 1950 to 49% in 2005 and is expected to reach 69% by 2050. In 2005, the total population of the Least, Less and More Developed Countries living in urban areas was 27%, 46% and 74%, respectively. The Least Developed Countries are now seeing the fastest annual growth rate in the proportion of the total population that is urban, at 4% between 2000 and 2005, compared to 2.7% for the Less Developed Countries, excluding the Least Developed Countries, 0.7% for the More Developed Countries and 2.2% worldwide (UN 2010).

2.3.7 Drivers of and barriers to demographic change

This section describes the most important drivers of change in mortality, fertility, migration and urbanisation rates, to enable a better understanding where policies may be able to positively influence demographic variables.

2.3.8 Drivers of and barriers to mortality change

It is sometimes assumed that economic growth is necessary for increased life expectancy, but in fact social development, especially education, together with public health and social support for the very poor play important roles. Cuba, Costa Rica and the Indian State of Kerala are examples of countries that have achieved high life expectancy despite low incomes. Different social development factors can play different roles in increasing life expectancy at different times and in different countries (Riley 2001).

The drivers of the initial declines in mortality rates in the More Developed Countries starting around 1750 were improvements in nutrition and public health services, including basic sanitation (see Box 2.3) and management of solid waste and provision of clean drinking water. In the developing countries the

decline in mortality was prompted by improvements in medicine and public health – the introduction of antibiotics such as penicillin, treatments for diseases such as tuberculosis and diarrhoea, and the use of DDT, which helps control malaria. These advancements have contained or eradicated diseases that once killed millions of people, and were accompanied by improved sanitation, better nutrition and the wider practice of healthier behaviours (Bloom *et al*. 2003), and better immunisation programmes.

The drivers of declines in maternal mortality have been sexual and reproductive health care and nutrition. Poor sexual and reproductive health care accounts for an estimated one third of the global burden of illness and early death among women of reproductive age (Bernstein and Hansen 2006). It was estimated that in 2008 that there were around 355,000 maternal deaths, with 50% of those deaths taking place in sub-Saharan Africa and 45% in Asia (WHO 2010). It is estimated that around 13% of annual maternal deaths are due to unsafe abortion, with around 97% of unsafe abortions occurring in developing countries (Hill *et al*. 2007). The most common cause of maternal mortality in all parts of the world is obstetric haemorrhage. For women aged 15-19, complications during pregnancy and birth count as the most frequent cause of death worldwide – it is twice as high compared to women between the ages of 20 and 24. Girls younger than 15 have an even higher mortality risk during pregnancy and birth. The dramatic declines in maternal mortality that were seen in the USA, UK and Sweden between 1900 and 2000 were due to improvements in obstetric care, changes in the abortion law and changes in patterns of childbearing (Diamond-Smith and Potts 2010).

Globally, the four major killers of children under 5 are pneumonia (18%), diarrhoeal diseases (15%), preterm birth complications (12%), and birth asphyxia (9%). Undernutrition is an underlying cause in more than a third of under-five deaths. Malaria is still a major killer in sub-Saharan Africa, causing about 16% of under-fives deaths (WHO 2008).

Every day, 6,000 people are infected with HIV, and in some countries HIV prevalence is still high. In Swaziland, for example, one in three adults now live with HIV (Glasier *et al*. 2007). In 2010 about 1.8 million people died from AIDS, of whom 1.2 million were in sub-Saharan Africa. However, in many African countries, rates of infection have declined and important improvements in the treatment of AIDS sufferers have been made, with an increase from 50,000 on treatment 8 years ago to 6.6 million in 2010.

Recent studies have shown that oral antiretroviral drugs (ARVs) can prevent heterosexual HIV transmission. Transmission rates were substantially reduced if the ARVs were taken by the HIV-negative partner and were virtually eliminated for at least two years if taken by the HIV-positive partner, although it is uncertain if this strategy can be brought to scale (Shelton 2011).

Box 2.3 Improvements in sanitation

Sanitation is the process of promoting good health by separating waste, such as urine and faeces, from human contact (WHO 2012). Poor sanitation, coupled with unclean water supply, dramatically increases the risk of water-borne disease and account for an estimated 4.0% of all deaths globally (Prüss 2002). More Developed Countries suffer virtually no mortality from disease due to poor sanitation, whereas in Less Developed Countries, 21 deaths per 100,000 people are caused by poor sanitation and water; in the Least Developed Countries this figure rises to 112 deaths per 100,000 (derived from WHO Data). In Uganda, where 98 deaths per 100,000 people are attributable to poor sanitation, nine in ten households use shared or basic latrines. These are a major source of solid waste runoff which contaminates waterways and facilitates disease outbreaks (see evidence received from Pro-biodiversity Conservationists in Uganda).

WHO projections (WHO 2008) indicate that improved sanitation will continue to lower mortality rates. A baseline scenario for global diarrhoeal disease is that 88% are attributable to poor sanitation (WHO 2004), 1.7 million deaths in 2008 will drop to 1.3 million in 2015 and 0.7 million by 2030. Yet it is expected that 2.7 billion will still lack adequate sanitation facilities in 2015. Continued efforts are essential if mortality is to fall as the global population grows.

As deaths from infectious diseases fall, Countries face an epidemic of chronic or "lifestyle" diseases. There is a general consensus that the most significant of the 'lifestyle' risks to emerge as a major threat to population health in the 20th century was cigarette smoking. Obesity is an independent risk factor for diabetes, cardiovascular disease and some cancers, and the increasing prevalence of obesity in the population may have a sufficiently large impact on mortality to halt present upward trends in life expectancy (see Box 2.4). The other lifestyle risks found in most of the populations of the world's most affluent countries are an unhealthy diet, lack of regular exercise and excessive alcohol consumption. (Howse and Harper 2009). However, in recent decades, the More Developed Countries have seen decreases in late life mortality which appear to be driven by advances in medical interventions. Pharmaceuticals are increasingly becoming one of the most important inputs for the production of health in More Developed Countries, and possibly for extending life expectancy.

2.3.9 Drivers of and barriers to fertility change

The causes of the huge fertility declines of the past 130 years are well established. Increased use of contraception is the major cause with important contributions from marriage postponement and abortion. Access to contraception and safe abortion are influenced by government policies and programmes. The broader drivers of fertility rate change include the empowerment of women (see Box 2.5), economic development, mortality decline, improved education, and the spread of new ideas and technologies. These are discussed below.

No country has experienced deep and sustained declines in fertility without prior or parallel mortality decline (Ni Bhrolcháin and Dyson 2007). The common argument is that parents reduce their family sizes as they realise that child mortality has fallen. However, there is little evidence that parents consciously adjust their reproduction to improving survival probabilities. It is more probable that falls in mortality steadily increase the number of dependent children in households, imposing an economic pressure that can only be relieved by a reduction in births. The

Box 2.4 Obesity and life expectancy

In all groups improved nutrition has played a large role in reducing mortality and extending life expectancy. However, just as improved nutrition has driven declines in mortality, in some countries anyway, it seems likely that it may also inhibit them. A combination of a more sedentary lifestyle and an increased calorie intake is leading to an increase in the average Body Mass Index, and a higher proportion of people being either overweight or obese. There is no sign of the trend flattening out. In England for example,1 in 5 adults are now obese. The proportion has trebled over the last 20 years, and two-thirds of adults over 45 years are overweight or obese (NAO 2001). Since obesity is an independent risk factor not only for diabetes, but also for cardiovascular disease and some cancers, the increasing prevalence of obesity in the population may have a sufficiently large impact on mortality to halt present upward trends in life expectancy (Olshansky *et al*. 2005). One recent estimate of the annual mortality associated with excess weight in the EU puts the figure as high as 1 in 13 (Banegas *et al*. 2003).

Although there is now accumulating evidence that obesity increases mortality risk, and the mechanisms by which this might happen are becoming better understood, estimates of the increased mortality risk associated with obesity are by no means uniform (Howse & Harper 2009).

In one study obesity reduced the life expectancy of forty year old non-smokers by 5.8 years for males and 7.1 years for females (Peeters *et al*. 2003). In other studies no excess mortality was associated with being overweight rather than being obese (eg Flegal 2007; Reuser 2008). The mortality risks of obesity diminish considerably in old age (eg Bender 1999). In the USA the association between obesity and mortality has declined over time (Mehta & Chang 2011). However, studies that control for smoking and 'reverse causality' – the fact that serious illness often causes weight loss - come up with much larger estimates (Adams *et al*. 2006; Lawlor *et al*. 2006; Greenberg 2007).

drivers of mortality decline were discussed in the previous section (2.3.8).

In the More Developed Countries, the initial phase of fertility decline, starting in the late 19th century, occurred without the benefit of highly effective modern methods of contraception. However, the advent of these methods and changes in social and economic factors, including the increased social and financial costs of children, rising ages at marriage and increases in non-marriage, divorce, increased acceptance of diverse sexual lifestyles, and a growing independence and labour force participation of women have played a part in the second phase of decline, starting in the 1960s. In many of the Less and Least Developed Countries, fertility decline started in the 20th century. Alongside the factors identified above, improvements in levels of primary and secondary school education alongside widespread health improvements also played an important role in reducing both fertility and mortality (especially infant mortality).

A number of countries that had high fertility in 1950 saw a much more rapid decline in the TFR than Europe, once they had access to modern family planning. For example, Bangladesh went from a TFR of 6.3 to 3.4 between 1975 and 1998 (BDHS 2007), Iran from 5.5 to 2.8 between 1989 and 1995 (Abbasi-Shavazi 2009), while the US went from a TRF of 6 to 3.5 between 1842 and 1900 (Sai 1993). Other factors could also influence this change in fertility. It has been argued that family planning programmes work best when desired fertility has declined because of socioeconomic development, and that they are more effective when integrated into other government policies in areas such as health, education and rural development (Rayner and Malone 1998).

There are some important exceptions where birth rates remain high, and high levels of unintended childbearing remain, such as in Mali, Burkina Faso, Yemen, Afghanistan and Pakistan, due to the severe barriers that are in place. Some of these barriers are obvious in nature (information, access and affordability) and some less obvious (unnecessary medical restrictions, concerns about social acceptability and effect on health) (Campbell *et al*. 2006; Casterline *et al*. 2001; Ruttenberg and Watkins 1997).

Family planning programmes are discussed in more detail in Chapter 5. The underlying drivers of changes in fertility rates are discussed below.

2.3.9.1 *Economic development*

There are many ways in which economic development, industrialisation and urbanisation may influence fertility (Notestein 1945). There are moderately strong associations between indicators of economic development such as GDP per head, and fertility. Economic development can lead to improvements in sanitation, nutrition and healthcare, which drive mortality decline, which precedes fertility decline. Economic development leads to an increase in the opportunity cost of time expended in childcare, and increased expenditure on children's education, health care, and so on, which is thought to reduce fertility rates. However, it is important to note that economic development is not a precondition for fertility decline; fertility rates have declined in countries with low measures of economic development, eg in Hungary and Bulgaria in the 1920s, Vietnam in the 1960s and Indonesia in the 1970s.

Education is widely seen to be another key driver of falling fertility. It is suggested that universal secondary school education, especially for women, not only enhances their opportunities for employment in the formal labour market, which it is argued will reduce the number of children they have, but also introduces them to alternative lives which include having fewer children. In addition, education facilitates better access to and information about family planning, helping to remove the barriers to information and technology available for managing family size. It also leads to a change in attitude in which 'quantity' of children is replaced by 'quality' (Becker 1991; Lutz *et al*.1999), ie couples want to have fewer children with better life chances (Lutz *et al*. 1999). Alongside this, more educated people have lower mortality (there is evidence that this is a real effect and not just owing to selectivity).

As Lutz *et al*. (1999) point out, these educational differentials can be very significant, particularly at the beginning of the fertility transition. Ethiopian women, for example, without any formal education have on average six children, whereas those with secondary education have only two. However as the transition proceeds, as in the case of Europe, the relationship becomes more complex. For example there is some

evidence that the strongly negative association of education and fertility is replaced by a U-shaped pattern in which the most educated women have a somewhat higher fertility than those with intermediate education. Others have disputed the direction of causality between female education and fertility reduction (Cochrane 1979; 1983). Women's education may well reduce fertility; however, the initiation of child-bearing may itself be a factor in the termination of education.

2.3.9.2 *Communication and technology*

In Europe and more recently in developing countries, it has been observed that changes in fertility were strongly conditioned by linguistic, religious and ethnic factors, suggesting that new ideas and behaviour were diffusing within populations with a shared culture and language. Moreover, the speed with which contraception use can increase and fertility fall within homogeneous populations also supports the view that reproductive change is fuelled by social influences and social learning. It is not known what was being diffused in historical Europe but it is clear from studies in developing countries that the advent of modern methods of contraception often evokes initial ambivalence and fear among women and is intensively discussed, along with related conversations about family size (Watkins 2000; Entwisle *et al*. 1996).

2.3.9.3 *Cultural drivers*

Views on why high levels of fertility persist throughout much of sub-Saharan Africa vary. Some see it as a reflection of low socioeconomic development, while others think it is a distinctive feature of cultural and social organisation that set the region apart from Asia and Latin America. It has been shown that Africans attach a higher value to large families than citizens elsewhere. One explanation for this pronatalism lies in the subordination of the nuclear family to the lineage (Caldwell and Caldwell 1987). However, the rapid increase in contraceptive prevalence once contraception was made realistically available in countries such as Zimbabwe and Rwanda suggests that access to family planning choices is pivotal, just as it was in Asia. The exception may be some countries in the Sahel[7] characterised by a low age of marriage and high prevalence of polygamy.

7 The Sahel is a belt that crosses Africa just south of the Sahara. The region is among the poorest and most underdeveloped in the world. It is characterized by low levels of seasonal rainfall. In recent years, rainfall has decreased and become more erratic (European Commission).

Box 2.5 Reproductive inequality and women's empowerment

Women bear the main physical burden of reproduction: pregnancy, breastfeeding and childcare. They also bear the main responsibility for contraception as most methods are designed for their use. Men, it may be argued, reap the benefits of children without incurring an equal share of the cost. It follows that women may be more favourable to the idea of small families and family planning than their partners but unable to express their inclinations in male-dominated systems. Such views received international endorsement in the Program of Action resulting from the UN conference on population in 1994. Paragraph 4.1 states that "improving the status of women is essential for the long-term success of population programs".

The labels "status", "empowerment" and "autonomy" are often used interchangeably and their conceptualisation and measurement are not straightforward (Federici *et al*. 1993; Presser and Sen 2000). At the national level, gender differences in schooling, wage employment and political representation are commonly used measures; alternatives include age difference between spouses, preferences for the sex of children and the prevalence of polygamy. The UN Development Program has developed a gender inequality index with which it ranks countries (UNDP 2010). At the individual level, freedom to travel unaccompanied outside the neighbourhood of residence, decision-making power, and control over household resources are taken to be dimensions of empowerment (Jejeebhoy 1995).

Despite extensive research, evidence on the central proposition – that women's empowerment is a critically important determinant of reproductive modernisation – is mixed, perhaps because empowerment on one dimension does not imply empowerment on others. For instance, Japanese women have traditionally played a minor role in public life but often control domestic budgets (Pilling 2007; Diggs 1998). Family size has fallen in Iran and women have become the majority in universities yet they continue to have low employment levels and face many restrictions on their behaviour, imposed by men.

Women often cite husband's opposition as a reason for non-use of contraception and the relatively high level of clandestine contraceptive use by women is also indicative of men's opposition (Biddlecom and Fapohunda 1998). Yet numerous surveys of men suggest that their reproductive aspirations and attitudes to contraception differ little from those of women, except in the high-fertility countries in sub-Saharan Africa where they appear to want larger families than women (Mason and Taj 1987; Becker 1996; Westoff and Bankole 2002). When spouses disagree about future childbearing, the husband's views do not inevitably prevail (Blanc 2001).

What of the reverse effect of lower fertility and widespread contraceptive use on empowerment? Transition from a fertility rate of, say, six births per women to two represents a profound revolution in the lives of women and the ability to manage family size is central to the autonomy of women. Under the high fertility scenario it has been estimated that women spend 70% of their lives bearing and rearing children whereas under a low fertility regime, the figure drops to 14% (Lee 2003). When fertility is low, marriage and the family need no longer dominate women's lives; increased participation in paid work more usually follows than precedes the decline in childbearing (Mammen and Paxson 2000).

2.3.10 Drivers of and barriers to migration

Migration patterns are shaped by a complex interplay of economic, demographic, political, social, technological and environmental factors (Massey *et al*. 1993; Brettel and Hollifield 2000) Conflict can be a trigger to move, but poverty, insecurity, lack of the rule of law, environmental degradation, the proportion of young people in source countries, as well as income differences between countries can be the underlying structural factors. Government policies in receiving countries are a further factor (Malmberg *et al*. 2006; OECD 2009). Individuals may feel compelled to move but in many cases do so for positive reasons – as students, to work, rejoin family, or retire to sunnier climates.

Demand for labour can be a structural feature of advanced industrial economies. For migrants, one of the primary reasons for migration is the quest for better economic conditions, with destination countries often benefiting from workers with complementary skills or workers that are willing to accept conditions unattractive to the resident labour force. Ageing populations can contribute to that demand and migrants can partially substitute for the declining numbers of young workers as well as caregivers for the elderly (OECD 2009).

Population growth can have two related effects on migration: it raises the young adult share of the population (ie the number of potential migrants) and it can create an oversupply in the labour market worsening the employment outlook in the sending country (Hatton and Williamson 2002). Migration from developing countries to developed countries relates strongly with rapid population growth and fast-growing labour forces in sending countries, in contrast with stagnating or shrinking labour forces in receiving countries (Martin 2009). Migration has the potential to impact upon population growth and structure through the interaction between the number of migrants, their relatively young age structure and their higher fertility (Harper 2011).

There has been a growing awareness that environmental changes, including climate change, may result in migration. Several authors have predicted that as environmental changes increase, migratory pressures will also increase (IPCC 2007b). Recent papers have emphasised that the environmental refugee scenario may be overstated and that environmentally related migration is complex and related not only to the temporality and kind of environmental change, but to other economic, political and social drivers. (Adepoju 2010; Warner 2010; Bardsley and Hugo 2010; Tocali 2009; Barnett and Weber 2010; Skeldon 2009). It is however likely that environmental change will affect migration now and in the future, specifically through its influence on the range of economic, social and political drivers which themselves affect migration. In the decades ahead, it is anticipated that millions of people will be unable to move away from locations in which they are extremely vulnerable to environmental change, because of lack of capital; and that people are as likely to migrate to places of environmental vulnerability as from them. It is those with lower levels of capital that are most likely to live in areas vulnerable to environmental change, creating a 'trapped population' (Foresight 2011a).

The mobility of people has in other respects been facilitated during recent decades by political reforms, cheaper transport and a transformation in communications that has broadened access to information, ideas and networks. Networks of kin and regions of origin can incentivise migration and choice of destination. Networks reduce the cost and risk of moving by helping migrants secure access to jobs and accommodation, providing information, contacts and support. New migrants in turn reduce the costs for later arrivals. Thus migration can become progressively more independent of the original drivers in sending and destination countries (Gurak and Caces 1992; Haug 2008).

2.3.11 Drivers and barriers of urbanisation

Virtually all nations that have seen high levels of urbanisation over the last 50 – 60 years have had long periods of rapid economic growth, alongside large shifts in employment patterns from agricultural or pastoral activities to industrial, service and information activities. Nations with high proportions of urban populations and the largest cities are those that have the largest economies. In the 19th and 20th centuries industrialisation, urbanisation and modern economic growth occurred at the same time, whilst in recent decades urbanisation has occurred in settings in which sustained economic growth and industrialization are largely absent (Dyson 2011).

Local factors such as the site, location and natural resource endowment, as well as the demographic profile of the population, can all have an influence on urban change. The scale and nature of urbanisation and the underlying causes differ between countries, within a country and over time. There are difficulties in calculating global urban statistics, due to the lack of data available for some nations. There are also variations between countries in how urban areas are defined (Satterthwaite *et al*. 2007).

2.4 Population challenges and opportunities

The previous sections have described the processes of demographic change, the demographic trends that are observed at the global and regional level, and the drivers of changes in these trends. It has detailed how the global population size, distribution, density and age structure are also changing. These changes are happening at different rates and on different scales in the Least, Less and More Developed Countries, presenting a variety of challenges and opportunities.

2.4.1 Population and economic development

The relationship between population growth and economic development has long been debated. Malthus in the 18th century was interested in the economic effects of rapid population growth and the relationship with the capacity of the earth to sustain it. These concerns resurfaced in the middle of the 20th century when it became clear that an era of unprecedented, rapid increase in the populations of the developing countries had started. Since Malthus, other authors have highlighted the potentially negative impact of continued population growth (eg Coale and Hoover 1958; Ehrlich 1968, 2008; Turner 2009) while others have argued that technological advance and institutional development could counter negative effects of rapid population growth on development (Kuznets 1967; Boserup 1981; Simon 1981). It is clear from this debate that economic development and the demographic transition are linked in complicated and reciprocal ways, and that different challenges and opportunities are presented at different stages of the transition.

In terms of the effect of population factors on economic growth the common view is that rapidly increasing populations have a negative effect on economic growth and employment, due to declines in natural resources and other forms of capital per head. The nature of the relationship between population growth and economic growth will depend on the rate of population growth; a slow population growth rate, of say 1% per annum might have an advantage over a negative growth rate, whilst higher growth rates, of say 2% or more, are unlikely to have a positive impact on economic growth. The rate of capital accumulation is also important; without major accumulation of capital per capita, no major economy has or is likely to make the low-to middle-income transition. Though not sufficient, capital accumulation for growth is absolutely essential to economic growth (Turner 2009).

More recently, the debate has refocused on the economic consequences of changes in age composition within a population (eg Mason and Lee 2006; Bloom *et al*. 2003). As discussed earlier in this Chapter, when a population goes through the demographic transition, inevitably the ratio of the elderly (65 and over) to young (under 15) increases and alters the dependency and support ratios of the population. The combination of these within a population influences the productivity and economic growth of that population as the young and the old tend to consume more than they produce, while those of working age (defined as those between the ages of 15-64 years) produce more than they consume, and therefore can save or transfer their production to earlier or later generations.

Declining fertility and the continued growth of the working age population due to the legacy of past high fertility (see Box 3.2 on South Korea) leads to a decline in the youth dependency ratio, creating the potential for a demographic dividend. The dividend is due to a substantial increase in the potential labour force, greater per capita output, and enhanced savings potential leading to economic growth (Lee and Mason 2010). This dividend may enable the population to increase its aggregate per capita income level before the fraction of elderly in the population rises, and to accumulate assets which can be drawn upon to help finance the consumption needs of an elderly population. However, the realisation of the demographic dividend (or bonus) is by no means guaranteed and is conditional on effective institutions for saving and investment, macro-economic policies and the alignment of

other factors such as terms of trade, the rule of law, secure property rights, education, and institutions that encourage public and private sector investment (Barro 1997). This stage is also only temporary and is inevitably followed by a decline in the ratio of workers to dependents as the population ages. About 30% of the rapid economic growth of the 'East Asian tiger'[8] economies is attributable to demographic changes (Bloom *et al*. 2000).

The economic consequences of population ageing remain uncertain. As fertility continues to decline and life expectancy increases, the old-age dependency ratio of the population increases, creating a demographic deficit. Research suggests that an increase in the dependent population has a negative effect on per capita income growth. This is based on two broad assumptions; that demographic decline leads to decline in economic activity because of a decline in demand for goods and services with consequent impacts on economic growth and employment, and demographic ageing leads to economic burden due to an increased requirement for pensions and healthcare and a reduced capacity to fund them (Bloom and Canning 2006; Bloom and Sousa-Poza 2010; Harper 2010a; 2011; Lee and Mason 2006). The impact of ageing on incomes can be mitigated by increasing labour force participation of those of working age, by raising retirement ages and by reform of pension systems. Moreover, it seems probable that low fertility societies are well positioned to invest heavily in human capital, thereby increasing productivity (Lee and Mason 2010).

There is a body of evidence that emigration can contribute to economic and social development, while development can, in the short term, increase the rate at which people leave. Emigration can hinder development through loss of skilled people ('brain drain') but can generate benefits through acquisition of skills, trade and investment connections, through liberation of women from traditional roles and through the injection of ideas and enhanced skills when migrants return. Remittances are a significant source of income for migrants' families which in turn contribute to the growth of local economies. In 2004, remittances to developing countries exceeded $125 billion per year while annual Official Development Assistance rarely exceeds $60 billion. The impact on rural households is particularly significant (evidence from Martin). Remittances by migrants tend to reduce global economic inequality. In some countries remittances from migrants make up a substantial proportion of the national economy, for example in 2009, 35% of Tajikistan's GDP was from remittances (Mohapatra *et al.* 2010).

In destination countries migration can similarly bring economic and social benefits, and costs. Migrants who work, study or join families contribute to meeting skill and labour shortages, bring investment, cultural capital and benefits to trade and international relations. In developed and developing countries they nevertheless may contribute to demands on accommodation and services, exacerbate rapid urbanisation, displace workers, reduce wages and be the focus of tensions where resources are scarce or cultural differences are unresolved (UNDP 2009). Migration can also be a factor in the growth and changing age structure and composition of populations (Coleman 2008).

8 The term 'Asian Tiger' is used to describe the developed economies of certain south-eastern Asian countries. The list varies between sources but commonly includes Hong Kong, Singapore, South Korea and Taiwan.

Migration can impact upon demography in numerous ways, and recent advances have been made in the understanding of the relationship between migration and the demographic deficit (Harper 2011). There is general agreement that migration will not prevent ageing and the so called demographic deficit but may slightly alleviate it (Coleman 2002; Espenshade 2001; Feld 2000; Lesthaeghe 2000). The impacts of migration on innovation, employment in general, and welfare are more complex and contested. Immigration will in the short term increase TFRs, population growth and labour market participation.

As covered in section 2.3.11, economic change is the primary driver of urbanisation (Satterthwaite *et al*. 2007). Rapid urbanisation throughout the developing world is seriously outstripping the capacity of most cities to provide services for their citizens (Cohen 2005). The challenge is keeping up with the rate of urbanisation, as people migrate to urban areas to seek out opportunities, and to ensure adequate living conditions for the urban poor.

The relationship between demography and economic growth should not be overstated; demography is not the sole determinant of economic success. Many other factors – quality of government, institutional structures, inherited culture, geographical location and resource endowment – are also important.

2.4.2 Demographic challenges and opportunities in the high fertility countries

The Least Developed Countries have the highest population growth rates in the world and are the least able to meet the needs of growing numbers of people (UN 2011). Countries in the very early stages of the transition typically have relatively high but declining mortality at all life stages, increasing life expectancy, high but declining fertility and rapid population growth. Family sizes may be large, there is likely to be a high youth dependency ratio, and gender and economic inequality may be high. Early marriage, polygamy and low status of women may also be present.

Keeping up with the pace of population growth is a challenge in these countries, most of which lack the resources to meet demand for infrastructure, basic health and education services, and job opportunities. In the poorest countries economic and reproductive inequality can be self reinforcing - unwanted childbearing is invariably more common among the poor than the rich as the poor have less information about contraception, greater misgivings about its use, and restricted access to service.

In theory, a rapidly growing population with a young age structure could contribute to a demographic dividend that stimulates economic and social development as occurred in parts of Asia (UNFPA 2011). In a country such as Rwanda this might happen, but in the Least Developed Countries in Africa, such as in the Sahel, and parts of western Asia such as Afghanistan, lack of education, a weak infrastructure and poor governance make this unlikely. According to the UN there is greater potential for the demographic dividend in the Asian Least Developed countries than in the African Least Developed Countries as their fertility rates are declining at a faster rate (UNFPA 2011).

Box 2.6 The Republic of Niger

The Republic of Niger provides an extreme example of a country at the early stages of the demographic transition and one that faces severe constraints on development. It has one of the highest rates of population growth in the world at 3.5% per year, implying a doubling of the population every 20 years, and over a quarter of women older than 40 have given birth to 10 or more children.

Life expectancy has improved significantly in Niger over the last thirty years, increasing from 39.5 in 1980 to 54.7 in 2011 (UN HDI 2011), but the average woman has over a one in twenty chance of dying in childbirth during her lifetime[9]. Recent government initiatives have led to Niger being one of the five countries with the greatest absolute reductions in overall under-five mortality rates, however child mortality rates remain high compared to some other countries, with infant mortality rates of 73 and under-5 mortality rates of 143 per 1000 live births (UNICEF 2011).

Niger has experienced little change to its TFR of about 7 over the last 50 years. Even assuming the TFR falls to 3.9 by 2050[10] (as assumed in the UN medium fertility variant) the population will grow from 15.5 to 55.5 million by 2050. Given recent trends in TFR and an estimated contraceptive prevalence rate of 15% (May 2011) this is considered by many to be an optimistic projection.

Niger's high fertility can be explained partly by its endemic poverty, poor access to education and health care services and little emphasis on making family planning available (IMF 2007). The TFR varies widely with the level of education of the woman (ranging from 4.6 children per woman with secondary school education to 7.3 for those without education) and income (6.2 children versus 8.0 children in rich versus poor households, respectively) (IMF 2007). However, Niger's polygamous culture is the primary reason for the continued high fertility levels experienced, together with large desired family size (in 2006 married women and men reported wanting an average of 8.8 and 12.6 children respectively (INS 2007)). This preference for large family sizes is reflected by a relatively low level (16%) of unmet need for family planning: (World Bank 2011a). These cultural dynamics mean that gender inequality is high (UNHDI 2011). Child marriage is common - 60% of girls aged 15-19 are married and 28% entered marriage before the age of 15 (Afolayan *et al*. 2008).

The combination of rapid population growth and a decline in mortality in the youngest age groups means that Niger currently ranks as the world's youngest population. This has implications for the economic development potential of the country; it undermines the potential to build up the savings needed to expand the country's infrastructure and to help lift the country out of poverty.

Household size is also a key poverty factor. Over 89% of the population live in rural areas and the economy is largely dependent on agriculture and so is vulnerable to climatic factors. During each year's "lean season", which extends roughly from June to October, Niger faces recurrent food and nutritional crises. In April 2010, approximately half of the country's population found itself facing moderate or severe food insecurity (Médecins Sans Frontières 2011).

A future in which population increase outstrips the production of food and other necessities of life is a real possibility for Niger. The big question is how such a disaster can be averted. Increased food production is certainly possible through expanded irrigation and improved agricultural techniques, though it is uncertain whether it can increase sufficiently to meet the needs of a population that may double in the next 20 years. Food self-sufficiency is not necessary for development, provided that exports of minerals and manufactured goods can offset the costs of food imports. International migration is likely to be a crucial safety valve. Nevertheless, it is difficult to see a bright future for the country without sharp reductions in fertility and population growth, together with increased investment in health and education to improve human capital and thereby enhance prospects for industrialization in the medium term. Because of the strongly pronatalist culture, reducing fertility voluntarily will require a massive communication effort as well as expanded access to contraception, and research on practical ways to raise the age of first birth.

Box 2.7 Urbanisation and growing urban poverty in Africa – the city of Nairobi

Despite being the least urbanised of the world's major regions, Africa's urban populations are growing at much higher rates than the other regions. Africa's high rates of urbanisation have not been accompanied by the broad socioeconomic transformations and economic growth that other regions experienced. Although urban areas have been the main drivers of the limited economic growth that Africa has experienced in the recent past (Kessides 2005), the inability of African economies to create enough economic opportunities for their rapidly growing populations has brought unique challenges in urban settings. A key outcome of rapidly growing urban populations amidst slow economic growth and poor urban planning has been the growth of informal settlements, commonly referred to as slums, in sub-Saharan Africa major cities. Estimates by UN Habitat indicate that about 62% of urban residents in sub-Saharan Africa live in slum settlements, and that the number of slum dwellers almost doubled from 103 million to 200 million between 1990 and 2010. Slum settlements are characterized by poor housing conditions, poor social services, poor basic amenities, poor health outcomes, insecurity, and unstable incomes and livelihoods.

Nairobi, Kenya's economic hub, typifies the challenge of growing urban poverty that many countries in sub-Saharan Africa are facing. The city's population grew from 120,000 in 1948 to 3,140,000 in 2009. The city grew at an annual average rate of 5% between 1989 and 1999, and 4% during the period 1999 – 2009, despite the fall in employment opportunities associated with Kenya's economic downturn during this period. Between 40% and 60% of Nairobi residents live in slum settlements.

Research carried out in the slums of Nairobi has documented the significant health and economic disadvantages that slum residents face, relative to other population sub-groups in Kenya. Although many of the slum residents are migrants from rural areas (only 15% were born in the slum settlements), who come to Nairobi in order to get better livelihood opportunities, only 3.6% of women and 22.3% of men get salaried employment and most of them end up in unstable and low-paying jobs. Slum residents exhibit poorer health outcomes compared to

Health/Population Indicator	Slum Settlements (2008)	Urban Areas in Kenya (2008)	National (Kenya 2008)
Infant Mortality Rate (per 1000)	65.5	59.2	62.8
Under Five Mortality Rate (per 1000)	86.2	74.5	83.7
TFR (children per woman)	3.3	2.9	4.6
Proportion of under five children with diarrhea	31.9%	19.4	17.1
Proportion of children with fever	64.2%	43.3%	42.3%
Proportion of children with fever who received treatment	42.9%	72.6%	59.1%
Proportion aged 18+ in Salaried Employment	Women: 3.6% Men: 22.3%		
% Below the Poverty Line	34.7%		

Source: African Population and Health Research Center (2002); Zulu *et al*. (2011); Emina *et al*. (2011)

9 Maternal mortality ratio is 820 per 100 000 live births, (UN HDI 2011).
10 Under the UN medium fertility variant which assumes continuous decline in TFR to 2050 (to 3.9).

other population sub-groups in Kenya due to a combination of three main characteristics of slum settlements. Firstly, slum dwellers live in congested locations, they reside in one-room houses, and lack access to safe drinking water, sanitation, and garbage disposal services. These poor environmental conditions increase their vulnerability to infectious diseases, including HIV/AIDS (Ziraba *et al*. 2009). Secondly, slum residents have limited access to quality health services since health care is mostly provided by informal and unregulated health providers. Finally, slum dwellers do not access the quality services that are found in non-slum parts of the city because they lack money to pay for such services (Zulu *et al*. 2011). These urban disadvantages also extend to other social services like education. Children in slum settlements have relatively high dropout rates and uniquely low progression rates from primary to secondary school (Ngware *et al*. 2011), thereby leading to poor human capital among slum residents.

The rapid urban transition that Africa is undergoing presents an opportunity as well as a development challenge. As in developed regions and other emerging economies, urbanisation can be associated with, and help propel, economic prosperity. But rapid urbanisation can present enormous challenges unless the economies transform fast enough to generate enough jobs for the growing labour force. Additionally, good governance and planning are required to develop the urban infrastructure and social services that meet the needs of the growing population, including decent housing and amenities for low income people.

In 2011, the third most populous city in Kenya, after Nairobi and Mombasa, became a refugee camp called Dadaab with 465,000 refugees as of July 2011 from drought and from conflict in Somalia. It possible that many will never return to their homes. It is highly likely that such migration will be repeated many times in the future as rapid population growth and climate warming meet across the Sahel. To the problems of slum life outlined above are added violence and rape as women and children walk many miles in search of food and water.

2.4.3 Demographic challenges and opportunities of medium fertility countries

The fertility of many of the Less Developed Countries has declined rapidly since the 1950s while mortality declined even more rapidly. A small number of the Least Developed Countries - Bangladesh, Cambodia, Myanmar, for example - also experienced rapid declines. Despite the decline in fertility many of these countries are experiencing rapid population growth due to population momentum and this is likely to continue for the next 50 years. For example although fertility in Asia and Latin America is now about 2.3 births per woman and is expected to fall further, population size is projected to increase between 2010 and 2050 by about 30%.

As a consequence of the rapidity of the fertility decline, many of these countries experienced a shift in the age structure, which may enable them to realise a demographic dividend. Countries in East Asia and South East Asia have already benefited while countries in South and Latin America (Loewe 2007) were less successful. In some of these countries the window of opportunity is just about to open (eg Cambodia), while in others the window is about to close (eg Republic of Korea and China). The main challenge in this group of countries is to provide productive employment for a rapidly growing labour force. This in turn requires matching the educational and training system to the employment skills required. When the economy is unable to generate sufficient employment or when the educational system is ill tuned to economic opportunities, civil unrest may result (see Box 2.9 on youth bulge).

Box 2.8 Latin America: one of the most unequal regions in the world – now seeing a convergence of trends.

The Latin America and Caribbean region is the most unequal economically, and the differences in trends and levels of almost all demographic indicators reflect enormous inequalities and high rates of poverty. Yet Latin America has an average income per capita above Africa, Asia, China and India. There has been a lot of progress in several areas, and most of this progress has directly or indirectly been brought about by demographic transformations (Cavenaghi and Alves 2011). Since 2003 the region has seen an accelerated increase in per capita income, and the percentage of people living below the poverty line dropped to its lowest level at 32.1% in 2010 (Leeson 2011).

By the mid 20th century, Latin America and the Caribbean were experiencing a population boom as mortality declined while fertility remained relatively high leading to population growth rates of almost 2.8% per annum in the early 1960s – the highest rates of growth in any region of the world. In 1950, the population of the region matched that of North America (Canada and the United States), but 60 years on the North was demographically overshadowed by its southern neighbours by more than 200 million people. By 2010, despite continued declines of fertility to around 2 children per female, the population of the region had increased by a third to 589 million, now comprising 8.5% of global population. At the same time, the region was becoming more urbanised, with 8% of the population living in urban settings in 2010.

The UN 2010 medium variant projects that the population of Latin America and the Caribbean will continue to grow, reaching 729 million by 2050, outranking its northern neighbours by almost 300 million by that time. Underlying this continued regional growth, however, is population decline, albeit modest, in a few of the smaller countries of the region (Barbados, Cuba, Grenada, Guyana, Jamaica, Puerto Rico and Trinidad and Tobago) continued modest increases in some other countries and population stabilisation elsewhere.

Despite the continued inequalities in the region, there is evidence of a convergence of demographic trends. Fertility across the region plummeted from 1950 to 2010 as individuals abandoned religious teachings on sex and fertility. In 1950, levels had varied from 2.73 in Uruguay to 7.6 in the Dominican Republic. By 2010 this variance was from 1.54 in Cuba to 3.71 in Guatemala. In the most populous countries of the region, the declines have been from 6.1 to 1.7 in Brazil and from 6.7 to 2.0 in Mexico.

Education, socioeconomic status and urban versus rural residence are all important determinants of access to family planning information and methods. Fertility tends to decline with increasing levels of urbanisation; to decline with increasing educational attainment of both males and females; and to decline with increasing socioeconomic status.

Similarly, most countries of the region began to experience significant mortality declines after 1950, which led to marked increases in life expectancies at birth for both males and females. Across the region, however, there has been and still is noticeable variation between countries. In 1950 life expectancy at birth for males ranged from less than 40 years in Bolivia and Haiti to more than 60 years in Uruguay, Puerto Rico, Paraguay and Argentina. By 2010, this range was from 60 years in Haiti to almost 80 in Costa Rica.

Box 2.9 Youth bulge

The term youth bulge refers to a population with a high proportion of people aged 15-24 or 29 years. A wide range of definitions have been used, including the percent of young people in the total population, in the total adult population and in the working age population (15-64 years). Youth bulges persist until a couple of decades after the onset of fertility decline which acts initially to stabilise and then reduce cohort size. In Least Developed Countries, the percentage of the working age population who are aged 15-24, remained constant at 36-37% between 1980 and 2010 but is projected to decline to 31% by 2030. In Less Developed Countries (excluding the Least Developed Countries), this indicator of the youth bulge has been declining since 1980 and is projected to fall to 22% by 2030 (UN 2010 medium projections).

In view of the fact that young adults, particularly men, are responsible for most crime and violence, it is perhaps unsurprising that some analysts of conflict have found a statistical link between youth bulges and the incidence of intra- or inter-state violent conflict, both in the more distant past and in the latter half of the 20th century, even after allowance for such obvious confounding factors as income level, ethnic heterogeneity, and type of political regime (Moller 1968; Fuller and Pitts 1990; Collier *et al*. 2007, Potts and Hayden, 2008). However, an unusually comprehensive study of events of major political instability, including ethnic and revolutionary wars, between 1995 and 2003, found no effect of youth bulges whereas political and economic factors emerged as strong predictors (Goldstone *et al*. 2005). Similarly, Urdal and Hoelscher (2009), in an analysis of violent and non-violent disorder in 55 major Asian and African cities, found no evidence that age structure was an important influence.

Whether youth bulges are a contributory cause of violent disorder remains uncertain but swollen cohorts of young people entering the working age population pose a huge challenge for sufficient job creation. Where policy and institutional contexts are unfavourable and the educational system poorly attuned to the job market, the consequence is high unemployment among young people and blighted aspirations. Conversely, when conditions are favourable and the job market buoyant, youth bulges are part of the "demographic dividend" and a force for rapid economic growth, as in East Asia.

2.4.4 Demographic challenges and opportunities of low fertility countries

All of the More Developed Countries are now in the late stages of the demographic transition, or have entered the 'second demographic transition', with TFRs below replacement rates. In 2010 the UN estimated the population of the More Developed Countries to be 1.24 billion and this is projected to reach 1.31 billion by 2050 under the UN medium fertility variant (1.48 billion under the high variant and 1.15 billion under the low variant) (UNPD 2011). Life expectancy in the More Developed Countries now stands at 77 years (both sexes) (UN 2010). This reflects a long history of declining mortality at all life stages.

In most of these countries (but not all) the demographic situation is defined principally by three dominant trends: a fertility rate that has been below replacement level for several decades now and shows no sign of rising above it; unprecedented and continuing declines in late-life mortality; and, in some cases, relatively high levels of inward migration (although not, for instance, in others such as Japan and some central and Eastern European countries). As a consequence these countries have experienced a decline in the proportion of younger people (through falling fertility), an increase in the proportion and number of older people (through both falling fertility and mortality), and a more ethnically diverse composition (through increased migration) (Harper 2010a). According to Howse (2010) there are four particular challenges posed by these trends:

- those that arise from the changing age structure of the population – specifically the increase in the proportion of older people and the decrease in the proportion of younger people (ie changing dependency ratios);

- those that arise from the ageing of the older population (ie more people surviving in 'late old age');
- those that arise from inward migration and the growth of migrant communities within the host society;
- those associated with persistent below-replacement fertility (ie population decline as opposed to population growth).

There is a widespread assumption that the structural ageing of the population leads to what has been called a demographic deficit. For example it is projected that for Europe, age-related public spending such as pensions, health and services for older adults will rise by 3 to 4 GDP points between 2004 and 2050, representing an increase of 10% in public spending (EPC and EC 2006). This will be particularly pronounced between 2020 and 2040. However, public spending may be protected by the general move within the EU to transfer responsibilities from governments and companies to individuals. There is also a reduced potential for the capacity of ageing populations to finance pensions and long term health and social care. In the EU for example, average annual GDP growth between 2004 and 2010 was 2.4%, and is projected to fall to 1.2% for 2030-2050 due to the reduction in the working age population (EPC and EC 2006).

The types of opportunities presented to a population in the fourth stage of the demographic transition have been less well considered. For example, a declining population can reduce pressure on natural resources. Population decline does not necessarily translate into a comparable decline in the size of the labour force because of the potential for increased labour force participation among women (eg in countries where it is currently low relative to men such as Japan and Italy), increased retirement age, and increases in net immigration which tends to select people of working age. It is also possible that ageing could lead to an increase in total spending rather than necessarily economic dependency, although this is dependent partly on the health status of the elderly. Furthermore even if the labour force shrinks, this does not necessarily lead to labour shortages. There may also be economic potential created by an ageing society – when considering the potential consumer possibilities of older people, such as health care, security, housing and home services, leisure and wellness.

Emphasis is shifting to the idea of demographic inertia, whereby groups experiencing very low fertility (TFR less than 1.5), across more than one generation, are predicted to retain low fertility as their social groups adapt to one or no children per couple. Some have raised concerns that population decline may result from a change in preference for smaller families, negative population growth momentum, and decline in income as the population ages. While migration may partially alleviate the so called demographic deficit, it is only in combination with significant increases in fertility, which is unlikely, that future working age populations can be fully replenished. However, migration in combination with increased productivity and extended working lives will go some way to alleviate the demographic deficit. Migrants currently increase national TFRs in the short term and make much less use of benefits and public services. Migrant workers also fill both the demand for highly skilled workers and the gap in unskilled employment arising from young people's unwillingness to undertake certain jobs, particularly in the growing old age personal care sector.

The shift to a low mortality and low fertility society results in an increase in the number of living generations, and a decrease in the number of living relatives within these generations. Increased longevity may increase the duration spent in certain kinship roles, such as: spouse, parent of non-dependent child and sibling. A decrease in fertility may reduce the duration of other roles, such as parent of dependent child, or even the opportunity for some roles, such as sibling.

Box 2.10 The UK in the context of Europe

The UK is a high income country with a per capita gross national income of $33,296 (2005 PPP$) (UN HDI 2011). In 2009 it had a TFR of 1.96 (Eurostat 2010), low mortality rates (infant mortality is at 5 per 1000 live births, the maternal mortality ratio is 12 per 100,000 live births (UNFPA 2011)) and high life expectancy (82 years for women and 78 years for men at birth, in 2009 (Eurostat 2010)). The ageing of the population and a decreasing workforce, a high population density, population growth due to a high migration rate and natural increase, and increasing number of households have had and will continue to have socioeconomic consequences for the country. While the EU-27 countries will see population shrinkage of around 0.2% per year between 2020 and 2045 (Italy and Germany for example, will be particularly affected with projected falls from 60 million to 57 million in Italy between 2010 and 2050, and 82 million to 74.5 million for Germany), the predicted UK population could increase over the same period from 62 million in 2009 to 74.5 million by 2050, partly due to natural growth and partly due to net migration (Eurostat 2010).

Ageing population and decreasing workforce:
In 2010, 16% of the UK's population was over the age of 65. This is predicted to increase to 24% in 2050. The proviso here is that by 2050, the number of people over the age of 65 years may no longer be a meaningful definition for "old age", and the "working age" population may be significantly extended beyond these boundaries. However these ages are used to estimate a country's "dependency ratio". (See Box 2.1 on demographic terms).

The next decade and beyond will see a rapid shift towards increased old-age dependency ratios in most industrialised countries. The EU-27 old age dependency ratio is set to double from 24.5% in 2009 to reach 50% by 2050 (Eurostat 2010), as the working-age population (15-64 years), decreases by 48 million between now and 2050, and the EU-25 will change from having four to only two persons of working age for each citizen aged 65 and above (European Commission 2006).

The structure of the UK population is projected to age gradually, with the number of people in the oldest age groups increasing the fastest. The proportion of people over the age of 80 in the UK will increase from 4.6% in 2010 to 9.0% in 2050, which is similar to the projected increase for Europe as a whole (4.2% in 2010 and 9.3% in 2050) (UNDP 2010).

Population growth:
The balance between population growth due to inward migration and population growth due to natural increase (growth due to an excess of births over deaths) has changed in the UK over the last 35 years. Between 1994 and 2007, net inward migration was the main source of overall population growth in the UK. A decrease in net inward migration was seen for 2008 until mid-2009, increasing slightly to the end of 2009, due largely to a fall in the number of people emigrating from the UK rather than an increase in the number of immigrants (UK RCEP 2011).

In the UK some of the economic consequences of an ageing workforce may be met through migration as a complement to other measures aimed at improving education levels and skills, housing mobility and the jobs available in the labour market. Across Europe for example the size of the working population would decline significantly (20% by 2050) without international migration, exacerbating the age dependency ratio and threatening economic growth and competitiveness. Several studies have concluded that overall migrants make a net contribution in the UK (Gott 2002; Sriskandarajah 2005). Similarly, research by Rendall and Ball (2004) suggests that almost half of overseas-born immigrants to the UK emigrate again within five years. This process of return migration among UK's overseas-born immigrants will lower the UK's old-age dependency ratio in at least the immediate future.

As this Chapter has described, it is not just the global size of the population that is changing, but also the distribution, density and age structure. From 2010 to 2050, it is projected that the global population will add 2.3 billion people, and become predominantly urban. Nearly a quarter of the population (22%) will be over the age of 60. The economic, social and environmental challenges and opportunities presented by these changes will differ greatly between the Least, Less and More Developed Countries.

2.5 Conclusions

1. **Population is about much more than total numbers of people.** All the components – composition, density, distribution - must be considered in the context of sustainable development and human wellbeing.

2. **There is huge demographic diversity between the different regions of the world.** Those in the Least Developed Countries are seeing high but declining fertility rates, high population growth rates, a high youth dependency ratio, and some of the highest rates of urbanisation in the world. Those in the Less Developed Countries are seeing declining fertility rates but continuing population growth and a potential demographic dividend, whilst those in the More Developed Countries are experiencing low levels of fertility, an ageing of the population and facing a potential demographic deficit.

3. **Globally, total population is still increasing although peak fertility has passed.** The annual increase in total numbers of the world's population peaked in the 1990s and is slowly abating. The percentage increase in global population peaked in the 1970s. In the 1980s it was close to 2% and the absolute increase in population was approximately 75 million a year. By 2050 global population is expected to still be growing by 40 million more births than deaths each year.

4. **The speed at which the demographic transition takes place is important;** different speeds create different social, economic and environmental challenges and opportunities for countries. Slowing rapid population growth in the Least Developed Countries is necessary but not sufficient for these countries to progress socially and economically.

5. **Continued rapid global population growth is inevitable for the next few decades but whether it continues in the longer term will be determined by the investments made and the policy frameworks constructed by countries and the international community.** The longer the delay in reducing fertility rates the more momentum is built into the system and the less likely it becomes that the global population follows the UN medium projection.

6. **Some demographic changes, such as age structural change and urbanisation must be adapted to and planned for.** Planning and investment are required for urbanisation, to realise the demographic dividend, to manage demographic deficit, and to identify opportunities presented by ageing populations.

7. **Migration for economic, social, demographic, geopolitical and environmental reasons will continue and may increase.** Migration can make an important contribution to economic and social development and to addressing some of the issues raised by age structural changes, but can bring challenges which need to be well managed at the global, national and local level.

CHAPTER 3

Consumption

3.1 Introduction

The previous Chapter described the dynamics of human populations and the diversity of demographic change around the world. The present Chapter describes the overall patterns of consumption and once again the diversity of these patterns. First, to understand how consumption is having an impact on the planet, it is necessary to consider what consumption is and why it matters. The profound inequalities among the peoples of the world are then described. To help understand why there are such huge variations in consumption levels between different parts of the world, the drivers of consumption are explored. We will revisit these drivers in Chapter 5, where we discuss ways to reduce consumption inequalities.

3.2 What is consumption and why does it matter?

Consumption serves people's needs, tastes and values and is usually defined in one of two ways; consumption of material resources or the consumption of goods and services (also known as economic consumption) (Evans and Jackson 2008) that are the direct inputs to human wellbeing (Dasgupta 2011). The latter definition refers to an economic process and is not restricted to material goods so that a variety of goods and services are consumed, some of which involve virtually no resource consumption at all (Jackson 2006). Material resource consumption generally refers to the consumption of natural resources or what is often referred to as natural capital (see Box 3.1), and has implications for resource scarcity and environmental degradation. This distinction between material and non-material consumption is important because while both are necessary for meeting human needs and delivering human wellbeing they have different implications for sustainable development.

Box 3.1 Capital assets can be classified as follows:

1. **Natural capital:** includes species, habitats, local ecosystems, biomes, sub-soil resources etc including farmland, biogeochemical cycles, the atmosphere, ocean, food, fibre, ecosystem services including aesthetic, spiritual and recreational values.
2. **Manufactured or reproducible capital:** includes infrastructure including roads, buildings, ports, machinery, equipment, housing, personal and commercial transport etc.
3. **Human capital:** includes education, skills, tacit knowledge, health.
4. **Knowledge capital:** includes science and technology, arts and humanities.
5. **Institutional (or social) capital:** the range of formal and informal arrangements between people, including rule of law, social norms of behaviour, habitual social practices, economic markets, traditions, governments at all levels.

Dasgupta 2010a.

Consumption has been conceptualised as the consumption of material and non-material goods and services within and sometimes outside of the monetised economy (UNDP 1998). Consumption is critical to human development and contributes positively when it:

- enlarges the capabilities of people without adversely affecting the wellbeing of others;
- is as fair to future generations as to the present ones;
- respects the carrying capacity of the planet;
- encourages the emergence of lively and creative communities.

This conceptualisation is useful because while it draws a distinction between material and non-material forms of consumption, it also emphasises that they are determinants of sustainable development. Material consumption does not necessarily lead to positive development, and is not always necessary for human development advances. It is possible that economic consumption (or the consumption of goods and services) can contribute positively to human and economic development, without causing environmental degradation.

Economists, sociologists, anthropologists, environmentalists, philosophers and theologians have different perspectives on consumption (UNDP 1998). This Chapter adopts an environmental approach, which focuses on consumption as it relates to the use of renewable (for example; water, wood and food) and non-renewable natural resources (for example, energy and minerals). Unsustainable use of this natural capital depletes the earth's resources, and has been termed the tragedy of the commons (Box 3.2). The environmental consequences are considered in the following Chapter. Natural capital provides the productive base for the economy and also provides many of the elements required for social, mental and physical wellbeing. The consumption of natural capital is a necessity for life, not a luxury and so the trends in consumption of natural capital warrant special attention in a discussion of the impacts of population.

There are huge variations in consumption patterns around the world, for several reasons. All forms of consumption are correlated with population size and levels of economic development. Because of the link between economic development and consumption, those in the More Developed Countries have the opportunity to consume more, while consumption possibilities for those in the Least and some of the Less Developed Countries are restricted. As international trade increases, the production of goods can become increasingly detached from direct consumption. Goods exported from one

Box 3.2 The tragedy of the open access commons

Many resources are subject to collective action problems: if each actor pursues what is in his or her short-term interest, things will go much less well than if all agree to abide by rules that are in the common interest. Collective action problems are sometimes thought to arise inevitably from common ownership of resources, but this is not the case. Hardin (1968), in coining the phrase the "tragedy of the commons" assumed that common ownership of physical resources such as fields and lakes is problematic because it will be in the interest of each to consume more of the resource than is sustainable. Thus, on Hardin's analysis, shepherds will tend to overgraze a field which is held in common, as each shepherd seeks to ensure that he or she has as many sheep as possible, and that each sheep is well-grazed. If all (or most) shepherds behave in this way, then the commons will become overgrazed, and its ability to support sheep will soon be destroyed.

However Hardin was mistaken to assume that all commons are open access, and can be used by anyone without control or rules. Almost all commons are closed access, with distinct rules and norms. Closed commons are and can be regulated in such a way that they can be successfully protected and sustained. (Ostrom 1990). Nonmaterial goods, such as knowledge, which are also vital for human wellbeing, are not subject to scarcity and can be provided for all without being in any way degraded (Wilson 2012).

country to another carry with them "embodied" material consumption, which is necessary for their manufacture. Thus the water use and CO_2 emissions of More Developed Countries appear lower than they would under full accounting, because they are partially outsourced to Less Developed Countries. The patterns of change in consumption also vary geographically and across income categories. It is the Least and Less Developed Countries that have the highest population growth rates, and as the economies and aspirations of these countries grow, so too will their consumption.

3.3 Material consumption patterns

This section considers the consumption of four material resources – water, food, energy and minerals. These resources are the most basic needs for survival, and in some parts of the world even these basic needs are not being met for some people. By contrast, high levels of material consumption seen in many parts of the world may lead eventually to loss of wellbeing for the consumer and, in an inequitable world with finite resources, also result in the deprivation of others.

The illustrative case studies demonstrate global and regional material consumption patterns. The examples are chosen for their relevance to population trends, and to human wellbeing. Water and food are renewable resources on which wellbeing and health depends. Most land use change over the past 150 years has been undertaken to enhance their provision to growing numbers of people. They also underpin other components of wellbeing although the linkages are less direct. Energy and minerals are necessary for the provision of food and water. Fossil fuel energy sources, like minerals, are effectively non-renewable.

3.3.1 Water

Water is circulated in its various physical forms between the land, oceans and atmosphere. The main components of the global hydrological cycle are precipitation on the land and the oceans, evaporation from the land and the oceans, and runoff from the land to the oceans (Kuchment 2004). The complete stock of the Earth's water is estimated to be about 1,400 million km^3 (Shiklomanov and Rodda 2003). Of the total stock, only 2.5% is freshwater, of which nearly 69% is frozen as icecaps and about 30% is present as soil moisture or lies in deep underground aquifers as groundwater not accessible to human use. 0.4% (140,000 km^3) of freshwater is accessible for direct human uses in lakes, rivers, reservoirs and shallow underground sources. These stores of water are not static; availability, renewability and quality depend on the transfer rates between them.

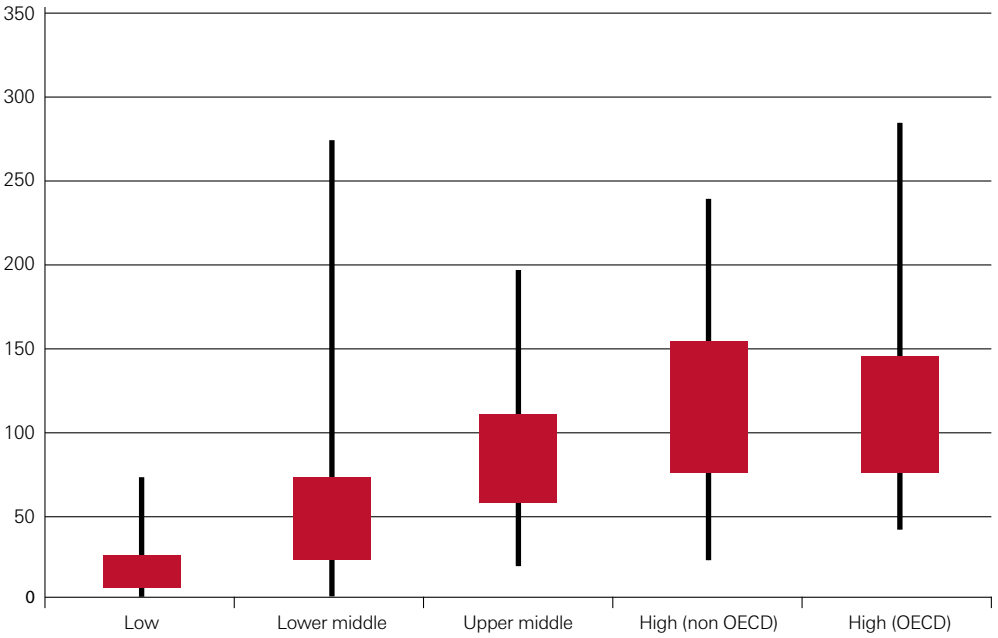
Freshwater is essential to life on earth. It is a natural resource which enables the production of food and energy, provides hygiene and sanitation and serves as the primary link between human society, climate systems and the environment. It is fundamental for maintaining human health, agricultural production, economic activity as well as critical ecosystem functions (Gleick and Palaniappan 2010).

Over the last few centuries global aggregate water use has grown exponentially (MA 2005a) and has been closely linked to economic development and population growth. A fifteen-fold increase in global water withdrawals occurred between 1800 and 1980 (Lvovich and White 1990) when population increased by a factor of four (Haub 1994): a 3.5 fold increase in average per capita consumption. Since 1980 per capita water use rate has dropped a little from 700 to 600 cubic meters per year although the aggregate global withdrawal continues to increase (Shiklomanov and Rodda 2003). Between 1960 and 2000 world water use doubled from about 1800 to 3600 km^3 per year (MA 2005a). Water use is dominated by agriculture (roughly 70% of withdrawals are for agricultural use (FAO 2010b), followed by industrial (19%) and then municipal (including domestic) applications (11%). Figure 3.1 shows municipal water withdrawal per capita across income groups.

A child born in the developed world consumes 30 to 50 times as much water as one born in the developing world (UNESCO 2003). In 2008 it was estimated that 884 million people were still without access to safe drinking water and 2.6 billion were without access to basic sanitation (WHO and UNESCO 2006) exposing them to preventable infectious diseases. The fresh water requirements for meeting basic human needs gives a total demand of 50 litres per day, which equals 18 m^3 per capita per year (Gleick 1996). This is based on a minimum drinking water requirement, basic requirements for sanitation, bathing and food preparation (Gleick 1996).

Figure 3.1 Box and whisker plot of municipal water withdrawal per capita (total population) per year (m^3) across income groups.

The box represents the interquartile range. The lowest point of the "whisker" represents the lowest data point that is within 1.5 times the interquartile range, below the first quartile. The highest point of the whisker represents the highest point of the data that is within 1.5 times the interquartile, above the third quartile.



Source: Aquastat (2008 data where available)[1]

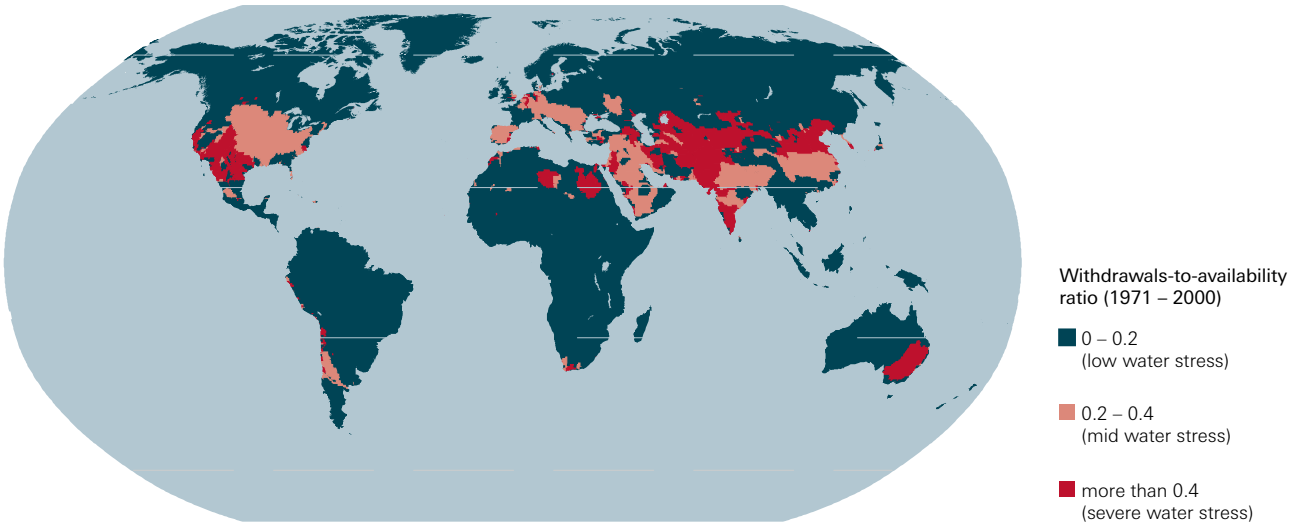
The world's natural water resources are distributed unevenly around the world. Among inhabited areas, at the continental level America has the largest share of the world's total freshwater resources with 45%, followed by Asia with 28%, Europe with 15.5% and Africa with 9% (FAO 2003). Central Asia has just 0.6% of the world's total freshwater resources. There is therefore wide variability in the total renewable freshwater resources available between countries; for example Kuwait has $10m^3$ per inhabitant while Canada has more than $100,000m^3$ per inhabitant (FAO 2003).

Figure 3.2 shows how water stress areas are likely to shift from late 20th century to late 21st century. In this figure, water stress is calculated by dividing water extractions (for irrigation, domestic water supply, industry etc) by the available water (i.e. rainfall minus evaporation). It is estimated that by 2025, 1,800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions (FAO 2007). Given the population of Africa is set to rise from 1 billion in 2010 to 2.2 billion in 2050 (UN medium variant), water stress for the continent will become increasingly likely. The situation will be exacerbated as rapidly growing urban areas place heavy pressure on neighbouring water resources.

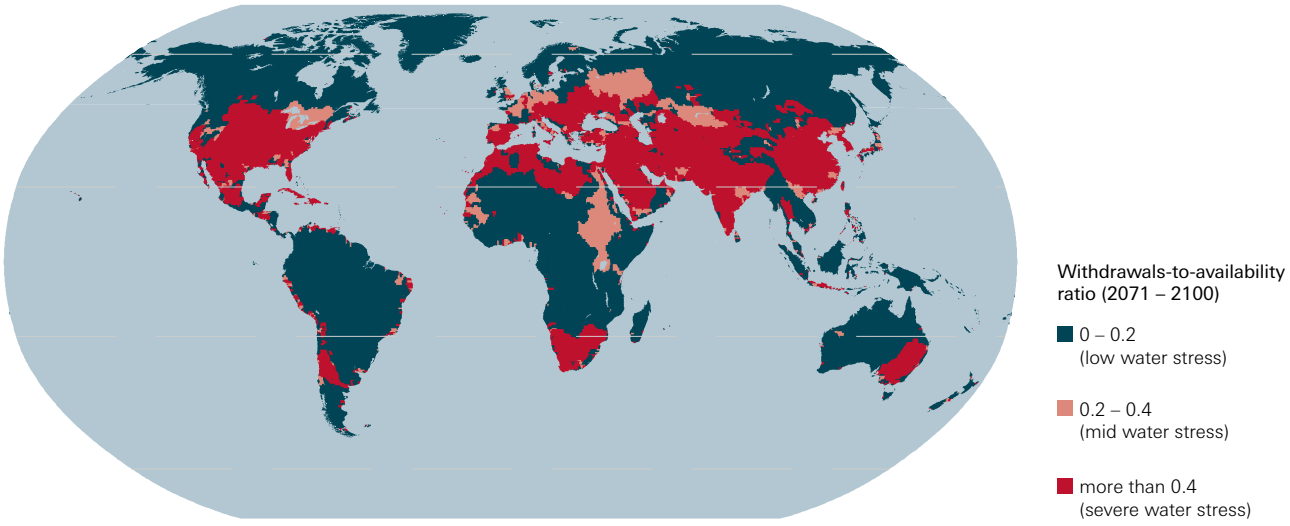
1 Grouping by income was made using the World Bank's grouping based on GNI per capita, into low, lower-middle, upper-middle and high-income countries (with the further subdivision of the high-income group into OECD and non-OECD countries). Information on this can be found at: http://data.worldbank.org/about/country-classifications. The list of countries in each group can be found at: http://data.worldbank.org/about/country-classifications/country-and-lending-groups/

Figure 3.2 Water stress, calculated as the ratio between water withdrawals and availability, for the late 20th and 21st centuries (see Flörke and Eisner, 2011).
ECHAM5 is an atmospheric general circulation model, from the Max-Planck-Institute.

Water Stress climate normal (1971 – 2000)



Water Stress ECHAM5 – A2 (2071 - 2100)



Virtual or embodied water refers to the amount of freshwater (including soil water) used during the production process of a good or service. Producing goods and services generally requires water (Hoekstra 2003). For example, it requires about 1,000 cubic meters of water to produce a ton of grain (Hoekstra and Hung 2003). Countries limited in available freshwater rely on importing food to compensate for lack of production ability (Brown and Matlock 2011).

3.3.2 Food

Important basic food groups include: grains; vegetables; fruit; meat, fish, and beans (including eggs, nuts, and meat alternatives); and milk (which includes yogurt and cheese). A healthy and balanced diet contains a variety of foods from within each food group, since each food offers different macronutrients (carbohydrates, proteins, and fats) and micronutrients (vitamins and minerals). On average, the body needs more than 2,100 kilocalories per day per person, consumed as food, to allow a normal, healthy life (World Food Programme 2011). Chronic undernutrition in the first two years of life leads to irreversible damage, meaning that children may never reach their full mental and physical potential. Poor nutrition can affect school performance, economic productivity and earning power in adult life (World Food Programme 2011).

Globally, between 1969 and 2005 food consumption has increased on average by about 360 kcal per person per day. This has amounted to a 15% increase between 1969 and 2005 (Foresight 2011b). The global demand is expected to change rapidly as emerging economies become wealthier and individual households can afford more varied diets including more meat, dairy products and fish. Fish consumption has increased from 9.9kg per year in the 1960s to a high of 17kg per capita per year in 2010 (FAO 2010b). However, wild marine fish catches peaked at 74.7 million tonnes in 1996 (FAO 2010b), and global fisheries production has only continued to grow due to aquaculture (fish farming).

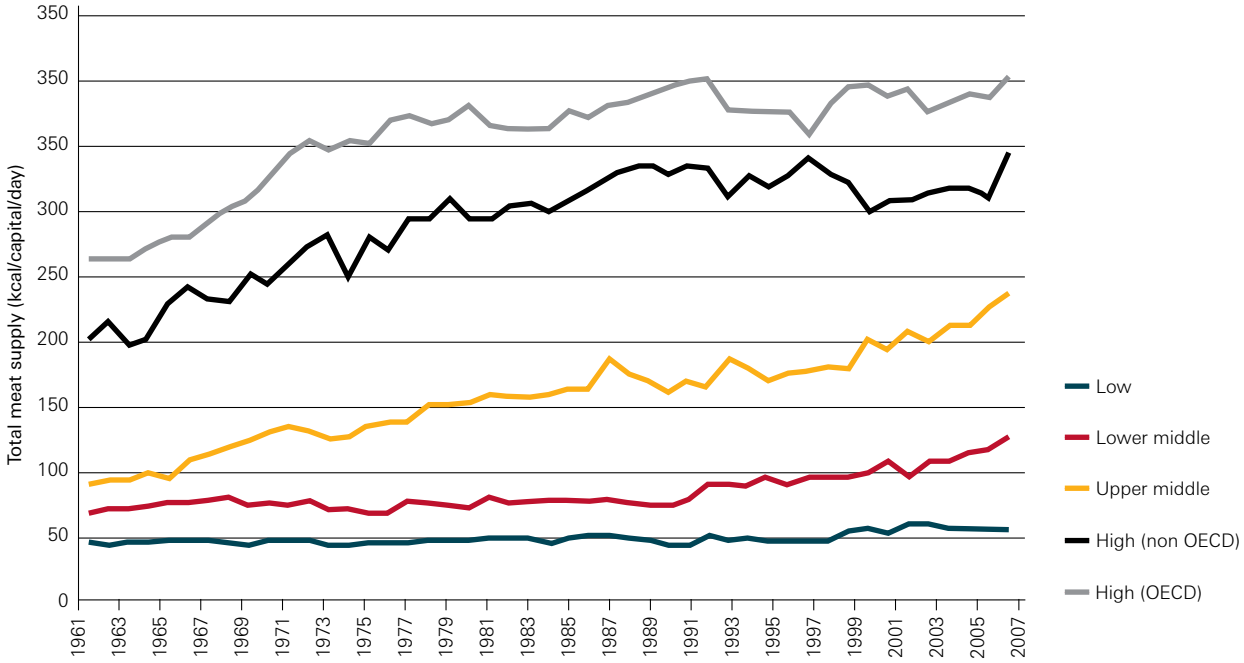
Access to food has generally (but not universally) increased as a result of rising income levels and falling food prices. The future trends depend on both the supply and demand. Demand is influenced by people's dietary preferences and the market value of the product before it is bought and consumed.

The increase in the average global food consumption per person has not been equal across regions. The per capita supply of calories has remained almost stable in sub-Saharan Africa for example (WHO 2003). In 2010 close to one billion people did not receive sufficient calories to meet their minimum dietary energy requirements (FAO 2010a; Defra 2010). Another billion people (estimates vary) are chronically malnourished: they do not get the vitamins, dietary minerals, essential fatty acids, and essential amino acids, necessary for health, even though they may get enough calories.

Crops grown for biofuels or livestock feed also can lead to price increases and food shortages. Trends and changes underway in population, development, urbanisation and globalisation can make food security harder to achieve as the demands for food and costs to consumers may increase. The effects of climate change, such as changes in temperature, shifts in seasons and more frequent and extreme weather events such as flooding and drought may also affect food security.

With increasing affluence most countries adopt a more varied diet with a higher proportion of animal protein, a phenomenon which has been marked in most of Asia in recent times.

Figure 3.3 Median total meat supply (kcal / capita / day) for each income category.



Source: FAOstat 'Food supply' database (see http://faostat.fao.org/default.aspx)

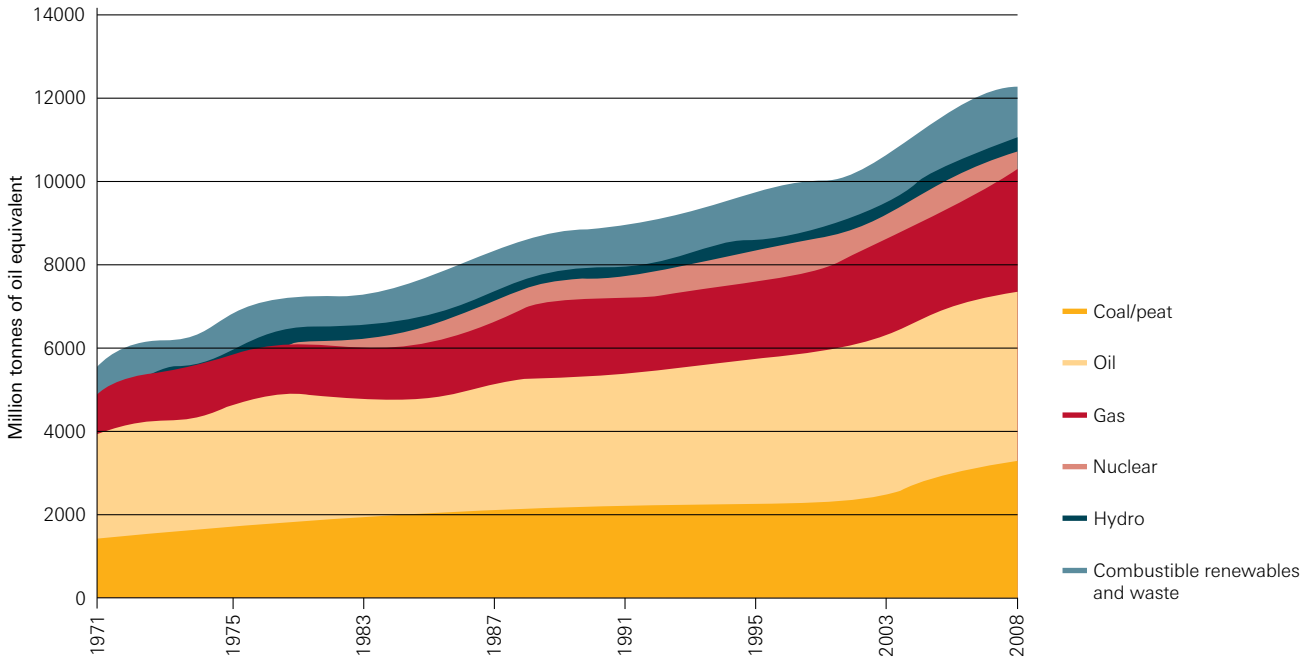
Differences in supply of meat are shown in Figure 3.3. Whilst median per capita daily meat supply in low-income countries remained steady from 1961 to 2007, at around 50 kcal per capita per day, the meat supply in high income (OECD) countries rose from around five times to up to eight times this level. In China and Brazil meat consumption increased markedly over the past 40 years, but the same has not been true in India where, for cultural reasons, meat consumption remains at a very low level.

On average, people in industrialized countries consume an average of 28.7 kg per year of fish, in developing countries 16.1 kg per year, and in Least Developed Countries 9.5 kg per year (FAO 2010b). Least Developed Countries are therefore likely to be the most sensitive to changes in the availability and affordability of fish, given the low baseline consumption and generally low resources to replace fish with other types of animal protein (Allison *et al*. 2009). This leads to a high risk of malnutrition. The differences and trends for vegetable food supply are similar to those for meat although the variations are slightly less extreme.

3.3.3 Energy

Of all the factors underlying the economic development of humanity, energy has a preeminent role. The invention of the practical steam engine and its development during the 1700s began the industrial revolution, which has led to an increase of energy use, per capita in developed countries, by an order of magnitude since that time, supplied by combustion of fossil fuels on a scale that has eclipsed other sources. The rise in emissions of carbon dioxide to the atmosphere has now led to measurable and dangerous climate change. In this section we are primarily concerned with the impact of energy consumption on the planet, and so shall focus on CO_2 emissions.

Figure 3.4 World total energy supply by fuel, from 1971 to 2008 (Million Tonnes of oil equivalent).



Source: IEA 2010

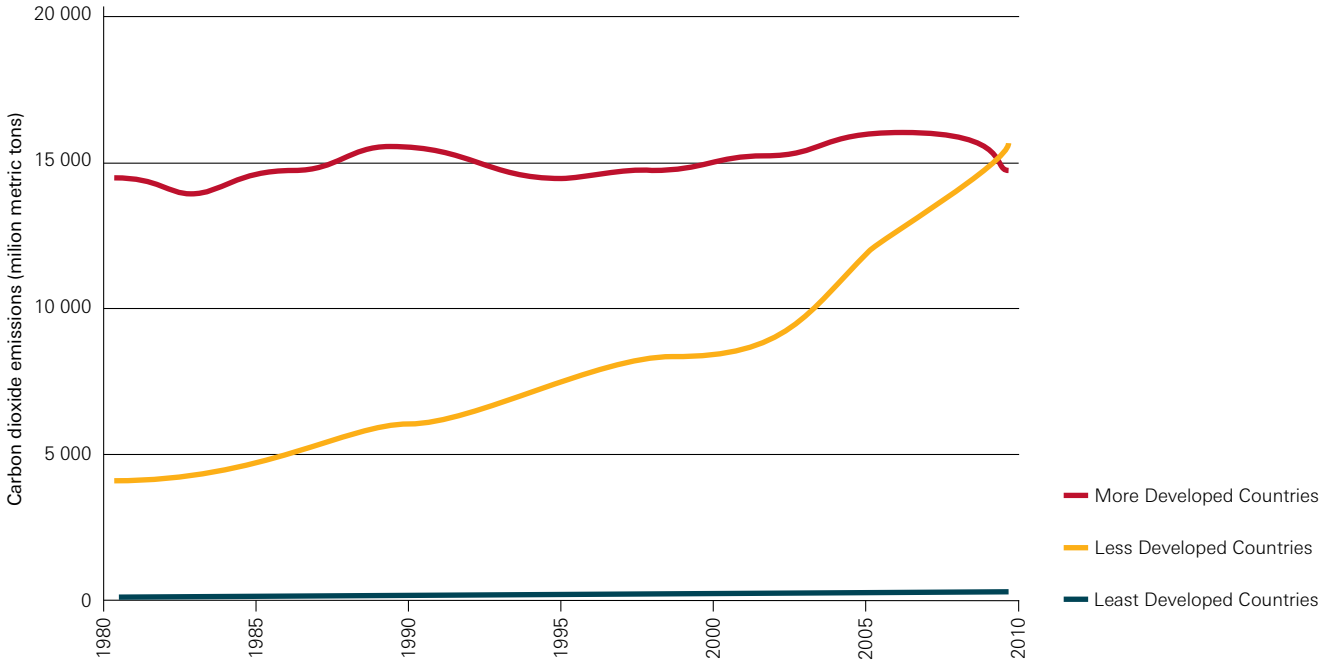
Figure 3.4 shows the global sources of energy. In 1900, the activities of humans released half a billion tons of carbon to the atmosphere per year. In 2000, they released 7.3 billion tons a year – a fifteen-fold increase. The human population of Earth in 1900 was 1.6 billion. The population in 2000 was 6.1 billion – a nearly fourfold increase. So average CO_2 emission per capita also increased fourfold.

Global trends in CO_2 emissions are driven by the amount and type of energy used and the indirect emissions associated with the production of electricity. Between 1990 and 2005, global CO_2 emissions from final energy use increased to 21.2 Gt CO_2, a rise of 25%. Manufacturing was the most important sector in 2005 with a share of 38% of energy/CO_2 emissions, while CO_2 emissions from transport (25%) were higher than for households (21%). The sectors rank differently depending on whether energy or CO_2 emissions are being considered, as they do not all use the same mix of energy commodities and so have different average levels of CO_2 emissions per unit of energy consumption (IEA 2008).

The overall picture is complicated by countries of different size at different stages of development and with different trends. Especially important at the global level are trends in countries with large populations currently with high or rapidly growing levels of emissions.

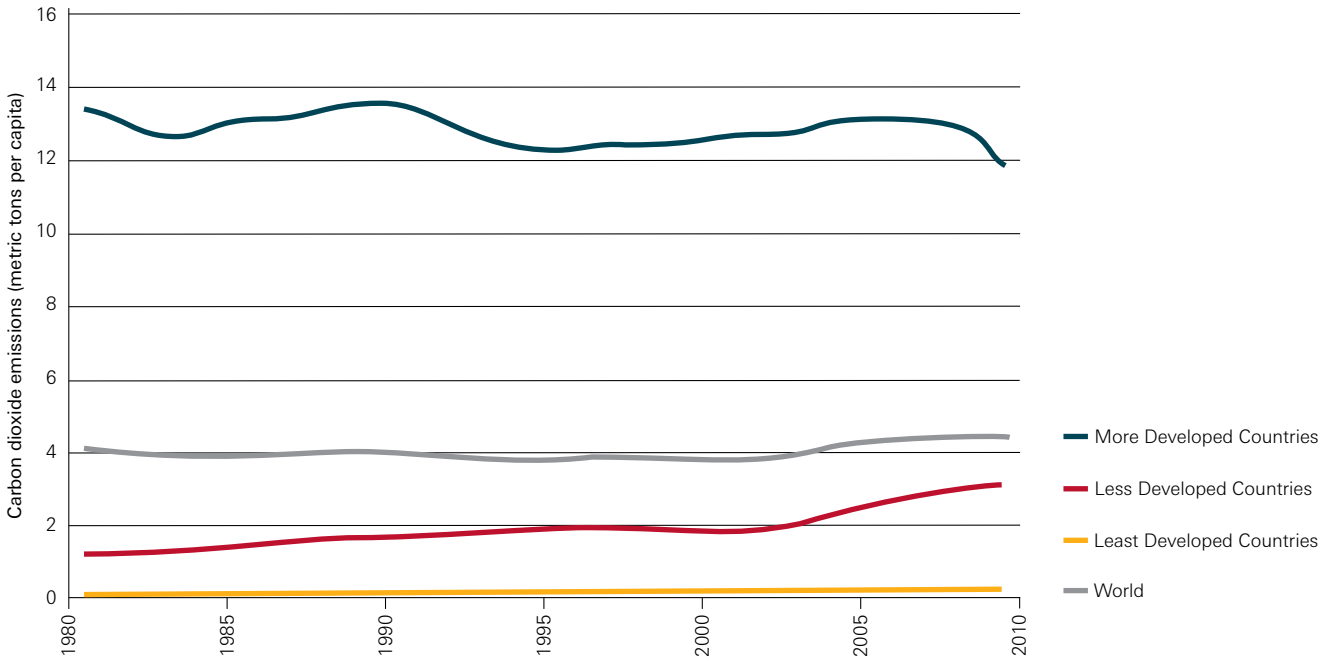
Carbon dioxide emissions are related to economic growth and level of development, and so there are marked differences between countries. As countries develop they tend to move towards emissions levels comparable to those of developed market economies. At present, per capita CO_2 emissions are 10 to 50 times higher in high income than low income countries (EIA 2011). Access to energy is very unequally divided, and energy insufficiency is a major component of poverty.

Figure 3.5 Total carbon dioxide emissions in Least, Less and More Developed Countries.
This figure shows the difference between the Least, Less and More Developed Countries in aggregate carbon dioxide emissions.



Source: EIA 2011

Figure 3.6 Per capita carbon dioxide emissions in Least, Less, and More Developed Countries.
This figure shows the difference between the Least, Less and More Developed Countries in per capita carbon dioxide emissions. It shows that per capita CO_2 emissions in the More Developed Countries are around three times higher than the world average



The per capita emissions for Figure 3.6 were calculated by dividing the CO_2 emissions (Figure 3.5) by population.

This section has shown the huge variation in energy consumption between the different income and development groups. More Developed Countries have per capita CO_2 emissions from 4 to 50 times those of Least and Less Developed Countries. But these patterns are changing fast: CO_2 emissions (both total and per capita) are growing up to 10 times faster in Less Developed Countries. The fastest growth in per capita carbon emissions is now seen in Less Developed Countries.

3.3.4 Minerals

Economic minerals comprise essential material resources for human activity and the economy; they are natural assets which are extracted from the ground and modified for their economic utility. They may be measured both in physical units such as area, volume, mass, or energy, and in financial terms which express their economic value. They comprise energy minerals (coal, oil, natural gas, uranium), construction minerals (sand, gravel, brick clay, crushed rock aggregates), industrial minerals (non-metallic substances such as salt, limestone, silica sand, phosphate rock, talc and mica) and metals. In addition, fifteen lanthanides plus scandium and yttrium make up the group of rare earth elements (REEs) (IUPAC definition).

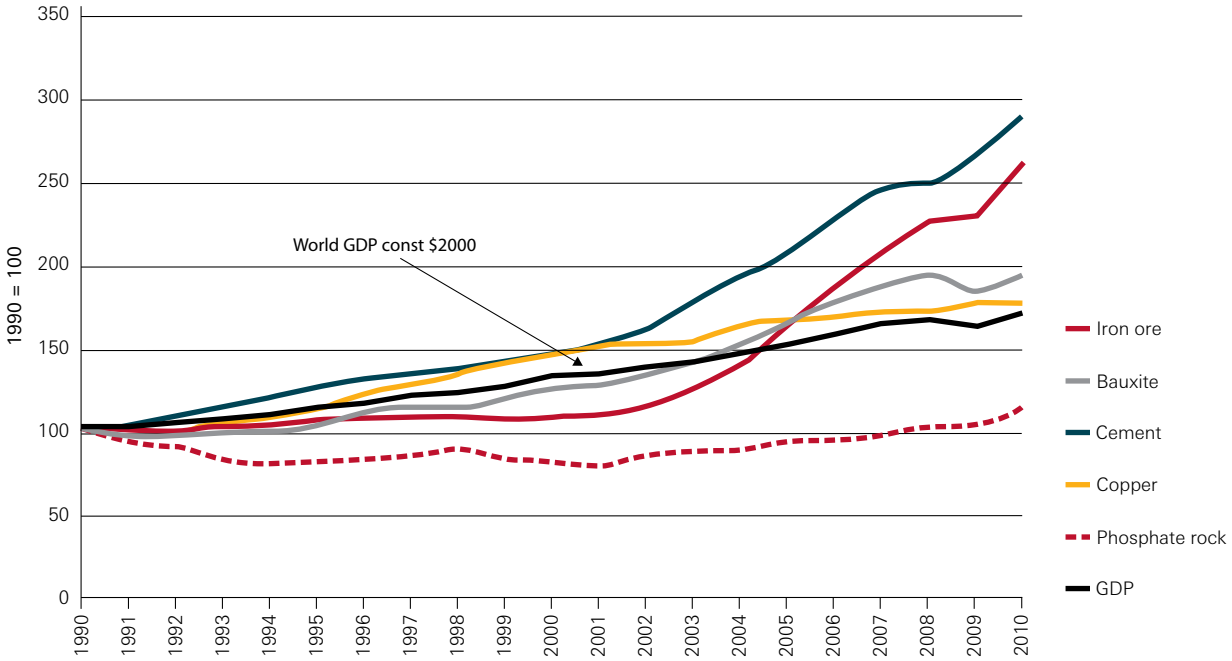
Minerals are ubiquitous in the earth's crust, but typically in very low concentrations. Where natural and geological processes have concentrated minerals sufficiently, they become economically viable deposits for use. Production begins with exploration, whereby such deposits are identified for extraction (open-cast quarrying, mining, or sometimes pumping); they are then refined, processed and transported for use by industry, construction and agriculture.

Interpreting measures of reserves, production and consumption presents challenges. Reserves are economic entities that depend on current scientific knowledge of mineral deposits and on the present price of the target metal or mineral; they are unreliable long-term indicators of availability. Historical and global records of mineral consumption are scarce and problematic to interpret. In contrast, excellent reliable records of mineral production exist both at national and global levels, in part because taxation is levied on production. Production data serve as a good proxy for consumption, and are used here.

Despite scarce concentrated deposits, mineral demand, especially metal demand, has undergone a sharp rise (see Figure 3.7). Diverse physical and chemical properties lend them to a wide range of unique purposes which are of increasing economic significance.

Globally, from 1960 to 2007 production of refined copper and lead increased fourfold, lithium by nearly as much, and tantalum/niobium increased 77 fold. Consumption of fossil fuels has led to the continuous increase in CO_2 since pre-industrial times (Keeling 1960; Keeling and Whorf, 2004b). Demand for rare earth elements has undergone a sharp rise in recent years. The price of lanthanum oxide has risen from US$5 per kilogram in early 2010 to US$140 per kilogram in June 2011 (DOE 2011). About 15000 tons per year of the lanthanides are consumed as catalysts, in magnets and in the production of glasses. Many technological devices use rare earth elements. The great majority of the consumption of minerals (especially metals) occurs in the most developed and highly industrialised parts of the world, whereas mining itself is widespread.

Figure 3.7 Global trends in world mineral extraction 1990 – 2010



Source: Jackson 2009

Considerable amounts of water and energy are needed to extract metals, which along with the pollution generated by the extraction processes, are the main constraints to greater sustainability of mining operations. Approximately 10% of active mines and 20% of exploratory sites are located in areas of high conservation value, while nearly 30% of active mines are located in water-stressed areas. Although mining activities may only cover a few square kilometres, exploration activities tend to spread much more widely. As well as creating competition for already scarce water supplies, local populations nearby or downstream can be adversely affected by an impact on water quality.

Developing countries with a growing volume of metallic mineral production typically face the challenges of managing the resource revenue effectively for sustainable development as well as minimising the adverse social and environmental impacts of mining activities (Collier 2010).

As finite resources, metals impose limits to economic growth unless relative decoupling and eventually absolute decoupling can be achieved (that is decoupling resource use from economic growth). Relative decoupling refers to a decline in the ecological intensity per unit of economic output (resource impacts decline relative to GDP). Absolute decoupling is when resource impacts decline in absolute terms. To date, global trends have shown mixed evidence for decoupling of resource use from economic growth (see Jackson 2009).

3.4 Drivers of consumption

For one billion people who live in extreme poverty, and a further billion who are so poor as to be malnourished, the chief drivers of consumption are the attainment of adequate living standards including basic commodities and services (FAO 2010a). The basic requirements of people are expressed in the Millennium Development Goals (MDGs), with a target date of 2015. For most of the Least Developed Countries the targets will not be reached by that time, but nevertheless the MDGs have provided a stimulus to progress. There are however other factors which are generally relevant, discussed below.

3.4.1 Preferences and social factors

As living standards rise, and countries proceed through less developed to more developed situations, the drivers become more diverse and subtle. One of

them is habit, which is based on past consumption, and influences current taste for goods and services. For example, India is not switching to a high meat diet as other developing countries are doing.

Other drivers, yet to be explored quantitatively in a systematic way, are due to the sociability of human beings. As social animals humans are both competitive and conformist, wanting to attain status in the community in certain ways and yet wanting simultaneously to be like others in other ways. In his classic work on the Gilded Age, Veblen (1899) spoke of "conspicuous consumption", to draw attention to consumption as a status symbol (such as expensive cars, clothes, and houses). If a consumption good is to be a status symbol, it must be conspicuous; hence the title of Veblen's classic.

Social scientists have characterised such forms of consumption competition as "rat races", with each household trying to "beat" all others in their consumption patterns (Easterlin 1974, 1995, 2001; Oswald, 1997). All people work harder and consume more than if all agreed to work less hard and consume less; the difficulty is to find a mechanism for encouraging such an agreement (Schor 1998; Frank 2011).

The impact of competitive consumption on sustainability was recognized long ago (Hirsch 1976; Heilbroner 1977). If goods are under-priced (see Box 4.3), and if those goods are conspicuous (e.g. expensive cars, air travel), then they are natural focal points for competition. Add in habits and a growing complementary infrastructure (filling stations, expanding motorways, airports) and the result is a spiralling, continually increasing exploitation of natural capital that adds less to human wellbeing than expected and jeopardises the wellbeing of others (including future generations).

Other patterns of consumption are conformist. They offer a visible way for people to relate to one another. For example, many people like living in a society where friends invite one another to social occasions. The reciprocity may increase the cost but it adds to personal wellbeing. What differentiates conformist consumption from conspicuous consumption is that individuals like to conform to the norm in such exchanges, termed "associational consumption" (Douglas and Isherwood 1996). It leads to a very different social dynamic from conspicuous consumption (where the goal is to exceed the norm).

In developed countries, a strong driver for most individuals is the attainment of a higher income. So prevalent is this, that it sounds unnecessary even to state the fact. Higher income usually leads to higher consumption, so whatever factors drive income may also drive consumption, which provides those marks of status, as well as material wellbeing. As a result, people are generally more content with an expanding economy than with one which is flat, let alone one which is contracting (which is pejoratively described as in recession).

At the national level, GDP has become an accepted measure of a country's prosperity and influence. In later Chapters the implications of measuring prosperity by GDP will be discussed further, but the consequence is that GDP is not only a result but also now a driver of income and consumption. National economic growth (as measured inadequately by GDP) becomes an end in itself, and governments encourage their workforces to be as productive as possible, in competition with those of other nations. And expanding economies, without regulatory measures, usually lead to higher consumption. During and after a global recession, citizens are encouraged to go shopping rather than saving, because in current models of the economy it seems to be the only way to escape from the financial doldrums (Jackson 2009).

The many components of this economic cycle include: marketing and advertising to influence consumer choice; high levels of individual and national debt; wrong pricing (discussed further in Box 4.3) leading to carelessness and waste. Each is a huge economic topic in itself. It is misleading to single out any one as being the key issue because all are part of a cycle of consumerism. Together with technological lock-in (Box 3.3) they establish a consumption momentum from which escape is difficult.

Box 3.3 Technological lock-in

The consumption of resources per capita often continues to increase after advancements in technology and processes which would permit its reduction. The drivers of this phenomenon are diverse.

The rate of change in levels of consumption with the arrival of a new technology is a function of the inertia of the existing technology regime and the rate of uptake of the new technology. Technologies are embedded within wider social and economic systems: these include structures of markets, patterns of consumer demand, systems of regulation and infrastructure. For instance, the electricity-generating regime is founded upon rules and practices, relating to large centres of power generation connected by high-voltage grid networks. Consumption patterns and supportive institutional arrangements have built around and reinforced this system for at least eighty years in more developed economies. Any transition to an alternative (eg distributed) technological model would require a body of organisational change and consumer uptake before it can take effect.

Lock-in is the process by which self-reinforcing barriers to change, inhibit or prevent the uptake of new technologies, many of which might improve the sustainability of resource demand. Forces of institutional lock-in arise from associations formed to represent collective interests, and by the adherence to convention. In other cases, apparently inferior designs become fixed in use by a process in which strategy and historic circumstance are as important as the design itself, creating technological lock-in. Examples include the VHS video tape design, QWERTY keyboard and light-water nuclear reactors. Once established, mass production, rapid development and conformity to the prevailing norm (eg for inter-operability) locked-in these technologies as the predominant designs in their respective markets. Such technologies yield increasing economies of scale, and implementation of new designs and processes in their place incurs additional "penetrational" structural and resource costs – even if long term consumption of resources, functionality, environmental impacts and cost might be superior.

(See Unruh, 2000; Smith *et al*. 2005; Jackson and Papathanasopoulou, 2008).

3.4.2 Age structure

Ageing is an important factor in consumption, especially of healthcare and energy resources. The U.S. Consumer Expenditure Survey found that households with an older "householder" or "household head" spent a substantially larger share of income than younger households on utilities, services, and health care, and a substantially smaller share on clothing, motor vehicles, and education. Since the most energy intensive goods are utilities and fuels, aggregated consumption in older households is more energy intensive than consumption in younger households (Dalton *et al*. 2008). In their projections of future U.S. carbon emissions to 2050, ageing had effects as large as, or larger than, the effects of technical change in some scenarios. In the United States in 1987-97, energy consumption for residential purposes increased with the age of the household head (from fifteen to eighty five). Also in the United States in the interval 1983-94, transport energy declined as the age of the household head increased. Similar trends have been demonstrated in China and India (O'Neill and Chen 2002).

3.4.3 Household structure

Households are likely to decrease in size in the future (Keilman 2003). Family size is falling and longevity is increasing, so the proportion of a lifetime spent without children at home is increasing. Additionally, two-adult households are progressively declining in frequency compared to one-adult households because people are living singly longer before they marry; divorce rates are rising; and the better survival from marriage to advanced ages of women compared with men means that many more women are being widowed and live singly. Finally, rising wealth increases the feasibility of living independently. As a consequence households are expected to grow in number much faster than the numbers of people. Smaller household sizes are more energy intensive per member of the population (OECD 2002).

3.4.4 Population movement

In China and India, energy consumption per person fell, while money spent per person to pay for energy rose, as people moved from rural areas to towns to cities, and as the sources of energy change (Pachauri and Jiang 2008). Biomass combustion (eg burning of wood or dung, often not a monetised resource) disappeared, while electricity use rose from almost nothing to a substantial fraction (Jiang and O'Neill 2004).

Evidence from the different routes taken by migrants suggests that migration often results in a significant income increase for the migrant (eg. McKenzie *et al*. 2010; Hanson 2008). Migration may also have an impact on access to credit markets and may change preferences, all of which are likely to affect the level of consumption of the migrant. Migration may also affect consumption in the migrants' home country. Migrants sent over US$ 300 billion back home in the form of remittances in 2010 (World Bank 2011). Substantial evidence from different countries indicates that households receiving these resources have different consumption patterns from their non-receiving counterparts, including the level of consumption and the distribution of spending among different goods and services (Castaldo and Reilly 2007; Adams *et al*.2008). Remittances may even allow several more members of the household to migrate. However, more than money and goods flow between the host and home countries through migrants. Migrants may also send home ideas, norms of behaviour, values and expectations that may affect consumption in the home country (Levitt 1998).

Migrants may affect the income of the non-migrants in the destination country (ie "locals") by affecting their labour market outcomes. Most studies suggest that, on average, the impact of immigration on local residents' wages is small (Card 1990; Hunt 1992), but this impact could be quite important for certain groups of workers, especially those with low skills (Borjas *et al*. 1992). This impact can affect the consumption levels of the local residents. The presence of migrants may also permit the production of certain goods at lower prices (eg prepared foods) which may lead to more consumption of those goods.

3.4.5 Food requirements

What people eat (meat vs vegetables), how they travel (cars vs bikes), or how they keep cool (air conditioners vs natural ventilation and light clothing) all affect demands on natural resources and the environment. Combined increases in world population and per capita food demand could result in a rise in total demand for food of 40% by 2030 and 70% by 2050 (FAO 2006).

Insufficient food energy intake is almost always accompanied by a deficient intake of most nutrients. Awareness of the consequences of insufficient energy intakes in children and adults has influenced health, food and agriculture policies around the world. More recently, the consequences of increasing obesity and nutrition-related chronic diseases have also been recognized as major factors for the health, food and agriculture sectors. These problems are increasing globally as a result of changes in diets and lifestyles that are reflected in changing food cultures and physical activity patterns among all segments of society, and not only among affluent groups or in the richest countries. Under-nutrition early in life, followed by an inappropriate diet and low physical activity in childhood and adult life increases vulnerability to chronic non-communicable diseases (FAO 2001).

3.4.6 Consumption and population

The sustainable development debate has, over recent years, been typified by those who argue that population growth is the source of current unsustainable trends, and those who believe that consumption is the primary culprit. This artificial distinction is unhelpful as it can lead to argument over whether policy should focus on reducing population growth or on improving the sustainability of consumption, while both are clearly important.

The relationship between population and consumption is not simple. Every member of society must consume a minimum amount of goods and services to survive. Each additional person added to the population will necessarily result in an increase in total or aggregate consumption. If per capita consumption is constant, each person added to the population increases total consumption by the same amount; but of course per capita consumption

is not constant, either over time or between richer and poorer segments of a population. Moreover, the age structure of a population, i.e. proportion of working age in the population relative to the number of young and old dependents, influences consumption and economic growth. The more people of working age there are in a population, the more potential producers there are, therefore there is more potential for economic growth; but again life is not simple. There must be jobs for the people of working age, and the productivity of those people at work depends heavily on their education, health, and the availability of local investment and credit to create productive jobs for them. The more economic growth there is, the more consumption there may be, but not necessarily; gross domestic product, for example, may grow because exports are increased, leading to little or no growth in consumption in the producing country (Stiglitz *et al*. 2009). Age structure affects consumption as each age group's behaviour is governed differently by tastes and perceptions about needs, but is constrained by general standards of living (Mason and Lee 2007). Increasing life expectancy increases the amount that people are able to save and therefore may increase their lifetime consumption levels if their savings lead to productive investments.

Box 3.4 Sustainable consumption in Ghana

In 2011, the population of Ghana stood at 25 million. The population is set to reach 49 million by 2050 (UN 2011a medium variant). For the Ghanaian population, fish is the main source of protein, largely because of its price relative to other sources of high quality protein such as milk, meat and eggs. The FAO has estimated that fisheries constitute 3% of total GDP in Ghana and has projected that in 2023, the demand for fish in Ghana will be 1,399,811 tonnes, while the supply will be 783,894 tonnes (FAO 2004).

It is estimated that 80% of the fish caught in Ghana per year is caught in artisan wooden canoes, which have no quotas for maximum catch size. The fishing port of Elmina, Ghana, is home to 80,000 canoes, each one struggling to maintain catch size. Common beliefs as to why catch sizes are decreasing include faulty or inadequate equipment and the presence of illegal trawlers within the 'Exclusive Economic zone'. Few know that overfishing of a finite resource, or a 1 degree warming of the sea that has killed off the zooplankton (the main source of food for herring), could be the main reasons. Pollution and ecosystem health contribute to the problem. There is not sufficient treatment of the waste going into the sea, leading to nitrogen pollution as sewage releases nitrogen into the environment. There is also an issue around coastal erosion, as people take sand from the beaches to build houses.

The canoe community in Ghana are a powerful lobbying group. All boats are registered with

the fishing associations, who distribute Government-subsidised diesel. The canoe fishing community also get subsidised engine parts for maintenance. The canoe fishers en masse are powerful because politicians like the employment opportunities offered by the industry – not just fishing, but preparing and selling the fish, transportation, maintenance of boats.

The Ministry of Food and Farming, Ghana, is working with partners towards sustainable management of the nation's fisheries. This is likely to become increasingly important as the population continues to rise and environmental factors continue to have an impact on fish stocks. Alternative sources of protein will need to be explored, as will alternative employment opportunities for thousands of artisan fishers.

3.5 Conclusions

1. **The consumption of water, food, energy and minerals is a basic need for survival, and in some parts of the world it is not being met.** By contrast, a high level of consumption in some countries may lead eventually to loss of wellbeing by the consumer and, in a world with finite resources, also result in the deprivation of others.

2. **Global consumptions of water, food, energy and minerals have grown rapidly in recent years, both overall and per capita.** The rates of change differ between different income categories, and countries with different population sizes.

3. The drivers of consumption are complex. **For those living in poverty, the primary drivers are the attainment of adequate living standards. For others, the drivers include habit, consumer competition, social conformity, and demographic factors such as age structure change and migration.**

4. **Consumption and demography are closely inter-twined. Every person must consume, and each additional person on the planet will add to total consumption levels.** Other than population size, demographic factors such as ageing or urbanisation can also influence consumption levels. Policies should not treat population and consumption as separate issues.

A finite planet

4.1 Introduction

Human wellbeing and the state of the natural environment are closely linked. The environment provides natural capital which, through production and consumption, forms the basis of many of the material and non-material inputs to human wellbeing. Wellbeing is discussed further in Chapter 5.

Functioning ecosystems support life on Earth, and human populations, like those of other species, cannot continue to grow indefinitely. On a planet with finite resources there are limits to growth. The challenge of understanding where those limits lie is more difficult than it might at first seem, because what constitutes a resource changes with scientific understanding, technological developments and human values. For example, in the 18th century oil from the ground was largely a valueless curiosity while human slaves were a significant source of economic income. Economic, political and cultural factors are of major significance in managing consumption and population growth within planetary limits, however those limits are inferred, so that finite resources and the potential for all people, and subsequent generations, to lead healthy and fulfilling lives are not compromised.

As demonstrated in Chapter 3 the consumption of natural resources is increasing around the world (although at different rates in different regions). The interactions between population, development and environment vary globally and regionally, and there are important differences among countries at different stages of development. Additionally, the structure and distribution of specific populations affect the consumption patterns and trends.

At a global level, the scale and rate of environmental changes observed over the last century are so large that this period of planetary history has been referred to as the Anthropocene (Crutzen and Stoermer 2000; Ellis 2011; Vitousek *et al*. 1997). This label is intended to indicate that human activities are having impacts on the Earth on a scale equivalent to major geological events of the past. The magnitude of change observed to date is leading humanity closer to, or in certain cases beyond, environmental limits, echoing earlier arguments that human population had moved beyond the planet's carrying capacity (Rockström *et al*. 2009 and see Figure 4.2).

With the increase in global scale environmental problems such as climate change, pollution, stratospheric ozone depletion, and ocean acidification, and as understanding of potential thresholds and feedbacks has grown, the finite nature of Earth is again receiving attention. As understanding has grown of the importance of natural capital for human wellbeing, so too have concerns about the risks of exceeding environmental thresholds.

This Chapter aims to summarise the impacts that population in combination with consumption has had on the environment and to discuss the implications for human wellbeing from the perspective of a finite planet.

4.2 Natural capital and ecosystems

Natural capital refers to the assets of the natural world that produce flows of goods and services valued by people. Natural capital stands in relation to the goods and services that flow from it as the amount of money (wealth, or capital, a stock) in one's bank account stands in relation to the interest one earns on that money (income, a flow of money per unit of time). Income from natural capital can be of direct use in consumption (fisheries), of indirect use as inputs in production (oil and natural gas; the wide array of ecosystem services), and of use in both (air and water). This report uses an inclusive definition, which includes fossil fuels.

Natural capital includes potential future use-value of a resource, combined with the irreversibility of its depletion. The genetic material in tropical forests provides an example, since it is not certain which parts of the genetic material will prove useful in the future. As tropical species become extinct, so does the genetic material they carry, and any potential future value the material may offer – future options for humanity – is lost. Accordingly, this additional worth of natural capital is often called an *option value*. The forest's worth could be from the products extracted from it (timber, gum, honey, fruit and bark), or from its presence as a stock (forest cover), or from both (watersheds). The stock could be an index of quality (air quality) or quantity. Ecosystems are interacting systems of living organisms and non-living components in a defined area of any size. Organisms in an ecosystem interact with their physical environment, acquiring resources from it,

influencing it through their behaviour and products, and being influenced by it. They also interact with each other: they compete for resources, feed on each other (by grazing, predation or parasitism) and cooperate in mutualistic relationships. The set of organisms and their interactions with each other and the physical environment determine a wide range of processes that underpin the operations of the natural world.

Like other species, humans are part of and dependent on these ecosystems and their properties. As organisms interact with each other and their physical environment, they produce, acquire, or decompose biomass and the carbon-based or organic compounds associated with it. They also move minerals from the water, sediment, and soil into and among organisms, and back again into the physical environment. In performing these functions, they provide materials to humans in the form of food, fibre, and building materials and they contribute to the regulation of soil, air, and water quality (MA 2003).

Ecosystem services are activities or functions of an ecosystem that provide benefit (or occasionally disbenefit) to humans. The Millennium Ecosystem Assessment (2003) developed the concept of ecosystem services using the four categories of provisioning, regulating, cultural, and supporting services (see Box 4.1).

Box 4.1 Ecosystem Services

Supporting Services are those necessary for all other ecosystem services, and their impacts on people are either indirect or occur over a very long time period. Changes in the other categories have relatively direct and short-term impacts on people. Supporting services include primary production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and pollination.

Provisioning Services are the products obtained from ecosystems, including food and fibre, fuel, fresh water, genetic resources, biochemicals, natural medicine and pharmaceuticals.

Regulating Services are the benefits obtained from the regulation of ecosystem processes, including air quality maintenance, climate regulation, water regulation, erosion control, water purification and waste treatment, regulation of disease, biological control, pollination, storm protection.

Cultural Services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

This classification is not absolute: some services can appear under more than one heading. For example, pollination is both a supporting service (through determining the structure and dynamics of natural plant communities,) and also a regulating service (through fertilisation of crop plants).

The UK National Ecosystem Assessment (NEA) distinguishes final ecosystem services that directly deliver welfare gains and/or losses to people through goods, from the general term 'ecosystem services' that includes the whole pathway from ecological processes through final ecosystem services, goods and values to humans (UK National Ecosystem Assessment 2011). Goods are products that are used or consumed by people: most goods provided by ecosystems also have other inputs: for example, food is a good that is essential for humans, but typically the food that people eat has been harvested, transported and often processed before it is eaten. In this case the good may be a loaf of bread and the final ecosystem service is wheat grain, but these depend on a wide range of other ecosystem services, including soil formation, nutrient and water cycling and disease control.

Changes to ecosystems and the services they provide may have either direct or indirect effects on human wellbeing (see Chapter 5). Direct effects typically occur quickly, through locally identifiable biological or ecological pathways. For example, pollution of wetlands may affect drinking water, the deforestation of hillsides can expose downstream communities to the hazards of flooding, and the destruction of mangrove forests to allow shrimp farming can damage fisheries and expose communities to tsunami damage (Barbier 2006).

Some changes to ecosystem services may take decades to have an impact. For example, where farmlands under irrigation become saline, crop yields are reduced; this in turn may affect human nutritional security, child growth and development, and susceptibility to infectious diseases. Beyond threshold points, limited or degraded supplies of fresh water may exacerbate political tensions, impair local economic activity and reduce aesthetic amenity. These dynamic, interacting processes jeopardise various aspects of human wellbeing.

The psychological and health aspects of being in direct contact with nature must also be properly understood. There is strong evidence to show that facilitating nature-based activity and social engagement (proving locations for contact with nature, physical activity and social engagement) is good for wellbeing through positive health benefits (Laumann *et al*. 2003; Pretty *et al*. 2005; Kaplan 2001; Maller *et al*. 2006; Wells *et al*. 2007; Bowler *et al*. 2010) as well as psychological and cultural benefits.

4.3 Trends in environmental change due to population and consumption

The two major drivers of environmental change are population and consumption (MA 2005b; de Sherbenin *et al*. 2007), and to date, the most significant direct causes of environmental change have been exploitation of resources, land conversion, pollution and invasions by non-native species. In addition, climate change and other forms of pollution are expected to become increasingly important factors (MA 2005c).

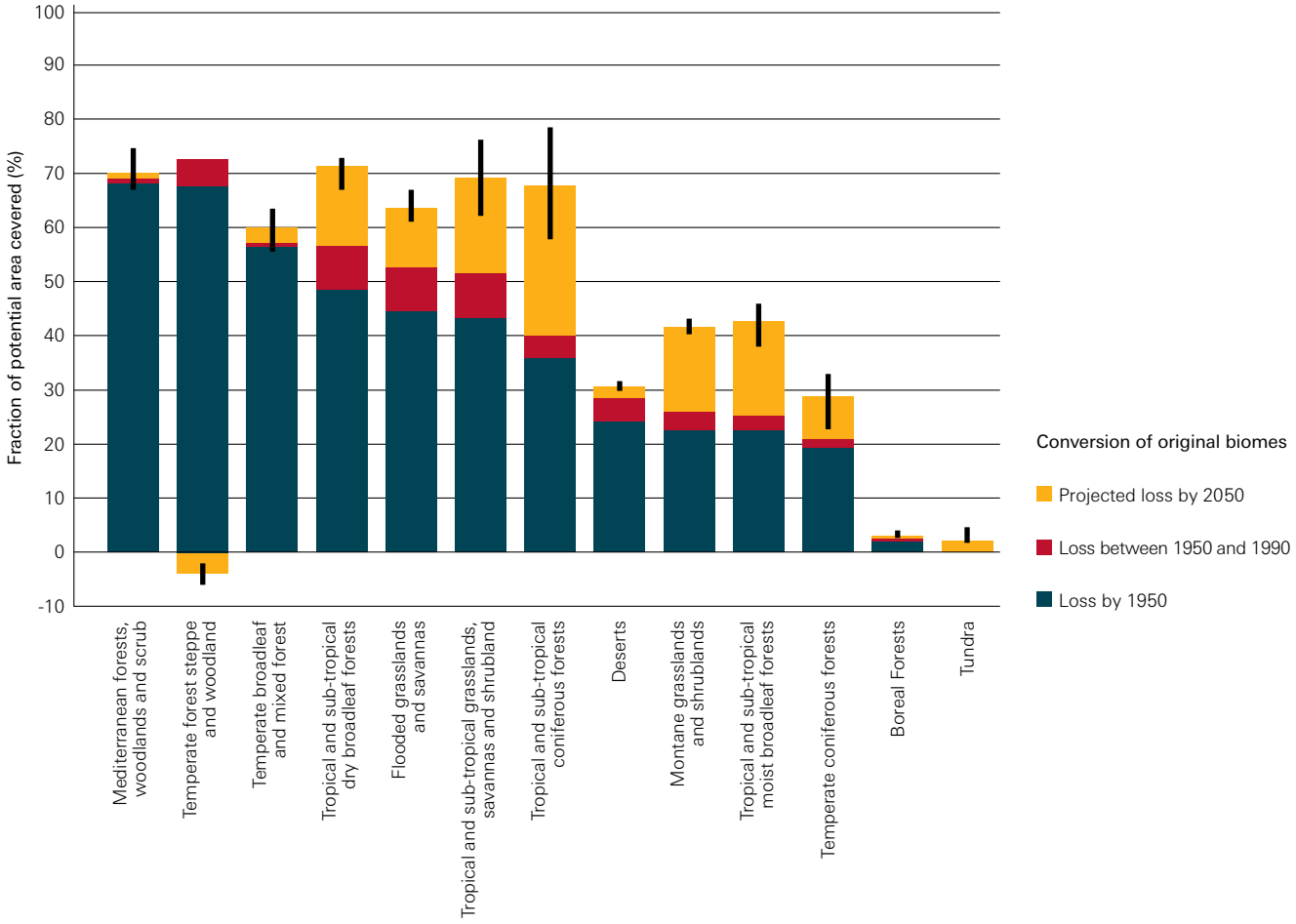
This section explores the nature and magnitude of the environmental change due to human activities with four examples: land-cover change, freshwater, oceans and biodiversity loss. Climate changes resulting from human activities have been extensively discussed elsewhere (Cohen 2010; Royal Society 2010; IPCC 2007c).

4.3.1 Land-cover change

Human population growth influences long-term patterns of land use, which is a major force behind environmental changes (Liu *et al*. 2005). By the year 2000 most of the terrestrial biomes were at least partially transformed for human use, and more than half of the terrestrial biosphere was transformed into intensively used areas dominated by people (MA 2005d; Ellis 2011). There is an accelerating transformation of land for human use - see Figure 4.1 overleaf (MA 2005e). At least 25% of the global land area is now devoted to some form of cultivation (as croplands, shifting cultivation, confined livestock production or freshwater aquaculture). Areas that have been long-settled including grasslands, croplands, rangelands and some woodlands are now largely transformed by people, and their original ecological communities altered or sometimes shifted outside their natural range. Other areas such as rangelands in savannahs, shrublands, and grasslands are also significantly transformed, but at lower levels of intensity.

One measure of the impact that people have on the world's ecosystems is through an estimate of the proportion of the total productivity of the Earth now used by people. Vitousek *et al*. (1987) first suggested that about 40% of the present net primary production in terrestrial ecosystems was being co-opted by people each year. More detailed work since has supported this basic conclusion, while emphasising significant regional variation. Scarcely populated but intensively cropped areas such as the North American Corn Belt, as well as densely populated regions such as large parts of Europe, India, China and South-East Asia, have much higher proportions of net primary productivity directed entirely to human consumption. This human appropriation of natural primary productivity inevitably affects other land uses and the status of natural habitats and wild species, but also raises concerns about how sustainable such high intensities of land use can be over longer time scales (Haberl *et al*. 2007).

Figure 4.1 Conversion of major terrestrial biomes for human use. The conversion before 1950 is based on the estimated extent of the original biomes before human impact began. The loss to 2050 is an average projected from the four MA scenarios, the error bar representing the range in each case.



Source: MA 2005e

4.3.2 Freshwater

Global freshwater environments are subject to an array of anthropogenic changes, which are attributable both to modifications of freshwater bodies themselves, and alterations in the global hydrological cycle of which they are a part (Alcamo *et al*. 2008). The capacity of inland freshwater environments to provide ecosystem services is in decline, according to a range of indicators (MA 2005a).

Significant changes in the physical characteristics of freshwater systems around the world are attributable to persistent changes in precipitation and long-term alterations of surface and subsurface moisture stores and run-off. Modification of freshwater flows has wide-reaching impacts. For instance, approximately 50,000 large dams are in operation today (Scudder 2005). The resulting flow alteration modifies channel and floodplain habitats, affects aquatic species' reproduction, can inhibit movement across, up-and down-stream, and can facilitate the invasion of exotic and introduced species (Bunn and Arthington 2002).

The chemistry and ecology of inland freshwater has also been modified by human influence. Measures of nutrient fluxes, eutrophication (enrichment of nutrients in water), salinisation, chemical contamination, microbial contamination and acidification consistently show human-induced change around the globe (Meybeck 2003). Freshwater habitats are experiencing high declines in biodiversity: for instance, one study projects that North American freshwater fauna will decline by 4% per decade, given current rates (Ricciardi and Rasmussen, 2001). Whilst surface freshwater quality has undergone some improvements in many More Developed Countries, it is continuing to deteriorate in many Less Developed Countries, particularly where

industrialisation and urbanisation is rapid (Alcamo *et al*. 2008). The loss of basic ecosystem services that freshwater provides will impact severely upon the many poverty-stricken inhabitants of Less Developed Countries.

Freshwater bodies suffer depletion where withdrawals substantially exceed natural recharge rates (Gleick and Palaniappan 2010). Well-known examples of such human impacts include the ongoing depletion of the Ogallala Aquifer in the US Great Plains at rates of between 1 to 3 feet annually. The aquifer supplies water for drinking and irrigation over a wide area of the USA (Clark and Brauer, 2010). The Aral Sea, which lies between Kazakhstan and Uzbekistan, has declined to approximately 10% of its original size since diversion of its input rivers to irrigation (Micklin and Aladin 2008). In both cases, human activities have made unsustainable changes to freshwater bodies, to the long-term detriment of both people and nature.

4.3.3 Oceans

Human activities are altering the ocean in a variety of ways, including the warming of the surface ocean and sea level rising. The effects of anthropogenic CO_2 permeating the ocean are described in Box 4.2.

Human activities, including intensive fishing around the world, are also altering ocean ecosystems beyond their natural state. Fish, shellfish, and other important species are declining in many places, large ocean predators are depleted everywhere and pollution, while poorly monitored, is an increasing problem in offshore as well as an established problem in coastal zones. One recent study mapped 17 human activities and their impact on the seas and found that 40% of the world's oceans have been heavily affected by human activities, including fishing, coastal development and pollution from shipping. The most severely affected areas are the North Sea, South and

Box 4.2 Ocean acidification

Related to, but distinct from, climate change, ocean acidification is a consequence of the increase in CO_2 emissions arising from deforestation, agriculture and burning of fossil fuels. Over the past 200 years the oceans have absorbed approximately a quarter of the CO_2 produced from these activities (Royal Society 2005). This has affected ocean chemistry and has caused the oceans to become more acidic - reducing the concentration of carbonate ions that are required for the growth and/or survival of many marine organisms, including coral reefs, most shellfish and some fish species. Although a global issue, impacts will be regionally variable, with the Polar Regions, upwelling areas, and coral reefs (the most biologically productive regions of the ocean) likely to be most affected. Whilst the impacts of these changes on oceanic ecosystems and the services they provide[1] cannot yet be estimated accurately, they are potentially large. Under current global emission rates it is projected that by 2020 10% of Arctic waters will be corrosive to species key to Arctic food webs and this could reach 80% by 2060 (InterAcademy Panel on International Issues 2009).

The effects of ocean acidification will be in addition to those due to climate change and pollution, making the impacts uncertain. Some species are likely to benefit, but others will not, leading to potentially profound ecological shifts as a result. Whilst there may possibly be some feasible localised technological fixes, the only practical way to minimise the risk of large-scale and long-term changes to the oceans is to reduce CO_2 emissions (Royal Society 2005).

1 For example in fisheries, coastal protection, tourism, carbon sequestration and climate regulation.

East China Seas, Caribbean, Mediterranean, Red Sea, the Gulf, the Bering Sea, the East Coast of North America and the Western Pacific, and few if any areas remain untouched (Halpern *et al*. 2008).

4.3.4 Biodiversity loss

According to the Convention on Biological Diversity, biodiversity is the variability of life within and between species as well as at the level of ecosystems (see http://www.cbd.int for more information). A recent assessment (GBO3: http://gbo3.cbd.int/the-outlook/gbo3/biodiversity-in-2010.aspx) concluded that despite an increase in conservation efforts, the state of biodiversity continues to decline.

Extinction rates of wild species are hundreds to thousands of times higher than 'background' rates in the fossil record (MA 2005e). Wild populations of vertebrates have declined on average by over 30% since 1970 (WWF 2010) and few areas are left that are not affected by human activities directly or indirectly. Since some habitats and wild species (especially those with generalist habits) are more resilient to human pressures, the impact of people on nature is to alter both the type and amount of wilderness left. Polar regions, deserts and mountain areas suffer fewer direct impacts, but indirect impacts of increasing population and consumption (eg through climate change) can affect these areas substantially. Highly productive areas of natural habitat in temperate and tropical zones have been and are being lost at unprecedented rates (see Figure 4.1), leading to the loss of the species that live only there. Large predators have high extinction rates and are declining at high rates everywhere, as are some of the areas of highest biodiversity, for example in South America and Southeast Asia, which are now undergoing rapid conversion to agriculture. Apart from the loss of option values to future human wellbeing, this represents a failure of stewardship by the most powerful species on earth.

These measures provide an aggregate indication of the scale of environmental changes that are occurring due to human activity. However, to understand the role that human population change plays in driving these global scale and rapid environmental changes requires closer investigation of the particular pressures from population size and consumption on the environment.

4.4 Modelling human environmental impact

Attempts to attribute environmental change to population size and growth alone are likely to be inaccurate oversimplifications (de Sherbenin *et al*. 2007), as there is no simple relationship between population growth and growth in consumption: people do not consume equally, due to social, political, cultural and technological effects (see Chapter 3).

A number of ways of conceptualising or representing the relationship between population growth, economic development and environmental degradation have been developed; none of these is unproblematic (not least because of their highly aggregative nature); some suggest that degradation is a 'phase' of development, others that degradation might intensify as development continues.

The **environmental Kuznets Curve** assumes that environmental degradation follows an inverted U-shaped curve as development proceeds. In Less Developed Countries, providing people's basic material needs is of greater urgency than environmental preservation; in the early stages of economic development, as economic activity per person increases, environmental degradation is taken to be an acceptable price. However, when a country has attained a sufficiently high standard of living, then people are assumed to care more about environmental amenities, pass environmental legislation and create new institutions to protect the environment. It is important to understand the Kuznets curve because some people use it to argue, probably incorrectly, that no policy interventions are required to prevent environmental degradation in the course of economic development. (For a more detailed description see, for example Torras and Boyce 1998).

The curve has been demonstrated to be appropriate only for a very limited set of cases, such as sulphur or particulates in the atmosphere, but not for the accumulation of waste or for long-term and more dispersed costs, such as carbon dioxide, which typically have been found to increase continuously with income (World Bank, 1992; Stern, 2006).

One of the most well-known frameworks for describing the relationship between population, consumption and the environment is the **IPAT**

equation (I=P*A*T). It relates environmental impact (I) to population size (P), affluence per capita (A) (a measure of consumption and production) and the level of environmentally damaging technology (T) (Ehrlich and Holdren 1971, 1972; Holdren and Ehrlich 1974).

IPAT identifies some of the important factors that influence environmental impact. When applied carefully it can also be a useful accounting identity for relating historical population trends, economic growth and changes in technological efficiency to the level of resource use and emissions. It enables questions to be asked about the potential for technological change, the relationship between economic growth and population change, and the potential feedback mechanisms between environmental impact and population growth. However, it does not account for other drivers of environmental changes such as policy, institutions and complexity of social factors that have been shown to be significant in regional and local scale assessments (Turner 1996). It has been criticised for being too simplistic, for treating the variables as being independent of each other, and for not allowing for non-linearities, thresholds and feedbacks in environmental systems (see evidence from Harte) or cumulative environmental effects. IPAT does not look at the effects of population characteristics (such as age structure, sex structure, distribution and density) that may influence both consumption and the technology used.

In an attempt to capture more complexity and interactions between the IPAT variables, Dietz and Rosa (1994, 1997) developed Stochastic Impacts by Regression on Population, Affluence and Technology or **STIRPAT**. STIRPAT allows for the consideration of context when analysing population-environment relationships by adding control variables to the model. For example, the model can include demographic characteristics other than population size, such as age structure and urbanisation (eg Dietz *et al*. 2007; Knight 2008). While most STIRPAT analyses have been applied at the macro-level of countries, the model can be used on any spatial scales from cities to nations (eg Scholz 2006). The first empirical application of STIRPAT analysed the anthropogenic drivers of carbon dioxide emissions (Dietz and Rosa 1997). Later applications focused on emissions as well as ecological footprint (eg Dietz *et al*. 2007; Rosa *et al*. 2004; York *et al*. 2003a, 2003b).

4.5 A finite planet?

There have been a number of different attempts to examine which resources are over-used or depleted or to see how close the human population is to some ecological thresholds, which are summarised in this section.

4.5.1 A sustainable population?

One approach has been to try to define an optimum population for the Earth. However, attempts to quantify the Earth's human carrying capacity or a sustainable human population size face the challenge of understanding environmental constraints, human adaptability, human choices and the interactions among them all. For example, what will humans desire and accept as the average level and distribution of material wellbeing in 2050 and beyond, and who will make those decisions? What technologies will be used? What physical, chemical and biological environments will people want to live in? What level of variability will people accept? And what level of risk are people willing to live with?

Most published estimates of Earth's human carrying capacity uncritically assume answers to these questions, though the answers are not necessarily made explicit. Cohen (1995) analysed over 60 estimates published from 1679 onward which in the past half century alone ranged from less than one billion to more than one trillion people. Van Den Bergh and Rietveld (2004) gave an updated survey of estimates of Earth's human carrying capacity. Cohen (1995) concluded that estimates are often highly political, intended either to demonstrate that there are too many humans already on Earth or that further growth presents no problems. Because no estimates of human carrying capacity have explicitly addressed the questions raised above, taking into account the diversity of answers, that vary across societies, cultures and times, it must be concluded that no reliable scientific estimates of sustainable human population size exist, and that such estimates would be provisional and technology dependent. Defining a pathway to a sustainable population, when there is no agreement of the final destination, is thus highly contentious.

A more useful approach to exploring the concept of a sustainable population has been to measure the ability of environmental systems to deliver the natural goods and services upon which humans depend. Despite the core problem in defining the limits to the planet and the role that the size of the human population plays in reaching or exceeding those limits, several approaches have been developed in the last 30 years, mostly from the perspective of the environmental sciences.

4.5.2 Ecological footprints

The ecological footprint is an estimate of the amount of the Earth's renewable resources requisitioned by human activities. It has been developed over recent decades by the Global Footprint Network (www.footprintnetwork.org), recalculated and reported annually in the WWF Living Planet report (WWF 2010). It is an accounting method using international statistics on resource flows of natural and renewable resources that are consumed by people and subsequent wastes that are naturally sequestered. Based on people's use of resources and the land area estimated to be necessary to support their production, the footprint is calculated to reflect the area of land surface that the human population, at some point in time or place, uses for consumption and to disperse associated pollution and waste.

The measures used to calculate the footprint are standardised to a common unit, a global hectare. This encompasses the average productivity of all the biologically productive land and sea area in the world in a given year. The footprint can be calculated separately for different nations and development groups, and can be tracked over time. The aggregation and disaggregation of data can pose some difficulties for interpretation of the footprint, which cannot account for heterogeneity of different land uses, and is insensitive to by-products of production, impacts on biodiversity and natural ecosystems, and to environmental change. However, the metrics do indicate trends and can be useful for comparisons over time and across different countries and country groupings.

The Global Footprint Network uses a measure of the capacity of the Earth against which to compare the footprint. Using this 'bio capacity' measure it is possible to estimate how much of the Earth (or how many planet Earths) it would take to support humanity if everybody continues current patterns of resource use, or under some other given lifestyle. This method suggests that the Earth's capacity was exceeded by people sometime in the 1980s and that by 2010 the estimate was that human activities were using about 1.5 times the area that would be available on the Earth on a sustainable basis. The biocapacity measures are not easily comparable to planetary boundaries (below) as they are based on accounting metrics and take no account of the Earth's processes and systems that define the boundaries.

The main problem with this approach is that the Global Footprint Network tries to account for all of humanity's multifaceted demands on the planet by reducing them down to one comparable unit: land area. This can miss some important side effects and whole activities. For example, energy produced by nuclear power is converted to global hectares by calculating how much biologically productive land would be required to absorb the carbon dioxide released if fossil fuels were burnt to generate an equal amount of energy. The challenge posed by waste nuclear fuels is not addressed. Nor is the difference between a tropical rain forest with its native species and the same area of a palm oil plantation if their net primary productions are equal. A Water Footprint has been developed independently to measure the water a population uses directly or indirectly (Hoeksta 2008). The trend seen in the Global Footprint Network is difficult to challenge, but the precise time when human activity exceeds the planetary capacity to support it is more open to question.

4.5.3 Ecosystem Assessment

An ecosystem assessment is a systematic evaluation of what is known about the status, trends and future trajectories of ecosystems, focusing on the benefits that they provide to people. Recent assessments, starting with the Millennium Ecosystem Assessment (MA) in 2005, have reviewed and analysed scientific information on ecosystems and the kinds of benefits that humans derive from them (MA 2005f). The MA concluded the following:

- Many changes that have been made to ecosystems have contributed to substantial net gains in human wellbeing and economic development (particularly by enhancing the provision of natural resources (eg food via agriculture and fisheries). However these gains have been achieved at growing costs in the form of the degradation of other ecosystem services, which has led to increased risks of nonlinear (and therefore unpredictable) changes, and the exacerbation of poverty for some groups of people (through loss of access to water, for example). These problems, unless addressed, will substantially diminish the benefits future generations obtain from ecosystems.

- The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals.

- The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be partially met under some scenarios that the MA has considered, but these involve significant changes in policies, institutions, and practices that are not currently under way. Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.

The MA documented that over 60% of global ecosystem services were deteriorating or already overused. The ecosystem services that were found to be enhanced were those related to food and, to some extent, fibre production. In many cases management of ecosystems for provisioning services, such as food, fibre and water, had led to unintentional deterioration in ecosystems' capacity to support other kinds of services, including important regulating services such as flood, pest and disease control, and climate regulation (MA 2005c).

Recently, the UK National Ecosystem Assessment (NEA) (2011) developed the MA scheme of ecosystem services to enable it to be integrated with economic and other schemes of valuation, with potentially large implications for public policy. The NEA divides ecosystem services into the supporting services that are the fundamental ecosystem processes; the final ecosystem services (principally the regulating, provisioning and cultural services recognised by the MA), which may provide direct benefits to humans; and goods which are derived from those services, typically by the input of other materials or actions and which can be ascribed actual values, whether economic or otherwise.

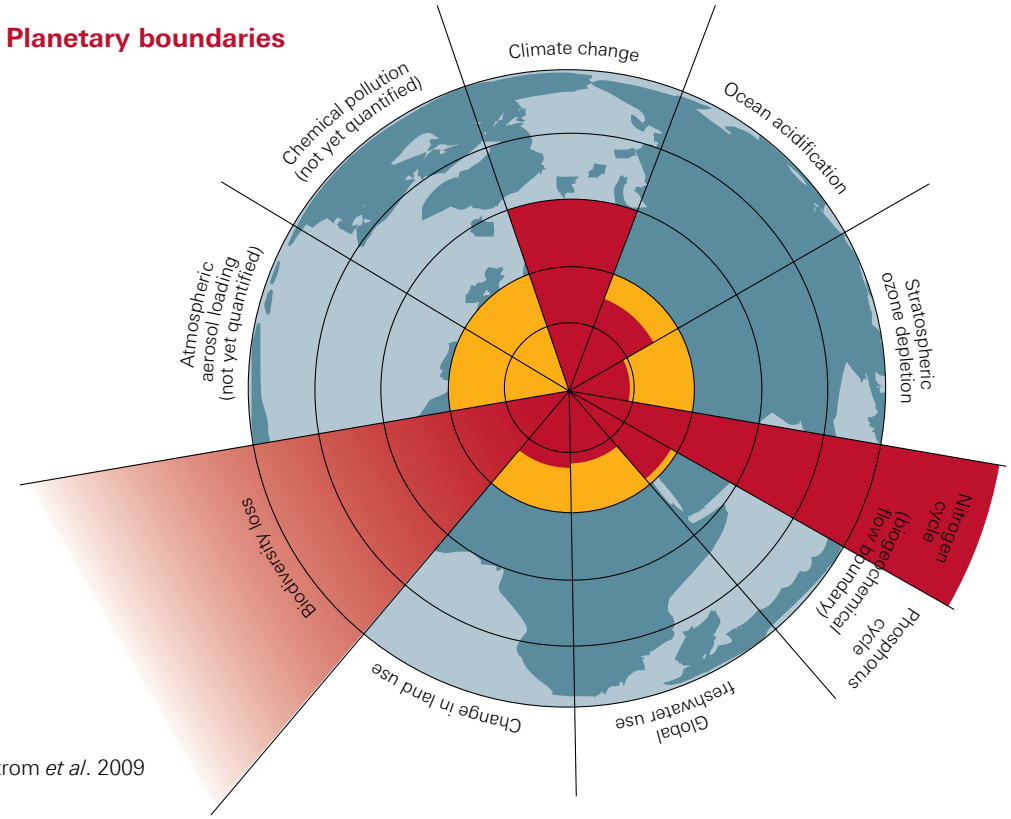
4.5.4 Planetary boundaries

Taking a systems approach to the Earth's processes, Rockström *et al*. (2009) defined nine 'planetary boundaries' that humanity needs to stay within to avoid unacceptable environmental change. The boundaries represent points at which human-linked changes in an Earth system reach a level beyond which it may be deleterious (ie reduce the ability of global systems to provide essential natural services and goods), or even catastrophic. A catastrophic change would be one that caused major loss of life or required substantial re-organisation of society; a global mean temperature rise of 4^0C or a large rise in sea-level would be examples of catastrophic change.

The Earth system includes the interacting chemical, physical and biological processes that underpin life, mainly through cycles for carbon, water, nitrogen and other elements, and the life cycles of species and ecosystems. People are part of these cycles and increasingly have come to dominate them, with potentially detrimental consequences in certain cases. Staying within the planetary boundaries defined by Rockström *et al*. (2009) should allow humanity to persist at standards of living deemed acceptable by the authors of this paper.

The nine boundaries identified were climate change, stratospheric ozone, land use change, freshwater use, biological diversity, ocean acidification, nitrogen and phosphorus inputs to the biosphere and oceans, aerosol loading and chemical pollution. Detailed study suggests that three of these boundaries (climate change, biological diversity and nitrogen input to the biosphere) may already have been crossed. However, the estimates for all are uncertain and the authors acknowledge that there may be many other boundaries that have not been identified.

Figure 4.2: Planetary boundaries



Source: Rockstrom *et al*. 2009

The planetary boundaries approach highlights which of the life support systems are most likely to involve problems for continued human wellbeing, but does not allow for the many alternative ways of operating within those boundaries. It does not easily lend itself to analysis of regional-scale changes, to spatial analysis or to integration with other disciplines such as demography, each of which is necessary to offer an integrated approach to population questions.

4.5.5 Evidence of limits to the Earth

The four markedly different approaches to analysing the Earth's environmental limits show that land use change and management have been extensively used to meet many of the immediate material needs of growing populations. This has resulted in substantial transformations of the land surface and some seas, especially in recent times, and this has fundamentally altered many Earth system processes. It is not yet certain whether humanity is approaching limits to the Earth's productivity, but humans have already altered some Earth system processes (such as climate regulation and nitrogen cycles) with known impacts. Other Earth system processes have been radically altered with almost certainly deleterious consequences that are poorly understood (eg biodiversity loss, ocean acidification), while others may have imminent consequences (eg freshwater availability, fisheries).

4.6 Will markets and technology neutralise environmental constraints?

The view that humanity is constrained by environmental limits has been criticised by many on the grounds that absolute resource scarcity does not exist and cannot exist because well functioning markets will stimulate substitution and innovation, and that technological or cultural innovation will provide alternatives. Some economists maintain that environmental degradation is a transient phase in development, or that technological fixes will soon address limitations in natural resources. However, most environmentally based analyses (see section 4.5) suggest that there are real limits to the Earth's resources, that impacts are already being felt and that they will increase in intensity unless there are major reductions in the pressures on the environment (MA 2005c; UNEP Global Environment Outlook http://www.unep.org/geo/GEO5_Products.asp).

4.6.1 Will the market provide substitutes?

Debates over ecological limits frequently centre on the extent to which people are able to substitute one thing or service for another. Many believe that problems arising from the depletion of natural capital can be overcome by the accumulation of knowledge, manufactured capital and human capital. Others believe there are limits to substitution possibilities.

Four kinds of substitution help to ease resource constraints, either local or global. First, one thing can substitute for another in consumption (nylon and rayon substituting for cotton and wool cloth, pulses substituting for meat). Secondly, manufactured capital can substitute for labour and natural resources in production (the wheel and double-glazing are two good examples). Third, novel production techniques can substitute for old ones (the replacement of horse power by the internal combustion engine for vehicle propulsion). Fourthly, natural resources themselves can substitute for one another (renewable resources substituting for non-renewable sources of energy).

These examples suggest the general idea that, as each type of natural capital is depleted, there may be close substitutes available, either at the same site or elsewhere. If this were true, then, even as constraints increasingly bite on any one resource base, humanity should be able to move to other resource bases. The enormous additions to the sources of industrial energy that have been realised (successively, human and animal power, wind, water, timber, water, coal, oil, natural gas and, most recently, nuclear and solar power) provide a historical illustration of this possibility.

When experts talk of the limits to conventional economic growth (ie growth in GDP), they often mean that the scale of human activity has increased so much since the dawn of the Industrial Revolution that unchecked continued GDP growth would place undue stress on the major ecosystems that remain. The cost of substituting manufactured capital for natural capital is rising. Low-cost substitutes could turn out not to be low-cost if their full environmental costs were to be included in their market price.

It is possible that a society accumulates manufactured capital, human capital, and knowledge – and perhaps even improves the character of some of its institutions - but depletes its natural capital to such an extent that its overall wealth declines. The problem is that if natural capital does not enter national statistics, no one in the statistical office realises that wealth has declined. Despite the decline in overall wealth, GDP per capita shows an increase and the United Nations' Human Development Index (HDI) records an improvement. If so, students of the economy are misled into thinking that all is well. However, even though that pattern of development could be viable for a while, perhaps for many years, it would not be viable indefinitely. If wealth were to decline continuously, the productive base would continually shrink. Eventually, GDP would have to decline, as would HDI. The world economy can engineer GDP growth by "mining" its natural capital for an extended period of time, but eventually the scope for that particular type of substitution will run out. Of course, a small country that is rich in a tradable form of natural capital (eg a sub-soil asset like oil) could accumulate wealth in other forms of capital assets, by drawing down its reserves and exporting them. But the world as a whole does not enjoy that luxury.

Typically it is assumed in conventional models of economic growth that nature is a fixed, indestructible factor of production. The problem with the assumption is that it is wrong: nature consists of degradable resources. Agricultural land, forests, watersheds, fisheries, fresh water sources, estuaries, the atmosphere - more generally, ecosystems - are resource stocks that are self-regenerative, but suffer from depletion or deterioration when they are over-used. (This excludes mineral resources, which are vanishingly slow to regenerate.) Moreover, the environmental sciences tell us that the extent to which manufactured capital and human capital, on the one hand, and vital forms of natural capital, on the other, are substitutable is very limited (see Ehrlich and Goulder 2007 for a formal account of what "limited substitution" means). At a time when natural resources were abundant relative to the demands on them, it was understandable for economists to assume that nature does not need to be counted, but it is not tenable in models of development possibilities open to the world today. The approach taken in modern growth models is also questionable because property rights to natural capital are often either vaguely defined or weakly enforced, so that natural capital and ecosystem services are underpriced in markets.

Official statistics on national income give the impression (by omission) that natural capital is of little importance; but official statistics are based on market prices, not shadow prices (Box 4.3). Studies of local ecosystems suggest that if shadow prices were to be used in economic statistics, the decomposition of national income into its various components would look quite different. For example, Repetto *et al*. (1989) and Vincent *et al*. (1997) estimated the decline in forest cover in Indonesia and Malaysia, and found

Box 4.3 Shadow prices and failure of property rights

Why do market prices not reflect nature's scarcity? If natural capital really is becoming scarcer, would their prices not have risen, signalling that all is not well?

If prices are to reveal social scarcities, markets must function well. However, for many types of natural capital, especially ecological resources, markets function poorly. In some cases they do not exist because relevant economic interactions take place over large distances, making the costs of negotiation too high (eg the effects of upland deforestation on downstream farming and fishing activities); in other cases they do not exist because the interactions are separated by large temporal distances (eg the effect of carbon emission on climate for future generations who are not present today to negotiate with current generations). Then there are cases (such as the atmosphere, aquifers and the open seas) where the migratory nature of the resource keeps markets from existing - they are called "open access resources", and they can experience the tragedy of the commons if not regulated (see Box 3.2).

The examples above point to a failure to have secure property rights: ill-specified or unprotected property rights prevent markets from forming or make markets function wrongly when they do form.

"Property rights" means not only private property rights of contemporary people, but also communal property rights (eg over common property resources), state property rights, and the rights of future generations to inherit a non-diminished productive base. At an extreme end are "global property rights", a concept that is implicit in current discussions on climate change. But the concept is not new. That humanity has collective responsibility over the state of the world's oceans was made explicit in the 1970s, when politicians said the oceans are a "common heritage of mankind"(United Nations 1970). The concept was that because future generations are not present to represent their needs and wants, the current generation is the trustee for the future. And because there are strong reasons to believe that left to themselves, individuals do not have the adequate motivation to act as trustees, something like a collective agreement on husbanding nature is required. This needs cooperation, not competition over natural capital.

The failure to establish secure property rights to natural capital typically means that the services that those assets provide are underpriced in the market, or the use of nature's services is implicitly subsidised. One calculation suggested that it is 10% of annual global income (Myers & Kent 2000). International organisations such as the World Bank have the resources to undertake such an assessment operationally, but they have hitherto been reluctant to do so.

An asset's shadow price means the net increase in societal well-being that would be enjoyed if an additional unit of that asset were made available, other things being equal. As shadow prices reflect the social scarcities of capital assets, it is only in exceptional circumstances that they equal market prices. Various methods for estimating shadow prices of natural capital are discussed in Freeman (1992).

As proposals for estimating the shadow prices of natural resources remain contentious, economic accountants can too easily ignore them and governments remain wary of doing anything about them. A firmer and generally accepted basis for natural resource accounting is therefore required (Arrow et al. 2003).

that when depreciation is included, national accounts there look quite different: net saving rates are some 20-30% lower than recorded rates. In their work on the depreciation of natural resources in Costa Rica, Solorzano *et al*. (1991) found that the depreciation of three resources — forests, soil, and fisheries — amounted to about 10% of GDP and over a third of capital accumulation.

Distortions in the pricing of primary factors of production influence research and development. The latter in turn influences the character of technological change. Because nature's services are underpriced in the market, innovators have little reason to economise on their use. It should not be surprising that new technologies (like the old ones) are rapacious in the use of natural capital.

It would be imprudent to trust the invisible hand of the market to guide humanity away from environmental thresholds. With natural capital absent on most balance sheets, it is being depleted without sufficient regard to the full long term costs, and there is insufficient market pressure to develop substitutes. Depletion of some resources and exhaustion of some ecosystem services are not smooth and linear, so that the market might not have time to develop technological alternatives, and in any case certain technological solutions may not be socially or politically acceptable.

4.6.2 Technology and environmental constraints

Recent assessments have attempted to evaluate the potential role of technology and its costs and benefits in alleviating environmental constraints (MA 2005f). In general, technology can be used to reverse some (but crucially not all) problems, and to mitigate others, but often there are risks of unintended and unexpected consequences. The MA identified several areas where there are good prospects of technologies relieving environmental stressors:

- enhancing agricultural production with reduced impacts on other ecosystem services
- supporting ecosystem service restoration
- reducing carbon emissions and increasing energy efficiency.

However, new technologies can also have negative impacts on ecosystems and human wellbeing, and their uncritical application can be damaging unless careful assessment is undertaken prior to implementation. The first steps of this sort of assessment have recently been taken for 'geoengineering' techniques for addressing climate change. Some types of geoengineering may one day be able to reduce environmental risk, but they often carry with them their own large, and as yet unquantified, risks (Royal Society 2009a). Human interference in the nitrogen cycle has provided food for billions of people, but so far has come at the cost of a number of dispersed and damaging side effects eg eutrophication of coastal waters, increases in tropospheric ozone, anoxic[2] marine areas and groundwater contamination (MA 2005g; Fowler *et al*. 2004).

Ecological and evolutionary processes are also vulnerable to human impacts. Impacts on ecological processes are nearly always unplanned and usually deleterious in effect: a broad range of interventions is involved, such as habitat change, the introduction of invasive species from other parts of the world, and the addition of pollutants, including both waste products and pesticides and herbicides. Evolutionary processes can be unintentionally but dramatically affected by the novel and often extreme selection pressures imposed by human activity, notably in harvesting pressures on fisheries and in the widespread use of biocides. Direct and planned intervention in evolutionary processes underlies all breeding programmes, but increasingly novel genetic technologies are being used to accelerate these processes and introduce novelty that would otherwise be unachievable

The delivery of four critical goods derived from ecosystem services (water, food, energy and minerals) is discussed in the following section. The consumption patterns of these goods have been detailed in Chapter 3.

4.6.2.1 Water

In terms of the global water cycle, water is largely a renewable resource with rapid flows from one stock and form to another and the human use of water typically has a negligible effect on natural recharge rates. Even so, fixed or isolated stocks of local water resources are being consumed at rates far faster than natural rates of renewal in groundwater and aquifers (Gleick and Palaniappan 2010). Irretrievable losses from irrigation represent one third of all water loss globally (MA 2005a). The degree to

which water withdrawal exceeds locally accessible supplies, or unsustainable water use, was estimated in the Millennium Ecosystem Assessment as being between 400-800 km^3 per year or 10-25% of total freshwater withdrawals (MA 2005a).

Water scarcity has become a globally significant problem over the last 40 years (MA 2005a). Between 1960 and 2000 the relative use ratio increased by about 20% per decade globally. Since 2000 this was expected to have slowed to about 10% per decade globally (MA 2005a) although in some regions it is expected to remain high due to population growth, economic development and urbanisation. In many world regions including West Asia, the northern plains of the Indian sub-continent, the North China Plain and the High Plains of North America, water withdrawal by humans already exceeds natural replenishment rates (Gleick and Palaniappan 2010). In addition to increased water demand, pollution from mining and industry, urban centres and agricultural runoff limits the amount of surface and groundwater available for domestic use and food production (MA 2005a). By 2025 three out of four people worldwide will face some degree of water scarcity (see evidence from Speidel).

There is a global mismatch between the availability of water and population density. Where water is available it is generally used inefficiently because it is almost invariably undervalued and underpriced (or free). Two key questions therefore are whether technological solutions could provide water in areas of limited availability and large population, and whether agricultural water can be used more efficiently.

Desalination is widely assumed to be a solution to water shortage, at least in areas near coasts. The energy costs of desalination are large but declining, with a theoretical minimum of just over 1 kWh m^{-3} (Elimelech and Philip 2011). Current plants use 3-4 kWh m^{-3} and emit 1.4-1.8 kg CO_2 m^{-3} of water produced. According to the International Desalination Association (2011), there are 15,988 desalination plants in operation worldwide, producing 66.5 million cubic meters per day, an increase of 8.8% over 2010. In the longer term optimised systems are likely to be linked to renewable sources of energy production (solar, wind). Desalination also brings a number of other environmental impacts, notably in the disposal of the concentrated brine stream and through the large infrastructure development necessary for treatment and distribution. Solutions to these problems are likely to be found, and may ensure that sufficient water supply for direct human consumption (but probably much less so for agriculture) is made available in areas of severe shortage.

Improving the efficiency of water use, however, is technically simpler. Many existing practices and technologies could be used if the price of water more accurately reflected its value, especially in relation to the recycling of water and its purification, and to the efficiency of its use in agriculture. Irrigation is the single largest use of water, and efficiency can be increased greatly by recycling, covering irrigation channels, irrigating at night when evaporation is reduced, and accurate measurement of crop requirements (Royal Academy of Engineering 2010).

4.6.2.2 Food

By definition, agriculture has always involved the application of technology to enhance natural ecosystem processes and services: adding manures and more recently inorganic fertilisers enhances the natural nutrient cycles in soil. The switch from manure to fertiliser that has accompanied intensive agriculture in the last 50 years has moved this process away from enhancement towards replacement, with typically up to 60% of the nitrogen in cereals derived from fertiliser in intensive production systems (Tilman *et al*. 2002).

Technology will be needed to play an increasing role if production is to match demand without significantly increasing the area of farmed land, through a 'sustainable intensification' of agriculture (Royal Society 2009b). The improvement of crop varieties through genetic modification and other enhanced breeding technologies can potentially increase the output of crops on marginal soils as well as improving food quality. If the gene complex that allows symbiotic nitrogen fixation can be transferred from legumes to cereals, the need for nitrogen fertiliser and the costs of production would be reduced, although yields would probably not be enhanced beyond current practice. Serious progress is being made on this 'holy grail' of GM crops (Charpentier and Oldroyd 2010; Foresight 2011c).

2 Where no oxygen is present.

However, such technological novelties should not hide the fact that major improvements in food production are possible not only through varietal improvement but also through the wider application of known crop management practices (Royal Society 2009b). These include integrated pest control and inter-cropping systems, in addition to capital-intensive technologies such as precision agriculture which may offer large benefits in countries already practising intensive agriculture.

Biological interactions in agriculture are more challenging for technological interventions. The use of biocides has been a traditional replacement technology for the ecological interactions on which, for example, organic agriculture relies. There is interest in biotechnology companies in making use of soil bacteria known as plant growth promoting rhizobacteria. Some of these have been shown to enhance plant growth in artificial conditions, but manipulating such a microbe to be useable on a large scale would require enabling it to outcompete other bacteria in the soil, something which is not yet feasible other than accidentally due to poor knowledge of the biology of soil communities. More seriously, if an attempt to create such an aggressive microbial strain were successful, it would inevitably spread from its target crop species into other managed and unmanaged ecosystems, with unpredictable consequences.

Enhancing plant-microbe interactions can improve plant health and soil fertility. Mycorrhizal fungi have been shown to be important for the majority of plants and, under conditions of phosphorus limitation, influence plant community development, nutrient uptake, water relations and above-ground productivity. They can also act as bioprotectants against pathogens and toxic stresses (Jeffries *et al*. 2002).

An extreme replacement technology is hydroponics, where plants are grown in glasshouses using nutrient solutions, without involvement of natural processes of decomposition (Jensen and Malter 1995). Since the nutrients are recycled, there is no loss and no eutrophication of runoff, so the approach is more environmentally benign than current intensive agriculture and is likely to be used on an increasing scale as prices rise. Unconventional foods from algal or microbial systems may also become more widely used in areas where other factors, notably fresh water supplies, limit conventional agriculture.

One biological interaction about which there is currently great concern is pollination. Many crops rely on insects for pollination and hence fruit and seed set. In many parts of the world there has been a significant and largely unexplained decline in numbers of pollinating insects, notably honey bees, and in bats, which are also pollinators. Simple technological solutions have been needed to sustain production in Californian almond orchards, where mobile bee hives are moved through the orchards, and in Szechuan (China) where hand-pollination of fruit trees is necessary (EASAC 2009a). Both of these are expensive solutions to replace a previously free service. It is possible to imagine breeding programmes to create self-pollinating forms of all crops that currently require insect pollination. Again such an approach would be time-consuming and expensive, and would of course be unnecessary if the decline in pollinators could be reversed.

Demand for and dependence on livestock has major implications for the environmental foot print of agriculture, since meat production requires greater use per food calorie of land, fertilizer and pesticides. Worldwide, the fishing sector supports the livelihoods of an estimated 540 million people and provides 3 billion people with at least 15% of their total animal protein (FAO 2010). If fish stocks continue to decline serious repercussions will be felt worldwide, particularly given the changes to food production systems that are predicted to occur due to climate changes (Garcia and Rosenberg 2010; Esteban and Crilly 2011). Recently, concerns have been highlighted about the state of global marine fish stocks (eg. Worm *et al*. 2009; FAO 2010; Smith *et al*. 2010) and the part they play in supporting food security and livelihoods for fishing communities (eg Béné and Heck 2005; Garcia and Rosenberg 2010; Béné *et al*. 2010; Srinivasan *et al*. 2010). Despite the varied relationships between people and marine resources, areas with high human population growth and high fisheries dependence, particularly for people in low-income food-deficit countries are likely to suffer the most if fish production decreases.

An increasing proportion of demand is being met from aquaculture, which in 2008 accounted for 45.7% of global fish food production for human consumption, and for 80.2% in China (FAO 2010). Concerns have been raised about the sustainability of aquaculture, with respect to use of wild fish products in feed for farmed fish, destruction of coastal

habitats, and impacts of veterinary drugs. Improved conversion efficiency from wild to farmed fish, and good governance to minimise environmental effects will be important for continued expansion.

Wild fish stocks can sometimes recover quite quickly, where the fish species have high reproductive replacement rates and when monitoring, control and surveillance are developed in order to prevent over-exploitation (Frank *et al*. 2011). The recovery can be facilitated by encouraging small-scale fisheries, as opposed to large-scale industrial vessels. Such a change provides more employment, uses less fuel, and generally has a lower impact on the environment (Pauly 2006). The process can be further facilitated by creating incentives to manage fisheries for long-term benefits, often by establishing property rights, instead of encouraging an open access 'race to fish' that depletes the common resources and threatens ecological stability. Strengthening the effectiveness and cooperation of regional fisheries management organisations (especially the enforcement of any agreed controls) would help to manage shared or migratory stocks, and could also decrease illegal fishing activities which are harmful from an economic and environmental perspective. Finally increasing the number, size and effectiveness of marine protected areas can provide vital habitat for fish to complete their life cycles, provide refuges, and replenish areas depleted by overfishing.

Surprisingly, an immediate solution to food shortage is near at hand if ways could be found to implement it. At present, the world produces enough food for all, but distribution is highly inequitable and seriously inefficient. In high income countries, consumers eat on average more food than is healthy for them; furthermore, unnecessary rejection and waste of edible food occurs for reasons of appearance or over-cautious sell-by dates, and 25% of food is simply discarded after purchase. In low income countries 50% of food may be lost between farm and consumer because of inadequate storage facilities and transport networks, and of market failure; much wastage of food is easily preventable, for example that due to rodent consumption in food stores. Avoiding losses, and curtailing overconsumption where it occurs, would contribute greatly to alleviating current malnourishment and to reducing food requirements in the future (Parfitt *et al*. 2010; Foresight 2011c; Partfitt and Barthel 2011; Hodges *et al*. 2010).

4.6.2.3 Energy

As described in Chapter 3, industrial development has been founded on cheap and abundant energy from burning fossil fuels. Limits are now being reached, not by shortage of fuels but by the consequent emission of CO_2 and other green house gases causing dangerous climate change. Emissions scenarios were produced by the IPCC (special report 2000) and some new analyses of the extent of decarbonisation required are shown in the following section. It is generally understood that there is an urgent need to switch to alternative energy sources or to capture and store CO_2 (CCS). No one approach is likely to suffice on its own, but a combination of nuclear, wind, marine, solar and CCS is in principle able to satisfy human needs, not least those of the Least Developed Countries which urgently need to escape from energy poverty. There is great scope for both existing and new technology in this area, provided the necessary investments are made (for review see MacKay 2008; DECC 2011). Difficulties arise from achieving agreement on full economic costing, including natural capital, without which business continues as usual.

Energy supplied by ecosystems in the form of biomass is still the chief energy source in many parts of the world, and is now increasing in industrial countries (in the form of biofuels) (Royal Society 2008). Many of the issues concerning the production of biomass are the same as for food; indeed food and biofuel production can and do compete for land and resources with undesirable consequences for food prices (Nuffield Council on Bioethics 2011). Approaches that rely on existing crops and arable land will exacerbate that conflict. One suggested alternative is using energy crops specifically developed to grow on "marginal land". However, there are serious problems with this. The concept of 'marginal lands' is poorly defined and is contested, as the marginal land of one person may be the traditional nomadic home of another, and all lands provide ecosystem services. Additionally, it is unclear how great a proportion of humanity's fuel needs can be met by developing "marginal lands" regardless of their definition. As in the case of food, a proposed alternative is to exploit microorganisms grown hydroponically, and much research is going into this area.

Ecosystem processes are also a crucial factor in mitigating the continued use of fossil fuels, by capturing CO_2 from the atmosphere. Climate change would be much more pronounced than it is today were it not for the carbon sequestration capacity of natural ecosystems, both terrestrial and marine, and there is some scope to enhance this capacity by planting trees on degraded soils and enhancing soil carbon storage in agriculture. One proposal is to convert biomass to charcoal (biochar), which is resistant to decomposition and has been suggested as a way of building soil carbon stocks (Royal Society 2009a). Other proposed routes to ecological carbon capture include the fertilisation of the oceans to increase plankton growth (Judd *et al*. 2008) and the accelerated weathering of rocks (Schuiling and Krijgsman 2006; Kelemen and Matter 2008; Royal Society 2009a).

Alternative sources of energy that would replace non-renewable fossil fuels are often intermittent in power output. The wind does not always blow, the sun does not shine at night or in bad weather. However, molten salt can be employed as a thermal energy storage method to retain thermal energy collected using solar power. When electricity is needed, the hot salt is pumped to a conventional steam-generator as used in any conventional coal, oil or nuclear power plant. Intermittency can also be alleviated by long range transmission of electricity over high voltage direct current (HVDC) grids (EASAC 2009b). For example, all of Europe's electricity could in principle be generated from solar power in North Africa (Desertec scheme – see www.trec-uk.org.uk), which could be complemented with wind and marine power coming from the north. Denmark's successful use of wind power, which is responsible for delivering 16% of the country's electricity needs (Sharman 2005) relies on exchanging electricity with pumped storage hydroelectric facilities in neighbouring countries.

Space heating can draw on lower temperature differentials. A small but growing number of seasonal thermal stores are being used to store summer energy for space heating during winter. Storage for cooling can make use of the large latent heat of ice: one cubic meter of water can store 93kWh of energy. A small storage facility can hold enough ice to cool a large building for up to a week. Increasingly ice is produced during off peak periods and used for cooling at later time. Heat pumps are already widely used for cooling (air conditioning), but can also move heat into buildings in cold weather. MacKay (2008) has shown that, even if the electricity used is generated from fossil fuel, heat pumps provide greater overall efficiency than burning fuel directly to heat buildings.

4.6.2.3.1 Effect of population and consumption trends on CO_2 emissions

The following carbon scenarios (Jackson In press) report levels of global carbon dioxide emissions from 2010 to 2050, calculated using a simulation model that divides the world into three economic regions – high, middle and low income countries – as defined in the World Bank's World Development Indicators (WDI) database[3]. The model uses base year assumptions taken from the WDI and calculates total carbon dioxide emissions in each region (and in total) as: Total Carbon Emissions = carbon intensity (g/$ in $2005 prices at purchasing power parity) x income per capita ($ in 2005 prices at purchasing power parity) x population.

Varying assumptions are made in each scenario about population, income per capita and the carbon intensity over time as follows:

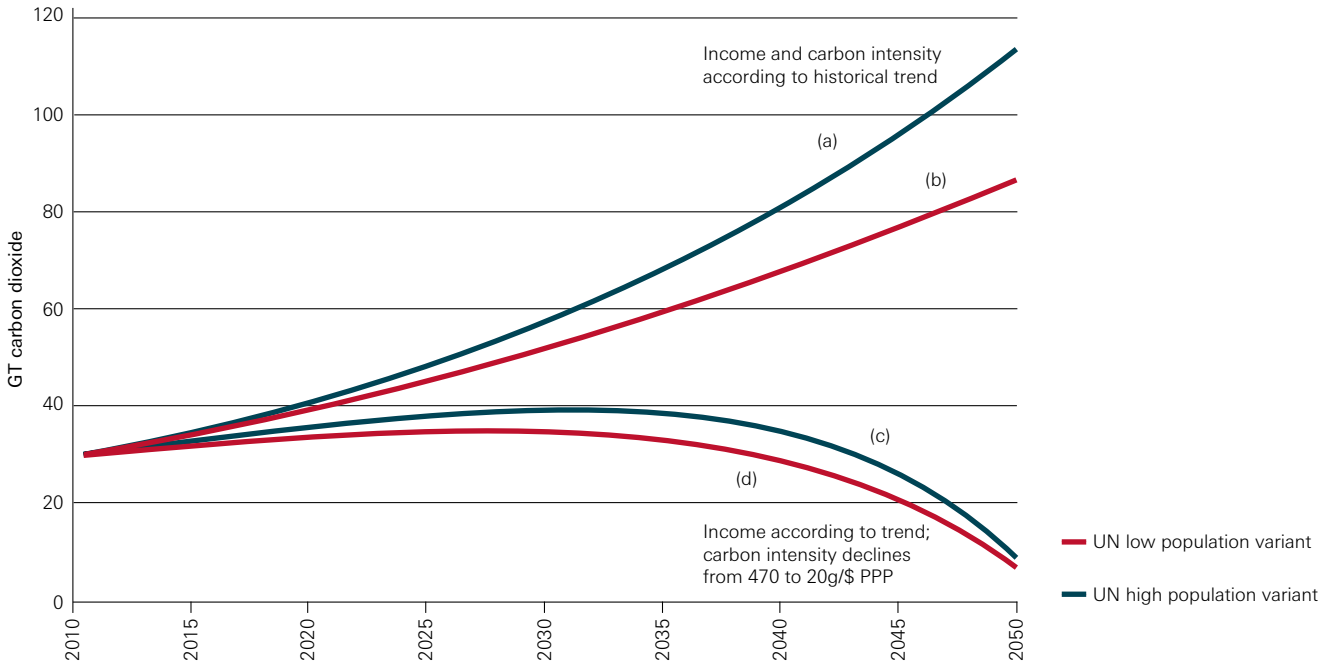
- The population scenarios take the upper (high) and lower (low) UN variants to model population change in each region.

- Three income scenarios are explored. In the first, per capita incomes are expected to rise in all three regions according to historical rates and expectations. Average incomes per capita would reach $50,000 in high income countries, $40,000 in middle income countries and $5,000 in low income countries. In the second income scenario, it is assumed that both the middle and low income countries catch up with the high income countries – who maintain their expectations of income growth. Incomes converge to an average $50,000. In the final scenario, incomes converge to a lower average per capita figure of $20,000.

3 The World Bank income categorisation of High, Middle and Low Income countries is not entirely congruent with the UN categorisation of Most, Less (excluding Least) and Least Developing Countries. However, for the purposes of this exercise the population trends for these UN regions have been used to scale the 2010 population data from the World Bank.

- Three carbon intensity scenarios are explored. In the first scenario, carbon intensity moves according to historical trend. For both the high and the middle income countries this means a substantial decline in carbon intensity. For high income countries, carbon intensity declines from around 360 grams per dollar of output in 2005 prices at purchasing power parity (g/$2005PPP) to 200 g/$2005PPP by 2050. For middle income countries the decline is from 620 to 340 g/$2005PPP. For low income countries, still passing through a carbon intensive phase of laying down infrastructure, carbon intensities are assumed to rise slightly to reach the same carbon intensity of 340 g/$2005PPP by 2050 as the middle income countries. In the second carbon intensity scenario, global carbon intensity across all regions is assumed to decline to around 20 g/$2005PPP. This is a substantial decline representing almost 95% reduction over the 2010 carbon intensity and an average annual decline of 7.6% per year. But this is the scale of carbon intensity reduction required to reach the middle of the 50-85% reduction window identified by the IPCC's 4th Assessment Report by 2050, assuming trend growth in population and incomes. The third carbon intensity scenario assumes a less drastic decline in carbon emissions to a level of 40 g/$2005PPP by 2050, representing an average annual decline of around 5.5% per annum.

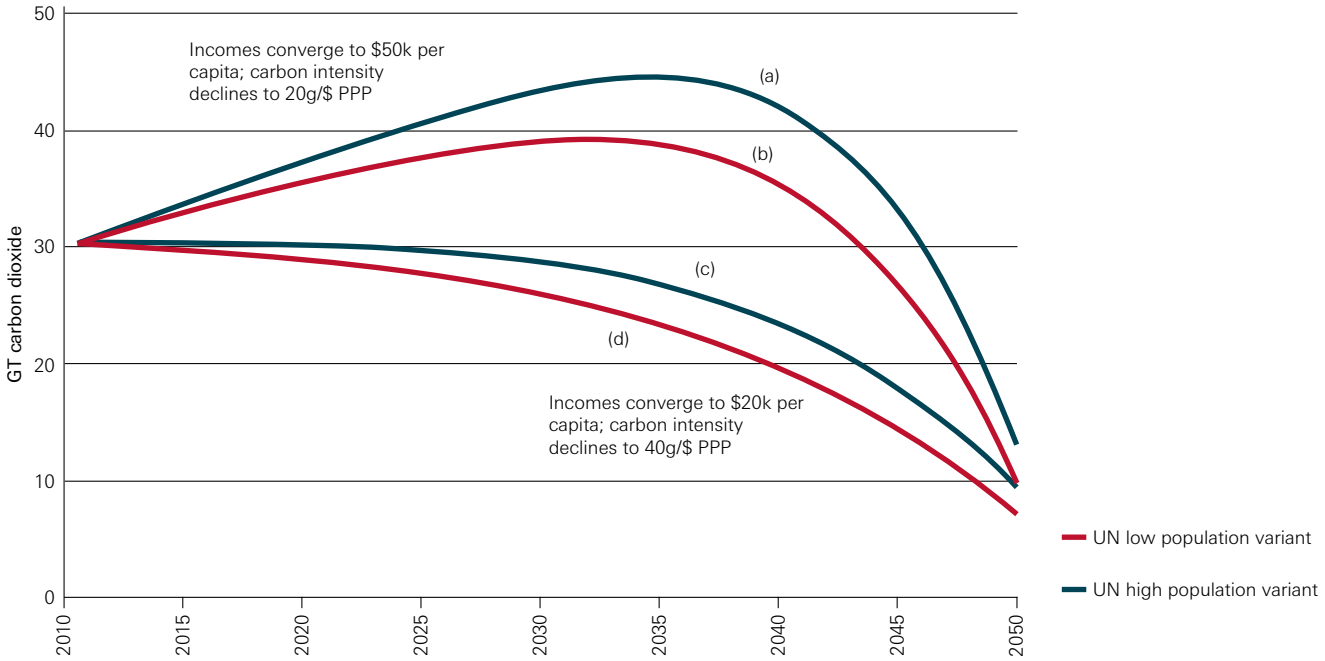
Figure 4.3 Carbon scenarios – income according to historical trend: an unequal world.
(a) and (b): Trend income growth and trend carbon intensity lead to very substantial increases in global carbon dioxide emissions and dangerous climate change. Population makes some difference in the extent, but even the low UN population variant does not stabilise global carbon emissions. (c) and (d): emission pathways for a world in which incomes change according to trend, but the carbon intensity is reduced across the world to less than 5% of its current value.



Source: Jackson T (In Press)

The impact of population is less pronounced in scenarios c and d in Figure 4.3, but reduces the height of the carbon peak along the way and therefore has an important influence on the total carbon entering the atmosphere between now and 2050 (Anderson & Bows 2008, 2011) produce an independent model which corroborates the results given here).

Figure 4.4 Carbon scenarios – convergence towards equal per capita incomes.
(a) and (b): incomes converge towards $50,000 per capita. The middle income and low income countries catch up with the high income countries, where incomes grow according to trend. (c) and (d): incomes converge towards $20,000 per capita. There is substantial growth in the middle and the low income countries, but a contraction in richer nations by around one third. A carbon intensity of 40 g/$2005PPP is sufficient to bring world carbon emission down towards the lower end of the emissions range defined by the 50-85% reduction window.



Source: Jackson T (In Press)

The most notable feature of Figure 4.4 lies not in the emissions endpoint for each scenario, but in the height of the carbon peak along the way. The higher this carbon peak the more carbon enters the atmosphere between now and 2050 and the harder the task of stabilising the global climate. It is significant that the high income convergence scenarios and to a lesser extent the high population scenarios increase this risk. These carbon scenarios highlight the combined importance of both slowing population growth and reducing per capita CO_2 emissions to stabilise the global climate.

4.6.2.4 Minerals

In 1980 the environmentalist Paul Ehrlich and economist Julian Simon made a bet on whether the price of a basket of five metals would fall between 1980 and 1990 (meaning supplies would become more plentiful) (Myers and Simon 1994). Although Simon won the bet, since the basket of prices did fall between 1980 and 1990, this trend has not continued. An equally weighted portfolio of chromium, copper, nickel, tin and tungsten, the metals at the heart of the debate over finite resources between Ehrlich and Simon, is now higher in real terms than the average of their prices back in 1980. Today's metals prices are likely to be due to the buoyancy of demand in the developing world rather than any serious shortages in supply.

Reserves are an economic rather than absolute concept. At any one time they are proved only as far as necessary to justify investment in infrastructure for extraction, and potential resources are invariably much larger. Projected scarcities are usually to do with human factors: economic and environmental costs, not least CO_2 emissions. The economics are complex, because many rarer metals are isolated as co-products of more common ones; for example gallium is found with aluminium and zinc, so if the demand for these metals falls gallium will become more costly. Extraction procedures are changing under the pressure of environmental concerns: for example, much copper production is now by solvent extraction rather than smelting.

The requirement for individual elements is a constantly changing target as new uses are discovered, and not all are readily substitutable. Here are two examples for which limitations may arise.

Platinum is one metal for which absolute scarcity is likely (Bloodworth pers comm), because of its unique catalytic properties (eg car exhaust cleaning and process chemistry). The related metals palladium, rhenium and osmium may also become limiting. It will become increasingly economic, as well as environmentally benign, to recover these metals efficiently. Recycling incentives, now commonplace in Europe, but less so in low income countries, will be needed.

Phosphate is essential for intensive agriculture, and concerns have been raised about the reserves, the greater part of which are in Morocco. On European farmland, where fertilisation has continued for many years, the soil has come to equilibrium and farmers should be adding only as much phosphate as is taken up by the crop; this has the dual benefit of reducing costs and minimising eutrophication of water runoff. In Less Developed Countries however, larger quantities must be added each year to increase crop yields, and so global use will continue to rise. Concerns have been raised about the contamination of some potential sources with cadmium and arsenic, but purification by dissolution and recrystallisation is already being practised, and will not pose an insuperable economic obstacle (Bloodworth pers comm). A stabilised human population of 9-10 billion, eating a diet with only a modest proportion of meat, should be able to conserve accessible reserves into the 22nd century. Meanwhile it is likely that improvements will be made in recovery of phosphate from effluents.

4.7 Conclusions

1. **On a finite planet there are environmental constraints on human population growth and material and energy consumption.** Some limits may already have been reached, and fundamental human needs for food, energy and water are at risk.

2. **Identifying exactly where the material limits of continuous growth in the global economy will emerge is difficult.** A combination of factors will most likely require increasing effort and expense to overcome. The associated environmental damage may result in sudden and irreversible impacts on the wellbeing of dependent communities.

3. **Progressive and irreversible loss of biodiversity reduces option values for future generations as well as being a failure of stewardship by the human species.**

4. **Technology has been vital for aiding human development of ecosystem services, and will continue to help avoid some of the impacts of a depleted natural environment.** Science is important in measuring what is happening, for example in climate change and in precision agriculture. Similarly, technology has a valuable role in reducing carbon emissions as well as increasing energy efficiency.

5. **The combined effects of market forces and new technologies are not able to overcome planetary boundaries on the scale necessary to avoid unsustainable pressure on the planet and much human suffering.** Consequently, additional policy measures will be needed, which are discussed further in the next Chapter.

6. Natural capital is absent from most balance sheets, and so is being depleted with insufficient regard to long term costs. **Developing and implementing accounting systems that value natural capital is vital, and is considered in the next Chapter.**

7. **Dematerialisation of the most developed and emerging economies is urgently required, but is only part of the necessary reduction of material consumption.** For example, the carbon scenarios in this Chapter highlight the combined importance of both slowing population growth and reducing per capita CO_2 emissions to stabilise the global climate.

Wellbeing of people and the planet

5.1 Pathways towards sustainable development

Current trends in global population and consumption, and concomitant changes in the environment, are unsustainable. A major change in the level and pattern of consumption is needed – one that reduces inequalities, recognises the right of individuals to choose whether and when to have children, provides for economic development possibilities and minimises impacts on the environment. A vital step towards achieving sustainable development goals will be to accept that there will be awkward truths and trade-offs. The number of people on the planet and the average each person consumes continues to rise. The economic benefits and environmental degradation that come from this increased consumption have not been distributed evenly, leading to extreme social inequity

This Chapter outlines the pathways towards sustainable development. These pathways require changing consumption patterns as well as planning for changes in population size, age distribution and movement and their associated impacts on the planet.

As shown in Chapter 4, the most immediate way to reduce the impact that human activity is having on the planet is to reduce material consumption by those that are consuming more than necessary, whilst assisting the vast number of people who currently do not have access to enough material resources. Politically, these measures, though urgent, will be extremely difficult to achieve. Some partial ways forward are reviewed in the next section, but much more is needed.

In the medium term it is imperative to stabilise populations, since otherwise the gains from material cutbacks will be overrun. Many countries are already on course to do so, but some are in a cycle of high fertility, overloaded services and environmental degradation from which escape is difficult. Despite the long term effect on impact, action is urgent. Because of population momentum, numbers continue to rise for decades after fertility falls; furthermore, the sooner fertility falls the sooner people will come out of poverty. Beyond 2050 it is difficult to avoid the conclusion that a gradual and equitable decline in numbers will serve humanity best, alleviating pressure on resources and increasing personal opportunities in future generations.

The linkages between population and consumption have been recognised by the international sustainable development community in the past – in the 1992 Rio Declaration and Agenda 21, the 1993 Population summit of the World's Scientific Academies, the 1994 Cairo International Conference on Population and Development Programme of Action (ICPD POA) and key actions subsequently agreed at ICPD+5, +10 and +15. More recently, consideration of population has been absent from sustainable development discussions (eg the 2002 Johannesburg World Summit on Sustainable Development), despite the implications of demographic change for a world with finite natural resources, the obvious social equity implications for the many millions of women around the world without access to reproductive health care including contraception and safe abortion, the social and economic development implications of high fertility levels in the poorest regions of the world, and the rapid ageing of societies which is now occurring in both developed and emerging economies. International meetings, such as the Rio+20 Conference on Sustainable Development and subsequent meetings, need to consider population and environment together. The history of international meetings on sustainable development has been extensively considered elsewhere, see for example http://www.uncsd2012.org/rio20/history.html for more detail.

5.1.1 Poverty reduction

A priority for the international community has been, and continues to be, to bring the "bottom billion" out of poverty. Globally, with 1.3 billion people living in absolute poverty (less than $1.25 per day) (World Bank 2012), much work is still to be done in reducing the current levels of inequality and poverty, and ensuring that the basic needs of every individual are met to enable them to achieve a minimum level of wellbeing (see Box 5.1). The 8 Millennium Development Goals (MDGs) give an outline of the minimum requirements for individuals to achieve wellbeing in the developing world. They provide an empirical benchmark in monitoring progress in wellbeing, globally. Progress against the Goals has been described extensively elsewhere (eg UN 2011c). The continued efforts by the international community to achieve the MDGs are a vital part of moving towards global sustainable development.

The MDGs set specific targets in the following areas:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Improve maternal health
4. Combat HIV / AIDS, malaria and other diseases
5. Promote gender equality and empower women
6. Ensure Environmental sustainability
7. Reduce child mortality
8. Develop a global partnership for development

In 2005 the Millennium Project identified that the Goals needed to be expanded to include access to reproductive health services and the protection of reproductive rights (UNDP 2005). The MDGs do not contain a specific goal or target on reproductive health, but they do contain specific targets related to components of reproductive health, including maternal health, HIV/AIDS and gender equality.

5.1.2 A Green Economy and institutional frameworks

The Green Economy, one of the major themes for the Rio+20 conference, has been defined by UNDP and the World Bank as one that results in improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities. Both organisations think of a Green Economy as one which is low carbon, resource efficient and socially-inclusive. The Green Economy is wide-reaching, and a number of issues discussed in this report are relevant, such as material efficiency, ecosystem services (both covered in Chapter 4), the demographic dividend (Chapter 2), changing consumption patterns (section 5.3) and urbanisation (section 5.5.4).

Institutional frameworks for sustainable development, the second major theme for the Rio+20 meeting, are concerned with strengthening integration between the three pillars of sustainable development: environmental, social and economic (WCED 1987). Institutional reform needs to create an evidence-based system of global reach that provides a framework for dealing with the world as it is expected to be, not as it is now. Consequently, institutional frameworks need to accommodate a warmer world due to climate change (and the associated impacts), an increased global population, a growing proportion of the world's population living in urban environments, an increase in middle class consumers, migration, and an ageing population. These issues are discussed further in section 5.5.

5.2 Human wellbeing

Wellbeing describes what is ultimately good for a person (Crisp 2008). Individuals who are experiencing suffering, or are not able to achieve wellbeing, are more vulnerable to social, economic and environmental shocks (Wolff and de Shalit 2007). Continually failing to achieve aspects of wellbeing such as good physical health, personal security, or access to enough material resources increases mortality. Some dimensions of wellbeing are explored in Box 5.1.

The achievement of wellbeing is underpinned by the international endorsement of human rights standards which not only restrain states from undermining wellbeing by infringing individual freedoms but require them to take positive steps to remove economic, social and cultural barriers to the realisation of those freedoms, without discrimination on any grounds.

One of the major obstacles to achieving human wellbeing in a sustainable way is that the conventional model assumes that consumption growth is the key to improved wellbeing Unfortunately consumption growth is also the driving force behind rising environmental impacts. Chapter 3 has detailed how consumption trends are increasing around the world. The greater the economic output, the more disposable income available to people, and the more they consume. It is hotly contested whether it is possible to deliver wellbeing and raise standards of living without the associated material throughput and environmental impact. This debate hinges on whether it is possible to live a better life by consuming less, and be more sustainable in the process. Evidence from some communities and societies give indications that this may be possible (Pretty 2011).

Box 5.1 Defining wellbeing

Wellbeing is closely but not exclusively linked to people's consumption possibilities, their economic wealth, and ultimately their impact on the environment. Wellbeing has both subjective and objective elements: it depends on both feeling good and having the objective conditions that are necessary to meet basic needs. How wellbeing is expressed and experienced is context and situation dependent and reflects local social and personal factors. However, it is common ground that *"basic needs are met, that individuals have a sense of purpose, that they feel able to achieve important personal goals, and participate in society"* (Department of Health 2010).

This report focuses on five core dimensions of wellbeing, all of which must be met for a minimally acceptable level of wellbeing to be achieved (MA 2003).

Having **enough material resources** is essential for human wellbeing. Enough material resources includes basic necessities such as food, water and shelter and enough income and wealth to be able to protect the person from unexpected shocks that could lead to destitution. Once a person has enough income to meet basic human needs, further increases in income and consumption appear to be less closely related to wellbeing. However, having enough is also partly relative: an important human need is to be able to appear in public without shame, and what counts as having enough to not be ashamed will vary according to society (Sen 1999).

Health pervasively affects both the length and quality of a person's life (Stiglitz *et al*. 2010). But it also matters for achieving other dimensions of wellbeing, such as having good jobs and adequate income, being able to participate as a full citizen in community life, or to attend school and adult education.

Freedom (of choice and action) includes both liberty of action and autonomy: having control over what happens and being able to achieve what a person values doing or being. Whilst different traditions place different weights on the value of freedom, it is widely agreed that it is of intrinsic value that individuals should be empowered to make decisions about their own life, enjoy liberty of conscience, have a voice in political discussions, and for women to make individual choices about childbearing. Giving citizens a democratic voice is also likely to have important protective effects on other elements of wellbeing (Sen 1999).

Security includes secure access to natural and other resources, safety of person and possessions, and living in a predictable and controllable environment with security from natural, human made disasters and war. Security is important for two reasons: both because of the direct negative effects that crime, accidents, natural disasters and climate change have on human lives, and also because of the corrosive psychological and social effects of the awareness of insecurity. Personal security is a core element for the wellbeing of individuals and of society as whole, and the experience of crime is one of the main factors shaping people's personal security. Crime may lead to loss of life and property, as well as engendering physical pain, post-traumatic stress and anxiety, but the biggest impact of crime on people's wellbeing appears to be through increased feeling of vulnerability (Anand and Santos 2007).

Good social relations include social cohesion, mutual respect, good gender and family relations and the ability to help others and provide for children. Social capital in the form of relations of trust, reciprocity, and obligations is vital for wellbeing. The frequency of contacts with others and the quality of personal relationships are crucial determinants of individual wellbeing. Activities are often more satisfying when shared with others. Social networks can provide material and emotional support in times of need. The nature of social interactions also has wider implications beyond immediate social groups, impacting levels of trust within and between communities, which is an important driver of other outcomes including democratic participation, crime levels and health (OECD 2011).

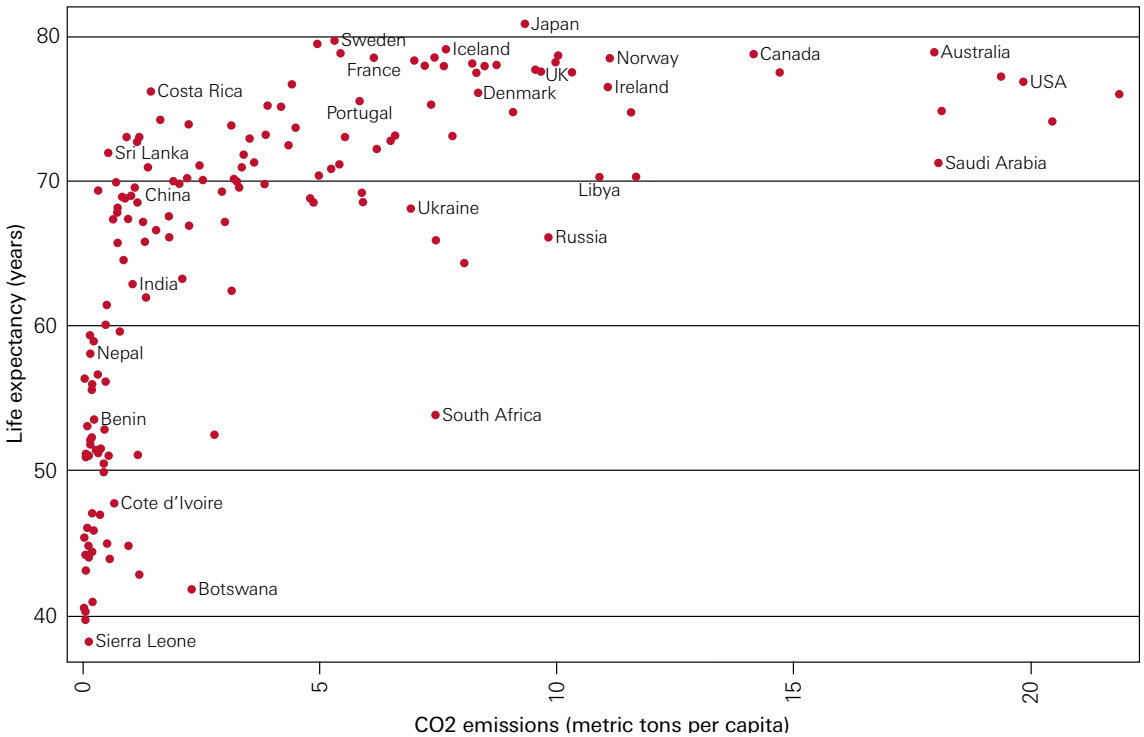
Many aspects of wellbeing are relative. The poorest people who lack basic resources of food, water and security and the human dignity they can bring are certainly made happier as they get wealthier, but after a certain threshold is passed wellbeing becomes largely independent of consumption (but not of other contributing factors to wellbeing such as freedom of action). For example, although countries' economies have continued to grow, their populations are not necessarily happier (Inglehart and Klingemann 2000). However, happiness is not an objective measure, and also causality in this relationship could arguably go either way: it may be that money does not bring happiness; or alternatively that those who strive hardest and are never satisfied become wealthier, yet still not happier. The lack of connection between CO_2 emissions above 5 metric tons per capita and longevity (an objective surrogate for health) is more compelling (Figure 5.1). A plot of longevity against income has a similar form.

5.3 Changing consumption patterns

Earlier Chapters have sketched both the limits to current material consumption levels and the enormous disparities in consumption between the richest and poorest. Many kinds of consumption must increase in the Least Developed Countries (UNDP 2005), but some kinds of consumption must stabilise and decline in the Most Developed Countries (whose ranks are being rapidly enlarged by the emerging economies). Continued international discussions leading to binding treaties are essential to reconcile the opposing needs.

This section illustrates some approaches to reducing material consumption. The topic is both politically fraught and the subject of much current research. The brief account given here can be no more than illustrative. As such, it runs the risk of appearing to trivialise an immensely complex subject, and indeed can do no more than scratch the surface of a very

Figure 5.1 Life expectancy versus CO_2 emissions by country



Source: The Spirit Level, Wilkinson and Pickett, 2009

large problem. However, the actions being taken at present are doing little more than scratch the surface. See, for example, OECD 2008, Jackson 2005, 2006, 2009 for more comprehensive discussions.

Material consumption is currently closely related to economic consumption. Economic consumption is a key component of GDP. Thus, growth in the GDP tends to drive increasing material throughput (see Chapter 3). There is a clear need to address the underlying economic model and go beyond the GDP in the measurement of economic progress. This task may be challenging in the short term – for political and structural reasons. But there are some powerful reasons for beginning to tackle it now. Irrespective of this need, immediate attention has to be focussed on dematerialising economies – decoupling economic activity from material consumption.

Considerable reduction in global material consumption is required to avoid going further beyond the planetary limits described in the previous Chapter. The necessary scale of reduction requires changes in the consumption patterns of individuals, businesses and governments through a combination of approaches. Some of these approaches are discussed below. These include adapting economic models, improving the resource efficiency of the economy, using incentives and measuring what matters most to people. New approaches and institutions will need to build on the collaborative as well as the competitive aspects of human nature. For example, altruism has been shown to be pervasive but its prevalence is dependent on cultural conditions and incentive structures (Schwartz 1993). There is an urgent need to reassess the institutions through which individuals, businesses and nations are encouraged to consume and to find ways to ensure that they are not based on ever-growing material consumption.

5.3.1 Economic models

The concept of a steady-state economy is to take a different path to achieve sustainable, healthy, and equitable lifestyles for citizens. This alternative to continued economic growth is a non-growing or steady state economy (Daly 1991; Meadows *et al*. 1972).

The circular economy is a move away from linear "take, make, dispose" industrial processes and the lifestyles based on them (Stahel 1981). The concept of an economy in loops (or circular economy) was based on the desire to create jobs, improve economic competitiveness, save resources and reduce waste prevention.

Any such developments cause great nervousness in developed economies, because of the dependence of full employment on constant growth. Rising unemployment is a quick route both to human misery and to loss of office for politicians. As the people of the Least Developed Countries come out of poverty they will of course become affected by the same pressures, and the growth of a huge globalised labour pool is a challenge for the coming century. A vital part of the changes envisaged must be to plan for jobs that do not require much material consumption. A more radical solution would be to adopt a model in which people do not work so hard once their primary needs are amply satisfied. This report is not the place to pursue these highly contested strands, but they cannot be ignored.

5.3.2 Technology and resource efficiency

Technology is of the greatest importance in increasing the sustainability of consumption, through efficiency savings, reducing pollution from consumption, elimination of waste, recycling and reuse, and exploitation of alternative resources. Examples have been discussed in section 4.6.2, and many practical proposals are put forward in a report from the Institution of Mechanical Engineers (IMechE 2010).

In the case of CO_2 emission, the decoupling required for the continued use of fossil fuels is very large (see section 4.6.2.3.1) and probably unachievable even when combined with efficiency savings (Jackson 2009), so the adoption of alternative energy sources is urgent. The arrival of peak oil output, and perhaps the imminent peak of all fossil fuels (Murray and King 2012), will provide additional pressure in that direction through market forces.

5.3.3 Incentives

By raising prices on less sustainable products, taxes and charges can be effective in influencing consumer behaviour towards sustainability. These tools help prices more accurately reflect the full cost of products by including any negative environmental impacts, thereby placing a value on natural capital, as discussed in section 4.6.1. This lets the market play a role in changing purchasing patterns (OECD 2008).

For example, road user charging has been introduced in a number of countries to encourage drivers to use their vehicles less, thereby reducing CO_2 emissions and congestion. The effectiveness of such schemes depends on their design, which could be combined with pay-as-you-drive insurance (POST 2006). Proposed road user charging systems in the UK have been met with some public opposition, including the formation of interest groups created solely to oppose road charging, such as Drivers Alliance.

The use of meters to reduce use of water and electricity is becoming more widespread. For example, in 2010 the UK Government committed to installing smart electricity meters in all UK homes by 2019 (DECC 2011b). The aim of this programme is to enable consumer behaviour change, and so change industry processes and customer service as well as to facilitate smart grids[1].

Common approaches to reducing household waste include waste disposal charges and recycling schemes. Waste collection charges are an effective approach to reducing the quantity of waste and increasing recycling. Decreasing water waste also requires a range of approaches. Denmark, Hungary and the Netherlands have successfully combined public information campaigns with increases in household water prices to decrease water wastage (OECD 2008).

In general, recycling of all minerals is increasing. Globally, over 50% of most ferrous metals are already recycled. For iron and steel the recycling rates are 70 – 90% (UNEP 2011b). By imposing a tax on aggregates, the UK uses 25% recycled material in concrete; France, with no such tax, uses only 5%. On an upward consumption curve complete circularity with zero input cannot be achieved, but overall the intensity of mineral use per economic unit is falling (UNEP 2011).

There are a number of measures that could be used to reduce food waste (Foresight 2011d). The focus in low-income countries is on measures to reduce post-harvest waste, whilst reducing consumer and food sector service waste are the primary targets in high-income countries.

Incentives can come in the form of monetary grants and tax reductions and make sustainable choices less expensive. Personal transport is a common target for subsidies and incentives in promoting consumers to buy lower emission, hybrid or alternative fuel vehicles (OECD 2008). Another is payment of feed in tariffs to encourage solar photovoltaic installation.

5.3.4 Behaviour change

Attention is increasingly being paid to people's behaviours and lifestyles in order to change consumption patterns. One example is the Behavioural Insights Team established by the UK Cabinet Office in July 2010 to find *'intelligent ways to encourage, support and enable people to make better choices for themselves'* (Cabinet Office 2011).

Social norms, habitual and automatic behaviour and public transport infrastructure have been identified as important influences on an individual's choice of transport mode (House of Lords 2011). It has been suggested that environmental awareness is not an important factor for many drivers, but there is evidence of individuals changing their driving habits because of the health benefits of walking and cycling.

The high level of public awareness of climate change in the UK does not always translate into cuts in individuals' greenhouse gas emissions, as behaviour is shaped by many psychological, social and structural factors (POST 2010). Changing individual behaviour is seen as only being effective when combined with other interventions. Combining community-based and participatory approaches with top-down campaigns and the creation of incentives to change behaviour is most likely necessary in changing habits and building support for policy.

The changing meat consumption with increasing gross national income was shown in section 3.3.2. This showed significant increases in meat consumption as gross national income increased in China, Brazil, UK and USA – but not in India, highlighting the importance of cultural values.

A hope has been expressed recently that people can be "nudged" into changing their behaviour without regulatory action by national governments being required for the change to be successful

1 A smart grid is an electricity network that can intelligently integrate the behaviour and actions of all its users to ensure a sustainable, economic and secure electricity supply, thanks to the pervasive incorporation of intelligent communication, monitoring and management systems (see http://setis.ec.europa.eu/newsroom-items-folder/smart-electricity-grids)

(Thaler and Sunstein 2008). The central idea is that behaviour can be influenced by altering the context or environment in which choices are made with the effect that behaviour is changed without individuals even noticing that this has happened. In the UK the proposal, which is attractive to central government, has been carefully examined by the House of Lords Science and Technology Select Committee (House of Lords 2011). The Committee concluded that non-regulatory measures used in isolation, including nudges, are unlikely to be effective and a range of interventions are required if a change in behaviour is to occur. This seems especially plausible if reduction in consumption of the magnitude that is likely to become necessary is to be achieved.

Probably the most important levers to change behaviour are education, the creation of economic (and fiscal) incentives, together with legislation involving sanctions for non-compliance. This lever is particularly effective when it is accompanied by public acceptance of the need for such legislation. Financial incentives may provide additional reasons for changing behaviour. If society as a whole deems a behaviour unacceptable or antisocial, peer pressure can be an effective tool for change. Suggestion via the media is important in changing attitudes, with television and radio being strong forces to bring about change and raise awareness (Westoff and Bankole 1997).

5.3.5 Measuring what matters

Modern society has put much effort into measuring and monitoring economic variables, whilst paying little attention to human wellbeing as the desired outcome. In industrialised, post-World War II economies, rising GDP has come to mean a thriving economy, more spending power, richer and fuller lives, increased family security, greater choice, and more public spending. However, GDP does not reflect health, life satisfaction or freedom of choice. It does not take account of losses of important natural and social capital, and it does not show if progress is sustainable. In the balance sheet, expenditure on disaster (eg cleaning up an oil spill) and expenditure on success (eg equipment that precludes the spill) are equally positive and are added together. Use of a new and expensive drug adds more to GDP than an equally effective but cheap off-patent drug. In the last few decades, whilst the pursuit of GDP has become one of the primary policy objectives for almost every country in the world, it has also come under sustained criticism.

When measuring sustainability, it is important to measure a society's *wealth*, which means the value of its *entire* set of capital assets. (For formal accounts, see Dasgupta (2001 [2004]) and World Bank (2006a). *Sustainable development* means growth in (comprehensive) wealth *per capita*. Market prices are a misleading guide for valuing goods and services, and they *under-value* natural capital to such an extent that market signals encourage profligacy in its use.

There is now growing recognition by leaders around the world of the need to measure what matters for people's lives in addition to income and GDP (Box 5.2). It has been suggested that the current understanding of how to measure wellbeing is at a similar stage to where macroeconomics was in 1950 when GDP was first measured (Layard 2005). However, measuring is one thing, but putting into practice is another. Despite the many flaws of using GDP as a measure, it is still attractive because it is a fully systematised body of knowledge – possibly the first such system to have a truly global reach – which allows for a relatively comprehensive understanding of the performance of the economy over time. GDP is also a strategic tool, in a world where nations compete against one another for economic and political significance. Not only is a nation's status in the world perceived to rise if it enjoys GDP growth, high GDP enables a nation to tilt the terms of trade with the rest of the world to its advantage. The benefits associated with GDP growth lead to a nations vying with one another for competitive advantage by bolstering GDP. No single nation can step aside from this competitive game without jeopardising the jobs, financial security and self esteem of its citizens. International recognition of the wasteful nature of such a form of competition is a needed first step.

Box 5.2 Alternative measures of progress

Wellbeing measures can be grouped into three categories: objective, subjective and economic. Objective wellbeing measures use metrics such as life expectancy, or years of education. Subjective wellbeing measures use metrics such as self-reported happiness or cognitive self-assessments. Globally, there is a growing trend for these sorts of measures, as Governments ask: "How happy are you? How well are you satisfied with your life?" The third category of measures uses economic metrics, such as GDP, net national income or the UNDP Human Development Index.

The Human Development Index (HDI) uses GDP per capita, life expectancy at birth, and literacy, so is a composite of one measure of economic activity and two measures reflecting aspects of human capital (health and education, respectively). HDI has been used to judge whether a country has improved its performance or fallen behind since 1990. HDI does not capture absolute improvements in its three factors – rather it is based on their relative levels between countries (UNDP 2011). As HDI does not include natural capital it is not an effective sustainability measure. In its 2011 report, the UNDP has drawn attention to the importance of natural capital, but has not incorporated it in the index. Empirical studies (eg Dasgupta 2010) have found that over the past three decades, GDP *per capita* in a number of poor countries has grown and the United Nation's Human Development Index (HDI) has improved even while wealth per capita has declined.

Other initiatives include the Bhutanese 'Gross National Happiness Index', which sets happiness and wellbeing of all people as the ultimate purpose of governance, Wellbebe in Belgium, the Legatum Prosperity Index (www.prosperity.com), the Canadian Index of wellbeing, QUARS in Italy, and the Good Growth Index (Demos 2011). In November 2010 the UK Prime Minister, David Cameron said at the launch of the UK Office of National Statistics' Measuring National Wellbeing Programme that *'It's time we focused not just on GDP but on GWB – general wellbeing'* (reported in The Guardian 2010).

In France, President Sarkozy set up a Commission on the Measurement of Economic performance and social progress, to identify the limits of GDP as an indicator of economic performance and social progress, and to consider the information required for the production of a more relevant picture (Stiglitz *et al*. 2010).

The New Economics Foundation's 'Happy Planet Index' (HPI) aims to measure human wellbeing and human impact on the planet. The HPI combines life expectancy, life satisfaction and ecological footprint. According to the Index, few nations are achieving one-planet living, and none are doing so whilst maintaining good levels of wellbeing. Costa Rica comes top of the Index, with a life expectancy of 78.5, a life satisfaction score of 8.5 and an ecological footprint of 2.3 global hectares (gha).

If the outcomes of the HDI and HPI are compared, not one of the top 10 countries of HDI appear in the top 10 countries of the HPI, and vice versa. Costa Rica, top of table in the HPI, comes in at number 62 in the HDI, with a HDI score 0.725, whilst Norway, top of the HDI comes in at 88 in the HPI, with a score of 40.4.

Despite the growing body of work looking at alternative measures of progress, including measures of wellbeing, as yet there is no consensus on a replacement for GDP, or if indeed there should be one. What is clear is that very few alternative measures of progress actually measure sustainability – a key element of development.

5.4 Demography for wellbeing

Some of the demographic changes that are expected in the coming years, such as the ageing of the global population, cannot be heavily influenced by policy interventions (though the effects on health can be). There are however a number of areas where policy interventions can have an impact, to both stabilise population and help all people to achieve wellbeing. The world, and in particular the developing countries, are expecting historically large cohorts of youth. How policies shape the behaviours of these cohorts can make an enormous difference in the ultimate size of the global population and to the wellbeing of its people. The effect of action versus inaction can mean the difference between an upward economic trajectory and a downward economic and sociopolitical spiral. For example, countries at an early stage of the demographic transition can maximise the potential demographic dividend that can occur when there is a high proportion of the population entering working age to those that are dependent by ensuring that: appropriate investments are made in education, access to healthcare and family planning services are assured, and trade policies and currency exchange rates encourage investment and entrepreneurial activities.

5.4.1 Education

Education provides economic benefits, builds strong societies and policies. It improves health (Cohen and Bloom 2005) **and is associated with empowerment of women and smaller families** (Lutz and Samir 2011). Improving education and skill levels can increase the productivity of an economy and its ability to compensate for a decline in the share of the working age population. In general, well educated people live longer, healthier lives, and are more resilient to change (Sperling 2006). Education has the potential to contribute to sustainable development efforts in many ways. Aside from the benefits that it can directly bring to a person, it can increase knowledge of sustainable consumption, of healthy and safe living, including reproductive health, and about the importance of the environment. The global community has pledged to achieve universal primary education for all on several occasions (at the World Conference on Education 1990, World Education Forum 2000, Millennium Declaration 2000 (Cohen and Bloom 2005)). Despite these pledges, it looks unlikely that this will be achieved. An estimated 335 million school-age children will be missing primary or secondary school in 2015; of these, an estimated 118 million will be absent from primary school. About one in five of these children will never enrol in or attend school (Cohen and Bloom, 2005).

Obstacles to achieving universal education include: children being kept at home to work, or for other reasons; education and schools competing for scarce resources with other projects, such as healthcare; education being stigmatised for political reasons; or for cultural reasons (Cohen and Bloom 2005).

Bringing primary and secondary education to all children will require change, such as open discussions at the national, regional and international level around the goals of education; a commitment to improving the effectiveness and economic efficiency of education in achieving its goals; and increased financial support for education (Cohen and Bloom 2005). Primary and secondary schools everywhere need to improve their effectiveness and efficiency, transparency and accountability, in achieving educational goals.

The ability (or willingness) of governments in poor countries to enforce school attendance is often greatly limited. The private costs and benefits of education and the mores of the community to which people belong influence their decisions. The very characteristics of a community that are reflected in low educational attainment for women can also be those encouraging high fertility (for example absence of associational activities among women, lack of communication with the outside world, inheritance rules that place women at a disadvantage).

In some of the Least Developed Countries there is no achievable way of training the teachers needed or building and maintaining the schools needed, leading to very low levels of education attainment. Only about one in three children will complete primary education in six African countries: Niger, Guinea-Bissau, Burkina Faso, Chad, Burundi, and Mali (Academy for Educational Development 2006). It has been estimated that in these countries nearly one in four children at the lower secondary level (ages 10/11 – 14/15) do not go to school, and one in two children do not attend at the upper secondary level (ages 14/15 – 18/19) (UNESCO 2005). Rapid population growth undermines the ability of a country to improve the level of education.

Estimates of how much it would cost to achieve both universal primary and secondary education range from $34 billion to $69 billion per year (with primary education being $6 billion to $35 billion per year and secondary education from $28 billion to $34 billion per year) (Cohen and Bloom 2005). There are considerable difficulties in producing accurate cost estimates, because of the uncertainties around estimating how to overcome the barriers, such as parents not enrolling their children in schools (Glewwe *et al*. 2006).

5.4.2 Healthcare

Better health is central to human happiness and wellbeing. It also makes an important contribution to economic progress, as healthy populations live longer, are more productive, and save more. Many factors influence health status and a country's ability to provide quality health services for its people. Ministries of health are important actors, but so are ministries of finance and other government departments, donor organizations, civil society groups and communities themselves. For example: investments in roads can improve access to health services; inflation targets can constrain health spending; and civil service reform can create opportunities – or limits – to hiring more health workers (WHO 2011).

Immunisation plays an important role in tackling mortality. The WHO's Expanded Programme on Immunisation (EPI) led to 80% of the world's children being immunised against six major infectious diseases by 1995 compared to only 5% in 1974 when EPI was launched. Increased demand and efficient service delivery were all helped by top-level political support, social mobilisation, and immunisation days (Diamond 2000). However, immunisation has not been sustained in all countries and in 2003 an estimated 27 million infants and 40 million pregnant women worldwide remained in need of immunisation (WHO and UNICEF 2005).

The global community has recognised the importance of improving sanitation by naming it among the Millennium Development Goals. Central to realising the targets is to provide connection to a public sewer or septic system and to promote the use of hygienic latrines. Seven out of ten people without access to improved sanitation live in rural areas (WHO and UNICEF 2010). In urban areas, where progress in improved sanitation has been higher (WHO and UNICEF 2010), the challenge is to keep pace with the growth of dense populations.

Food security is achieved when people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO 2008). The 1996 World Food Summit plan of action states that poverty eradication is essential to improve access to food. Other priority areas include providing access to means of production such as land, water, inputs, improved seeds and plants, appropriate technologies and farm credit.

Rapid population growth, wars, civil strife, natural disasters, climate related ecological changes and environmental degradation have adversely affected millions of people by stopping them being able to meet their dietary needs. Although food assistance may be provided to ease their plight, it is not a long term solution to the underlying causes of food insecurity. It is important to maintain an adequate capacity in the international community to provide food aid, whenever it is required, in response to emergencies (Potts *et al*. 2011).

As discussed in Chapter 2, obesity is an independent risk factor not only for diabetes, but also for cardiovascular disease and some cancers. **The increasing prevalence of obesity in the population may have a sufficiently large impact on mortality to halt present upward trends in life expectancy** (Olshanky *et al*. 2005).

5.4.3 Family planning

Voluntary family planning programmes are a key element to continuing the downward trajectory of fertility rates, especially in countries where the unmet need for contraception is high. Family planning services reduce barriers by making a range of family planning choices easily available and when necessary subsidising services and public information campaigns. The Demographic and Health Surveys which have now been conducted in most of the developing world show that 200 – 215 million women wish to delay or stop the next pregnancy. Perhaps 100 million are not using any contraception, usually

because they lack access to it or face barriers to its use (Campbell *et al*. 2006). While fulfilment of unmet need has been one of the main driving forces behind fertility decline in developing countries (Feyisetan and Casterline 2000), many programmes have also sought to increase demand for contraception and reduce fertility by promoting the concept of smaller families. However, as Ni Bhrolcháin and Dyson (2007) point out, only a relatively small number of countries (such as Iran, see Abbasi-Shavazi 2009) have had sufficiently comprehensive and strong enough programmes to exert a clearly detectable impact. It is important to recognise that other factors can influence family size, and that family size can fall, albeit more slowly, without government sponsored family planning programmes.

To meet the need for family planning, it is important to make as wide a variety of methods available through as many different distribution channels as is practical. Individuals need different methods at different times in their fertile life.

Throughout the developing world many barriers stand between women and the family planning methods and information they need to manage whether or when to have a child.

Research in the Philippines has shown that reasons given by women for not using family planning include health concerns, the belief that they are unlikely to get pregnant in the future, the costs of contraceptives being too high, personal or religious (predominantly Catholic) opposition to certain contraceptive methods and opposition from partners or family (Guttmacher Institute 2010).

Many countries' barriers are established inadvertently by their governments' medical associations and ministries of health (Campbell *et al*. 2006).

Religious views are not universally opposed to the use of family planning in the form of intentional or artificial contraception. The Roman Catholic Church has endorsed natural family planning while consistently opposing modern contraceptives, while the Eastern Orthodox and Protestant churches relaxed their traditional opposition in the course of the 20th century. Most Islamic scholars interpret the Qur'an as saying that decisions by couples on the use of contraception should be respected, although the views of Islamic leaders on acceptable types of contraception vary. Some consider the use of oral contraceptives or implants to be undesirable or even forbidden, whilst others encourage their use as long as these methods do not interfere with a woman's health and wellbeing (Pathfinder International 2004).

Unsafe abortion induced by traditional means is thought to kill almost 50,000 women a year (Harris *et al*. 2011). The risk to the women of an unsafe abortion can be over 100 times higher than a safe abortion by medical or surgical means. Induced abortion is an important variable in achieved family size, whether abortion is legal (as in the UK) or illegal (as in the Philippines). Some argue that there should be no controversy, because access to safe abortion secures the good of the mother's autonomy. Others believe that more is at issue: namely, the status of the developing embryo and foetus and what kind of treatment they deserve.

The consequences of inadequate family planning programmes are of particular concern in West Africa and across the Sahel, where between 1991 and 2004 the use of effective contraception among married or cohabiting women rose only from 7% to 15%, despite evidence of much higher levels of unmet need. In 2004 only 29% of women were aware of the two main methods of contraception (pills and injectables) and a source of family planning supplies, a vivid illustration of the neglect of this health intervention (Cleland *et al*. 2011). Typically it requires an increase in contraceptive use of 15% to reduce fertility by one birth per woman. If the pace of change in use observed between 1991 and 2004 is maintained, it will take 25 years for fertility in West Africa to fall from its 2000 – 2005 level of 5.6 births to 4.6 births. This 'business as usual fertility scenario' is well above the United Nations medium projection and also exceeds the assumption of its high projection. It is possible that increased resort to induced abortion might compensate partially for lack of contraception but abortion is illegal in most West African countries and commonly unsafe. West Africa already has the highest risk of abortion-related mortality of any region with an estimated 140 abortion deaths per 100,000 live births (Shah and Ahman 2009). Thus the consequences for maternal health are severe.

The cost of providing family planning services is low compared with sums spent on combating infectious disease, and rapidly repays the expenditure in terms of educational attainment and reduced health costs. Cost estimates for implementing family planning in the developing world range from $6.7 billion to $7.7 billion per year (Population Action International 2010). Further details of the different activities required around the world (and their associated costs) are given in Box 5.4.

Box 5.4 Family planning across the globe

This Box uses the UN Population Division's 2010 revised population projections to divide the countries of the world into three groups based on their fertility rates to show the different family planning challenges faced around the globe.

Replacement fertility and below: All countries in this category already have broad access to contraception and most to safe abortion (Campbell *et al*. 2006). Women in some countries where abortion remains illegal (eg. Ireland or Malta) travel to neighbouring countries where it is legal (eg England or Italy). These are all developed countries, or rapidly growing economies such as Brazil.

Intermediate fertility: Birth rates in countries with TFRs from 2.1 to 3.9 are likely to continue to decline towards replacement level if appropriate investment and policy changes are made to meet the unmet need for family planning. Many potential users cannot afford the full cost of modern contraception and their needs should be met from domestic budgets and by the international community. Most cost analyses emphasise health facility based family planning and underplay the role of social marketing and community based distribution. In these countries government services tend to be used by the richer people, while the poorest either get no health care or they go to the private informal sector (Prata *et al*. 2005). Rumours and misinformation, such as rating oral contraceptive use more dangerous than childbirth, remain a common reason for not using family planning. A good deal is known about culturally sensitive, cost-effective ways to counter misinformation (Campbell *et al*. 2006). In an area of Tanzania where women listened to a radio drama, Twende na Wakati (*"Let's Go with the Times"*), 14% of listeners cited the programme as a reason for adopting contraception. The program cost $0.34 per person adopting family planning (Vaughan *et al*. 2000).

High fertility countries with a TFR of 4 and over: These countries include one fifth of the world's current population. In addition to improved access to family planning these countries also need to increase the age of the first birth. Radio and television dramas have been used successfully and cost effectively to delay marriage in developing countries. A great deal more research needs to be done to discover which interventions can be scaled up and what they would cost.

5.5 Planning for change

The previous section discussed ways of influencing demographic factors that impact on people's wellbeing and the planet. This section explores some ways to deal with the anticipated demographic changes.

5.5.1 Examples of integrated policy approaches

Population, health and environment (PHE) projects aim to improve the health and wellbeing of local peoples whilst conserving the critical ecosystems upon which they depend. They often operate in remote and sensitive landscapes where communities have little access to health services, particularly family planning, and poor provision of improved water sources and sanitation. The Woodrow Wilson Centre's Environmental Change and Security Program looks at PHE initiatives linked to development and conflict around the world (see evidence from the Woodrow Wilson Centre). Many PHE projects operate on a local scale, but some large-scale projects have been launched, such as the Integrated Population and Coastal Resource Management (IPOPCORM) project in the Philippines which now works in 33 municipalities covering over 350,000 people in a biodiverse area. The project has established 88 marine sanctuaries, and access to family planning services has increased 13-fold (see evidence received from PATH Foundation).

A very large scale example of integrated policy is the Bangladesh Rural Advancement Committee, now known simply as BRAC (Hulme and Moore 2008). Established in 1972, it is said to be the largest NGO in the world, providing health, family planning, education and finance for household development to a claimed 110 million clients. Along with the Grameen Bank (winner of the 2006 Nobel Peace Prize), which provides microcredit and promotes self empowerment, BRAC has been important to the remarkable success of Bangladesh in slowing population growth and starting to lift people out of poverty. Both organisations have a strong focus on women and girls.

5.5.2 Dealing with a young population

A higher proportion of the population entering working-age can produce greater per capita output and enhanced savings potential, leading to economic growth (Lee and Mason 2010). For this potential to be realised, effective institutions for saving and investment, macro-economic policies and alignment of other factors such as terms of trade, the rule of law, secure property rights and institutions that encourage public and private sector investment are required (Barro 1997). Where family planning has been accessible and birth rates have fallen moderately rapidly, as in the so-called 'Asian Tigers,' between 25 and 40% of economic growth is attributable to demographic change (Harper 2010b).

5.5.3 Dealing with population decline and population ageing

Approximately half the world's population now lives in countries with replacement level fertility or below (Wilson 2004). This reduction in fertility rates leads to a shift in the age structure of the population, from young to old. This shift, combined with the increase in longevity now seen in many countries, leads to an ageing of the population. In some countries, such as Greece, Italy, Russia, Korea, Hong Kong, Singapore or Japan the TFR is as low as 1.4.

Ageing of the population strains social insurance and pension systems and challenges existing models of social support (Turner 2009). An ageing population is now a global phenomenon, yet the social and economic conditions are so different in the developed and developing regions that policies have to be selected from a quite different set of options with different criteria guiding the choice between them (Howse 2007). Adequate finances and planning are required to ensure that long-term care of an ageing population is available. There are decisions to be made about the extent to which long-term care should be provided by the State or the individual.

For some countries, such as the UK, the ageing of the population is a relatively slow process and can be largely accommodated by modest, step wise increases in the age of retirement and raising productivity, complemented by a level of migration to meet skill and labour shortages. People are not only living longer in such countries, they have healthy lives at an older age. However, raising fertility or increasing immigration in order to maintain pensions as a fixed proportion of the gross domestic product is a mistaken, mechanistic approach (Turner 2009). Turner calls for a 'wealth optimising model' which takes into account the increasing years of healthy life,

a slow rise in the pensionable age, capital inheritance and wider welfare considerations of population density.

Forward planning can soften the impact of an ageing population on other social and environmental factors. For example, how ageing and urbanisation interact to impact upon the environment can be optimised by designing more energy efficient buildings and public transport. Education of especially vulnerable populations in nutrition and health can minimise the future costs of ageing while improving individual wellbeing.

Problems around economic support for older populations will mean that policymakers and employers have a role to play in enabling older people to continue to work, if they are able and willing to do so. This will require changes to working practices, job design and cultural attitudes including addressing discrimination against older and disabled people, if they are to succeed (POST 2011).

In contrast to rich countries, where support of the elderly is more easily affordable, support in mid-income countries typically comes from the family. As urbanisation, migration and employment of women become more widespread familial support is likely to come under pressure, and in these countries state support of the elderly infirm may not be affordable.

5.5.4 Planning for urbanisation

Urbanisation can be an engine for economic growth and, if well planned, cities have the potential to offer many benefits. Urbanisation can produce efficiencies in energy, transportation, housing and distribution of foods. The net effect on efficiency savings depends on the efficacy of political and institutional arrangements in regulation and remediation, and the pace of urban growth. Denser concentrations of populations are associated with greater use of public transport so energy consumption may be reduced. In the US, urban households drive less than rural ones.

If poorly managed, urbanisation can constrain economic growth and compound poverty. While cities command an increasingly dominant role in the global economy as centres of both production and consumption, rapid urban growth throughout the developing world is outstripping the capacity of most cities to provide adequate services for their citizens (Cohen 2006). Developing countries will be building the equivalent of a city of a million people every five days from now to 2050 (Cohen 2008). Many international agencies have yet to recognise adequately either the anticipated rapid growth of small and medium cities or the deteriorating living conditions of the urban poor (Cohen 2006). Refugees from violence and ecological change are also adding to urban growth, especially in parts of Africa. As cities grow they become more diverse, often leading to greater inequality. Consequently, a large number of urban residents in developing countries suffer to a greater or lesser extent from severe environmental health challenges associated with problems such as inadequate sanitation. There are also problems with urban sprawl, poor urban governance, and air pollution.

5.5.5 Planning for migration

As covered in Chapter 2 migration patterns are shaped by a complex interplay of economic, demographic, political, environmental and social drivers in sending and destination countries. Migration can, only to an extent, be planned for and managed. Chapter 2 showed that migration can contribute to the wellbeing of populations in countries of origin and contribute to development strategies if it takes place in ways that minimise brain drain and maximise returns from migrants' financial and human capital (Select Committee on International Development 2004; Malmberg *et al*. 2006; Chappell and Glennie 2009; OECD 2009; UNDP 2009; World Bank 2006b). Emigration must not be an alternative to measures to promote development but *'large gains to human development can be achieved by lowering the barriers to movement and improving the treatment of movers'* (UNDP 2009).

Migration currently lacks a coherent international governance framework. Although the nature of migration necessitates cooperation across borders, states have been reluctant to commit fully to international agreements because controlling who enters the territory is seen as integral to state sovereignty. The absence of an overarching UN framework of governance has led to a proliferation of bilateral, regional and international mechanisms for inter-state dialogue and negotiation, including since 2007 the Global Forum on Migration and Development (GFMD 2010; Betts 2011).

Countries experiencing a decline in population of working age can also benefit from migration as one element of a package of solutions to that problem. Across Europe, without international migration, the size of the working population would decline significantly (20% by 2050), exacerbating the age dependency ratio and threatening economic growth and competitiveness relative to parts of the world where the working age population continues to grow. Migration alone cannot mitigate the impact of population ageing but can complement measures addressing education and skills, housing mobility and the jobs available in the labour market. The optimal bundle of policies will vary across regions facing differing demographic and economic challenges, including measures to increase the employability and participation of young people, women and older people, thus reducing demand for labour migrants. Analysis shows, however, that raising participation rates alone would, in Europe, be insufficient to offset the declining workforce, so that migration of people with appropriate skills will continue to be necessary to reduce the gap. Evidence received during the study has suggested that 'sending and receiving countries should explore win-win solutions that allow the countries and economies involved as well as the migrants to gain from geographic mobility of labour and skills' (Münz 2009).

Development is not a key factor (and in most cases not a factor at all) when developed countries determine the "desired" level of immigration. In most cases, developed countries make immigration policy decisions based on social, cultural, political and economic factors of the receiving country. However, there are policies that receiving countries can adopt in order to maximise its developmental benefits.

There has been an increasing focus on dialogue and partnership between sending and destination countries in recent years, exploring mutually beneficial options including ethical recruitment and circular migration schemes (where migrants contribute on a temporary basis before returning with acquired skills and resources); co-financing of education; and measures to protect the working conditions of migrant workers. Ensuring that prospective migrants have accurate information on the labour market and living conditions can facilitate informed decisions and counter unethical recruitment practices. The International Organisation on Migration (IOM) makes a contribution to this in some parts of the world but this is an area where greater provision could benefit migrants, source and destination countries. International and bilateral agreements could also do more to ensure that migrant workers are not treated in ways that threaten their human rights and wellbeing (Solomon and Cholewinski 2009; UNDP 2009).

The UN Development Programme, in cooperation with the European Commission, UNHCR, UNFPA, IOM and the International Labour Organisation (ILO) run a Joint Migration and Development Initiative supporting exchange of good practice as well as concrete interventions in Africa and Asia. Examples include a project in Moldova to improve the financial literacy in rural areas of remittance recipients and senders, and a project in Morocco that is providing advice on opportunities for employment, education and entrepreneurship within Morocco, so that any

decision to migrate is taken in full knowledge of opportunities at home. Whilst there appears to be no evidence on the impact of these particular initiatives there is value in this approach to managing migration in ways that maximise the benefits and minimise the costs for all concerned. To avoid 'brain waste', destination regions including the EU could do more to recognise qualifications gained abroad so that migrants are not employed below their skill level.

Policy makers in destination countries have to consider not only the impact of migration on national and regional economies but also impacts on local politics, communities and services. This is no less true in less developed destination countries, but capacity can be lacking to implement appropriate measures. In 2005, for instance, only 11 African countries had a policy on the integration of non citizens. Issues arising from South-South as well as South-North migration should be considered; and policies to foster integration should be in place (Bakewell 2009). The scale of South-South migration and its significance to the wellbeing of migrants and host populations indicates the importance of integration (and re-integration) measures in all destination countries, not only in the most affluent states. Measures to foster the labour market, social and civic integration of migrants can help to maximise the benefits of migration and its acceptability to other residents. It has been argued that 'Changing attitudes towards migration from being a burden to a benefit of the European territory' is a necessary part of the approach (De Beer *et al*. 2010). Investment in education, language and skills training, coupled with measures to address discrimination and social tensions where they arise, can help to avoid a future migrant underclass (OECD 2009).

5.5.6 Planning for flourishing

In light of progress during recent decades, there are now grounds for optimism that the human population will stabilise during this century. This will not happen automatically: investment is urgently required, and there are serious conceptual barriers to be overcome, but the costs are not great. With goodwill and prompt action, on a voluntary basis with full recognition of human rights, a plateau of perhaps 10 billion people is achievable by 2100.

This achievement will be necessary but not sufficient to provide a sustainable future in which all can flourish. **At present there are no well charted ways for 10 billion people to achieve lifestyles like those enjoyed in the Most Developed Countries, because the only known way forward is economic growth, and that will come into collision with the finite earth. Technology can help, but without socio-political change it cannot solve.** There is much work to be done.

5.6 Conclusions

1. **The most immediate way to reduce the negative impact of human activity on the planet is to reduce material consumption of those who currently consume the most.** Longer-term, the stabilisation of the population is essential to avoid further exceeding planetary limits and increasing poverty.

2. The economic benefits and environmental degradation associated with increased consumption have not been distributed evenly around the globe, leading to social inequality. **A priority for the international community must be to bring the 1.3 billion people living on less than $1.25 per day out of absolute poverty**, and to reduce the inequality that continues around the world today.

3. **A priority for the most developed and the emerging economies must be to stabilise, and eventually reduce, material consumption and to adopt sustainable technologies.** This can be achieved by (amongst other approaches) improving resource use efficiency, reducing pollution from consumption, using alternative resources and technologies with lower environmental impact, facilitating behaviour change (through incentives or policy) and decoupling economic activity from environmental impact.

4. Most measures of societal progress, such as GDP, are inadequate because they do not include measures of natural capital – they do not measure sustainability. If sustainable development goals are to be achieved, society must have a full picture of how it is developing, and if development is sustainable. **There is a need to measure what matters to people's lives, in addition to GDP.** Measures of wellbeing can improve our understanding of the factors driving societal progress.

5. **Education provides economic benefits, builds strong societies and policies, and improves health.** Girls' education is a crucial step in developing the autonomy of women and it helps facilitate the adoption of voluntary family planning. Bringing primary and secondary education to all children will require political and financial support, which is estimated to cost between $34 billion and $69 billion per year.

6. **The cost of making family planning universally accessible in developing and least developing countries and delaying the age of the first birth in the least developed settings are extremely modest** compared with the cost of inaction in these two fields. Implementing family planning in the developing world is estimated to cost between $6.7 billion and $7.7 billion per year.

7. **Urbanisation can be an engine for economic activity and cities have the potential to offer many benefits if well planned.** However, it can constrain economic activity and compound poverty if poorly managed.

8. **Migration can contribute to development and to meeting the needs of ageing countries if well managed in ways that maximise the benefits and minimise the costs, including measures to protect human rights and foster economic, social and civic integration.** Migration can also provide significant financial benefit to the migrant's country of origin through remittances.

9. **Population and consumption are inseparable factors in sustainable development**, as demonstrated by the evidence and endorsed by the international community on several occasions. Discussions of sustainable development should take into account demographic factors and the influences on them. **Good planning is essential to maximise human wellbeing from these changes.**

CHAPTER 6

Conclusions and recommendations

6.1 Human impact on the Earth

During the writing of this report, the human population reached 7 billion, crossing a threshold rightly recognised as a landmark. Humans have expanded their range and activities far beyond that of any other species, with no end in sight for their journey of discovery, understanding and ingenuity.

However, human impact on the earth raises serious concerns. This report has explored the interactions between population, consumption and the environment. Humans are consuming resources and producing waste at an unprecedented rate. Population and consumption are both important: what matters is the combination of increasing population and increasing per capita consumption. Both global population and global consumption continue to rise and signs of unwanted impacts, interactions and feedback are growing – for example climate change reducing crop yields in some areas – and of irreversible changes – for example the increased rate of species extinction.

The relationship between population, consumption and the environment is not straightforward as the natural environment and human socioeconomic systems are complex in their own right. The multiplication of numbers of people by the amount each individual consumes tempts commentators to cherry pick evidence to suggest that one of these factors outweighs the other. The reality is that both population and consumption are significant. The biophysical boundaries to the Earth's capacity to meet human needs are finite, but how those limits are approached depends on lifestyle choices and associated consumption; these depend on what is used, and how, and what is regarded as essential for human wellbeing. The extreme diversity of regional situations has been illustrated throughout the report, as well as the highly variable proposed routes forward. In some regions continued high fertility locks people into poverty, while in others there is concern about high proportions of elderly people in the population. In some regions per capita consumption is far above the level that can be sustained for everyone in a population of seven billion or more, while 1.3 billion people continue to live in extreme poverty.

A coherent assessment of challenges to people and the planet, and how they should be addressed, is critical for achieving sustainable development.

6.2 Consumption, population and equality

Consumption plays a key role in enhancing individual wellbeing, as a multiplier of the impacts of people on the environment, and as the engine for economic activity. The consumption of goods and services delivers the various dimensions of human wellbeing. The economic and environmental outcomes of demographic change are, directly or indirectly, a consequence of material throughput via resource consumption and waste disposal.

In the short term it is of the utmost urgency to reduce consumption and emissions that are already causing damage, for example greenhouse gases, deforestation, and land use change amongst others. Furthermore, unless the goal is a world in which extreme inequality persists, it is **necessary to make space for those in poverty, especially the 1.3 billion people living in absolute poverty, to achieve an adequate standard of living**. We take the view that reduction of inequality is in itself an important goal, but are aware that the matter is contested. It is indeed possible to imagine an unequal yet sustainable world, but such a world would deny many people the opportunity to flourish.

Mortality has shown a welcome decline almost everywhere, with generally increasing life expectancy, due to improved standards of living in nutrition, behaviour, public health, and medicine. Fertility has fallen and is now at or below replacement in More Developed Countries, and parts of Asia and Latin America. Overall people are healthier, wealthier and more educated. However, vast inequalities remain. Some of the Least Developed Countries face severe problems of increasing population size that interferes with achieving a basic standard of living. As a whole, population is still growing at a rate of 1 billion in 12 years, because of the demographic momentum inherent in a large cohort of young people. The global rate of population growth is already declining, but the poorest countries are not experiencing, or benefiting from, this decline.

Many of the complex problems that face the world in the coming decades will be ameliorated by slowing rapid population growth in the Least Developed Countries and averting unintended pregnancies everywhere, including the More Developed Countries. In the long term a stabilised population is an essential prerequisite for individuals to flourish, but this is by no means a coercive prescription. Flourishing is about individuals' rights, responsibilities and wellbeing. **Meeting the need for family planning is a fundamental health issue**, and therefore is important in its own right irrespective of arguments about population. Population growth can be slowed within a framework that fully respects human rights and establishes appropriate policies and investments. Help with family planning should preferably be provided in a framework that includes education and healthcare.

The shift from high mortality and high fertility to low mortality and low fertility is known as the demographic transition. Of key importance is the speed at which the transition occurs and the spacing of the stages. Rapid demographic changes present challenges, but also opportunities. Countries with declining fertility but continuing population growth have a youth bulge: if well managed this high fraction of people of working age provides a boost to the workforce and a rise in prosperity (as achieved by the 'Asian tigers'); if poorly managed, it can lead to high unemployment and potential conflict. In countries that completed the transition fifty years ago the population is ageing: this brings challenges of social care, reduced economic activity, health care, and equitable distribution. These problems will be transient and will reduce as the population bulge passes through.

Countries where mortality has fallen without transition to lower fertility are experiencing high population growth and a high proportion of children, in which health and education services struggle to keep up. Without timely intervention to facilitate and promote reduced fertility, these problems will persist, building even greater demographic momentum. **Policy and directed investment have an important role to play in reducing negative and maximising positive environmental, social and economic impacts of demographic change**.

During the 1960s to early 1990s, population growth was on the agenda for discussion at the international level. It has taken a back seat more recently because of perceptions that global population growth is no longer a problem, concerns about coercive family planning, religious and cultural sensitivities, and the view that while it is one contributor to poverty and inequality, it is difficult to understand or to influence. In fact, rapid population growth is still a major problem in some regions of the world, and globally is of concern from the perspective of a finite planet. The longer the delay, the more difficult it becomes to move toward sustainability. The cost of providing a family planning service to all who need it would be some $7 billion per year.

Recommendation 1

The international community must bring the 1.3 billion people living on less than $1.25 per day out of absolute poverty, and reduce the inequality that persists in the world today. This will require focused efforts in key policy areas including economic development, education, family planning and health.

Recommendation 2

The most developed and the emerging economies must stabilise and then reduce material consumption levels through: dramatic improvements in resource use efficiency including reducing waste; investment in sustainable resources, technologies and infrastructures; and systematically decoupling economic activity from environmental impact.

Recommendation 3

Reproductive health and voluntary family planning programmes urgently require political leadership and financial commitment, both nationally and internationally. This is needed to continue the downward trajectory of fertility rates, especially in countries where the unmet need for contraception is high.

Recommendation 4

Population and the environment should not be considered as two separate issues. Demographic changes, and the influences on them, should be factored into economic and environmental debate and planning at international meetings, such as the Rio+20 Conference on Sustainable Development and subsequent meetings.

6.3 Migration, urbanisation and ageing

Migration for economic, social and environmental reasons will continue, as well as flight from conflict and persecution. Environmental change, interacting with other factors, will affect migration now and in the future, although those that are most vulnerable to environmental change may not be able to migrate far. Migration can contribute to economic and social development, and with other measures to alleviate the challenges of ageing population. Migration in combination with increased productivity and extended working lives can help to reduce the ratio of dependents to workers.

Policy makers should prepare for international migration and its consequences, for integration of migrants and for protection of their human rights to maximise the gains and minimise the costs of migration for all concerned.

Migration within countries often involves urbanisation, which can both increase consumption (eg by increased use of appliances) and decrease it (eg by increased use of public transport). **Urban planning is essential** to avoid the spread of slums, which are highly deleterious to the welfare of individuals and societies. **Developing countries will be building the equivalent of a city of a million people every five days from now to 2050**.

Recommendation 5

Governments should realise the potential of urbanisation to reduce material consumption and environmental impact through efficiency measures. The well planned provision of water supply, waste disposal, power and other services will avoid slum conditions and increase the welfare of inhabitants.

6.4 Education

Education in itself is an unfettered good, and **universal high quality education to at least 16 years of age is a prerequisite for human development**. Full provision has been estimated to cost an additional $34 billion to $69 billion per year. It promotes wellbeing and is necessary for good governance. In high fertility societies investing in young women is of particular importance, and will bring a positive return in health, and earning capacity of the girls who stay in school and the consequent empowerment of adult women. Education pays off in their own life satisfaction, in the survival, health and education of their children, and in household and national prosperity. Education has also been shown to raise the lifetime earnings in both developed and developing countries. For ageing populations education is also of great importance; in general, well educated people live longer healthier lives, and are more resilient to, and capable of, change.

Recommendation 6

In order to meet previously agreed goals for universal education, policy makers in countries with low school attendance need to work with international funders and organisations, such as UNESCO, UNFPA, UNICEF, IMF, World Bank and Education for All. Financial and non-financial barriers must be overcome to achieve high-quality primary and secondary education for all the world's young, ensuring equal opportunities for girls and boys.

6.5 The role of science and technology

Science is most often thought of as supplying practical solutions – which it does with great success. A huge amount has yet to be accomplished in mitigating problems and improving the human estate. For example, developing and deploying renewable energy sources that do not emit greenhouse gases is of pressing importance; many solutions are at hand, and others will be found. Crop strains are being developed that provide higher yields or are tolerant to adverse conditions, and will be extremely valuable, especially in the face of climate change. The elimination of most diseases, especially those of childhood that have been so far neglected, is a very large but accomplishable task.

However, it is wrong to suppose that technology on its own will solve all problems. **Barriers must be overcome not only by technology, but also by changes in usage and governance.** Furthermore attention must be paid to the socio-economic issues associated with technological deployment and growth in population and consumption, otherwise technology will always be catching up. Science has a crucial role to play in improving the understanding of causes and effects, and ways to intervene effectively to limit the most damaging trends.

For example in food production and distribution 30% or more of food is wasted by inadequate storage or transport facilities, by market distortion, or simply by being discarded. Saving even part of this loss would alleviate present hunger and help in the challenge of meeting future needs. Furthermore, without better planning the hoped for improvements from scientific development may largely be lost. Recently the situation has been worsened by the search for renewable sources of energy. First generation biofuels offer little saving in greenhouse gas emissions over oil, yet are being allowed to displace food crops from agricultural land and destroy natural habitats.

Partly for this reason, **the role of science in measuring and diagnosis is of at least equal importance to its role in providing solutions.** For example, detailed measurements made over the course of many years have provided a clear perspective on climate change. Information allows for better solutions; these may be innovative or traditional, but in either case the science for diagnosis is crucial.

Humanity needs to learn to act collectively and constructively in the face of long term and therefore sometimes elusive threats, not just when faced with immediate and tangible ones. In addition to identifying threats attention must be paid to warnings and responses undertaken accordingly. The best technology applied in the context of a thoughtful society increases the chances of the majority of humanity flourishing rather than merely surviving.

Recommendation 7

Natural and social scientists need to increase their research efforts on the interactions between consumption, demographic change and environmental impact. They have a unique and vital role in developing a fuller picture of the problems, the uncertainties found in all such analyses, the efficacy of potential solutions, and providing an open, trusted source of information for policy makers and the public.

6.6 Economic governance

Consumption is closely linked to current economic models based on growth.

In the Less Developed Countries, economic development is essential to reduce levels of absolute poverty and improve living conditions. Addressing the plight of the world's poorest people will increase the chances of having healthy, well-educated populations that can cope with tomorrow's problems (whatever they turn out to be). Above a certain income level wealth seems to have little effect on individual well-being, though natural impulses of aspiration and perception of worth relative to others continue to drive consumption.

It is difficult to identify exactly where the material limits on continued growth in the global economy will emerge. It is most likely that a combination of factors will require increasing effort and expense to overcome. Declining resource qualities will require higher energy inputs and lead to rising commodity prices. Water stresses in many areas of sub-Saharan Africa and Asia will lead to famine and conflict. Increasing exposure to pests, diseases and natural hazards associated with climate change will undermine the resilience of ecosystems and livelihoods. Increasing disruption to ecosystems will lead to regional or local environmental collapse. The knock on impacts on the wellbeing of dependent communities may be sudden and irreversible.

The implication of these constraints is that the material throughput of the economy cannot grow forever. The economy of the future must produce goods and service of value to humanity with dramatically reduced physical impact.

But today's market system is distorted by failure to price environmental and social impacts, leading to perverse incentives for unsustainable activities. GDP is a poor measure of social wellbeing and does not account for natural capital. In the past it has proved to be an attractive measure for policy makers because it reduces many complex issues into a single figure that can be compared between countries. It is also a strategic weapon in a world where nations compete for economic and political significance – often at the expense of future well-being.

A better measure than GDP is one of comprehensive wealth – which includes the value of a country's entire set of capital assets (natural, manufactured, human, knowledge, and institutional). Many leaders around the globe are now aware that something more than GDP is needed to measure what matters in people's lives and to secure resources for future generations. But a consensus on a replacement measure or set of measures has not yet been achieved, partly because of the central role of GDP in global economics. In practical day-to-day transactions GDP is very firmly established and can only be superseded by general agreement. The series of difficult meetings on climate change illustrate how hard it is to reach such agreements. Nevertheless, there is cause of hope: a century ago, the concept and apparatus of GDP did not exist. If such a limited and inadequate measure can attain dominance in a few decades, surely it can be replaced by better measures.

Given business as usual, environmental degradation will continue, compromising fundamentally important ecosystem services, the provision of goods like food, energy and water and making it ever more difficult to move the planet to a sustainable economy where today's activity does not threaten the welfare of future generations. Therefore **decoupling economic activity from material and environmental throughputs is needed urgently** – for example, by reusing and recycling materials (circular economy), obtaining energy from renewable sources (zero carbon economy), and by consumers paying for the wider costs of their consumption. Decoupling cannot be the sole panacea: it must be applied as one of a package of measures.

Beyond these measures, there is a need to explore alternative models to the growth-based economy. This is not to suggest simply abandoning the current model. There are serious challenges in devising an economy with flat or contracting GDP. The most significant of these arise from the need to generate full employment for the working age population, the need to stabilise debt-based financial systems, and the need to maintain high quality public services. None of these difficulties eliminates the urgency of addressing the problem. Industrial strategies which encourage and support sectors with low material throughput and high employment potential will need to be developed that also provide sufficient numbers of jobs.

Recommendation 8
National Governments should accelerate the development of comprehensive wealth measures. This should include reforms to the system of national accounts and improvement in natural asset accounting.

6.7 Road map

Humans have interacted strongly with the environment since people mastered fire, settled in every continent except Antarctica, invented agriculture, and launched the industrial revolution. Humanity is now approaching a crucial time in this ongoing interaction, making this a critical moment for policy makers.
Over the next 30 – 40 years the confluence of the challenges described in this report provides the opportunity to move towards a sustainable economy and a better world for the majority of humanity, or alternatively the risk of social, economic and environmental failures and catastrophes on a scale never imagined. This report has outlined some possible pathways to achieving a sustainable economy, through the combination of application of socially applicable technology, political leadership and institutional reform.

The problem of resource allocation is often referred to as the tragedy of the commons, but that phrase can be taken to mean that by just dividing up the commons into separately owned lots all will be well. Sometimes that is the case, but some commons are valuable as commons (for example human knowledge), and parts are impossible to divide up (for example the atmosphere). Regulation of the many commons that concern all humanity must be achieved by high level negotiations that do not fall back exclusively on appeals to "my nation's interests". Beyond the very short term, the real interests of nations lie in solving global problems in an equitable fashion, not just in each struggling to stay ahead. Implementation requires farsighted leaders who are able to convince voters at home that the conclusions are necessary and just and serve their long-term interests.

So long as an excess of competition between nations continues, the future of humanity is in doubt. Changes to the current socio-economic model and institutions are needed to allow both people and the planet to flourish by collaboration as well as competition during this and subsequent centuries.

Recommendation 9
Collaboration between National Governments is needed to develop socio-economic systems and institutions that are not dependent on continued material consumption growth. This will inform the development and implementation of policies that allow both people and the planet to flourish.

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Glossary

Biodiversity	The variability of life within and between species as well as at the level of ecosystems (according to the Convention on Biological Diversity, see http://www.cbd.int for more information).
Biofuel	A fuel produced from organic matter or combustible oils produced by plants. Examples of biofuel include alcohol, black liquor from the paper-manufacturing process, wood, and soy-bean oil.[1]
CO_2	Chemical formula for carbon dioxide.
Demographic deficit	Occurs when there is a higher proportion of dependents to workers in the population, potentially leading to reduced productivity and restricted economic activity.
Demographic dividend	Occurs when there is a higher proportion of workers to dependents within a population, and therefore a potential for added productivity which can increase economic activity, assuming that the correct policies are in place to take advantage of this.
Demographic inertia	The tendency for current population parameters, such as growth rate, to continue for a period of time; there is often a delayed population response to gradual changes in birth and mortality rates[2]. A common example occurs when a well-below replacement level of fertility becomes established over several cohorts.
Demographic momentum	The tendency for population growth to continue beyond the time that replacement-level fertility has been reached because of the relatively high concentration of people in the childbearing years.
DFID	(UK) Department for International Development.
EC	European Commission.
Ecosystem Services	Activities or functions of an ecosystem that provide benefit (or occasionally disbenefit) to humans. Can be split into four categories (supporting services, provisioning services, regulating services, cultural services) as explained in Box 4.1.
Eutrophication	The enrichment of water by mineral and organic nutrients (normally nitrates and phosphates) that promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content and often causes the extinction of other organisms.
Green Economy	Defined by UNDP and the World Bank as an economy that results in improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities.
HDI	Human Development Index, a composite statistic used to rank nations' development by measuring income, health and education. Developed by the United Nations Development Programme.
HPI	Happy Planet Index, a composite statistic used to rank nations using a measure of human wellbeing and human impact on the planet. Developed by the New Economics Foundation.
IAP	The global network of science academies, formerly known as the InterAcademy Panel on International Issues; the former acronym has remained in use.
ICPD	International Conference on Population and Development.
ICSU	International Council for Science, formerly known as the International Council of Scientific Unions; the former acronym has remained in use.
IMF	International Monetary Fund.
MA	Millennium Ecosystem Assessment.
OECD	Organisation for Economic Co-operation and Development.
Old-age dependency ratio	The old-age dependency ratio is the number of persons 65 years and over per one hundred persons 15 to 64 years.
Purchasing power parity (PPP)	A currency conversion rate that both converts to a common currency and equalises the purchasing power of different currencies. In other words, it eliminates the differences in price levels between countries in the process of conversion.[3]

1 IPCC WG II (2007) Impacts, Adaptation and Vulnerability.
2 See http://wildlife.state.co.us/SiteCollectionDocuments/DOW/WildlifeSpecies/SpeciesOfConcern/GreaterSageGrouse/StatewideConsPlan/Glossary.pdf
3 OECD: http://www.oecd.org/department/0,3355,en_2649_34357_1_1_1_1_1,00.html

Replacement Fertility	Replacement level fertility is the average number of children born to a woman so that a population exactly replaces itself from one generation to the next (Craig 1994). In More Developed Countries, this is roughly total fertility rate of 2.1 children per woman, but the global variation is substantial, ranging from less than 2.1 to 3.5, due principally to variation in mortality rates (Espenshade 2001). This report, assumes a replacement level fertility of 2.1 children per woman.
Sahel	A geographic region in Africa marking the transition in between the Sahara desert in the north and the Sudanian Savanna in the south. The Sahel forms a wide (up to 1000km) 'belt' across Africa between the Atlantic Ocean and the Red Sea.
Total dependency ratio	The number of persons under age 15 plus persons aged 65 or older per one hundred persons 15 to 64. It is the sum of the youth dependency ratio and the old-age dependency ratio.
Total Fertility Rate (TFR)	An age adjusted, period measure of lifetime fertility, derived by adding age-specific birth rates in a given year over all ages of childbearing. When the rates for the individual ages are combined, the resulting figure represents the average number of children a hypothetical cohort of 1000 women would have in their lifetime in the absence of mortality before the end of child bearing (Siegel and Swanson 2007).
UN	United Nations.
UNCED	United Nations Conference on Environment and Development.
UNDP	United Nations Development Programme.
UNESCO	United Nations Educational, Scientific and Cultural Organisation.
UNFPA	United Nations Population Fund.
UNHCR	Office of the United Nations High Commissioner for Refugees.
UNICEF	United Nations Children's Fund.
UNPD	United Nations Population Division.
WWF	World Wild Fund for Nature, formerly known as World Wildlife Fund, the former acronym has remained in use.
Youth bulge	A population with a high proportion of population aged 15-24 or 29 years. A wide range of definitions have been used, including the percent of young people in the total population, in the total adult population and in the working age population (15-64 years). Youth bulges persist until a couple of decades after the onset of fertility decline which acts initially to stabilise and then reduce cohort size.
Youth dependency ratio	The number of persons 0 to 14 years per one hundred persons 15 to 64 years.

Appendix 1: details of evidence received

To inform the study an open call for evidence was issued in was issued in July 2010, following the Working Group's first meeting, which resulted in 104 responses that informed the study. Expert workshops were also held on the role of industry, non-governmental organisations and technology. Given the breadth of the study the report was also sent to ten Fellows for comment in addition to the formal Review Panel.

We are grateful to the following individuals and organisations who responded to the call for evidence and to those who provided additional evidence at the request of the working group.

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- Sir John Beddington CMG FRS
- Benevolent Organisation for Development, Health and Insight (BODHI)
- Bixby Center for Global Reproductive Health
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- International Institute for Applied Systems Analysis (IIASA)
- International Planned Parenthood Federation
- International Union for Conservation of Nature
- International Union for the Scientific Study of Population (IUSSP)
- Adam Izak-Sunna
- Dr Yuji Ishiguro
- Dr Eric Kaufmann
- Dr Ashok Khosla
- Dr Maurice King
- Professor Roger Leakey
- Leopoldina – National Akademie der Wissenschaften
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- Rainer Münz
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- Dr Ricardo Oses
- Dr Jane O'Sullivan
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- Population and Sustainability Network
- Population Matters
- Population Media Center
- Pro-biodiversity Conservationists in Uganda (PROBICOU)
- Professor Phil Rees
- Dr Peter J Richerson

- Benoît Rivard
- Robert S. Strauss Center for International Security and Law
- Peter Salonius
- Science Council of Japan
- Professor Ludi Simpson
- Alan Stedall
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- John Taves
- Clive Thompson CBE
- Dr Graham Turner
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- United Nations Association of Scotland
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- Matthew Watkinson
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- World Wide Fund for Nature (WWF)
- Dr Valerie Yule

The following Fellows for providing comments on the draft report

- Sir Roy Anderson FRS, Imperial College London
- Professor Michael Batty CBE FBA FRS, University College London
- Sir Roy Calne FRS, University of Cambridge
- Professor David MacKay FRS, Department of Energy & Climate Change
- Lord May of Oxford AC FRS OM Kt, Past Royal Society President
- Professor John Pickett CBE FRS, Rothamsted Research
- Professor John Pyle FRS, University of Cambridge
- Lord Rees of Ludlow FRS OM Kt, Past Royal Society President
- Professor John Shepherd CBE FRS, University of Southampton
- Dr John White FRS, University of Wisconsin

Workshop attendees – NGO, Technology and Industry workshops

- Sir Roy Anderson FRS, Imperial College London
- Rachel Baird, Christian Aid
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- Richard Carter, Water Aid
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- British Embassy, Switzerland
- British Embassy, Washington
- British High Commission, Malaysia
- British High Commission, New Delhi
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Appendix 2: country groupings

Throughout the report we have referred to the Least, Less and More Developed Countries. These are the United Nations' definitions of regions, and are defined in the following ways:

Least Developed Countries
Any country defined as 'Least Developed' by the United Nations General Assembly in its resolutions (59/209, 59/210, 60/33, 62/97, 64/L.55). This is based on low performance in three criteria: per capita gross national income (GNI), human assets and economic vulnerability to external shocks.

Less Developed Countries
Any country which is not 'Least Developed', but is in a 'Less Developed region', comprising all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia

More Developed Countries
Any country which falls into a 'More Developed region', comprising Europe, Northern America, Australia, New Zealand and Japan.

http://esa.un.org/wpp/Other-Information/WPP2010_Special%20Aggregates%20-%20list%20of%20groupings.pdf

List of least developed countries from http://www.unohrlls.org/en/ldc/25/

Africa (33)

1 Angola
2 Benin
3 Burkina Faso
4 Burundi
5 Central African Republic
6 Chad
7 Comoros
8 Democratic Republic of the Congo
9 Djibouti
10 Equatorial Guinea
11 Eritrea
12 Ethiopia
13 Gambia
14 Guinea
15 Guinea-Bissau
16 Lesotho
17 Liberia
18 Madagascar
19 Malawi
20 Mali
21 Mauritania
22 Mozambique
23 Niger
24 Rwanda
25 São Tomé and Príncipe
26 Senegal
27 Sierra Leone
28 Somalia
29 Sudan
30 Togo
31 Uganda
32 United Republic of Tanzania
33 Zambia

Asia (14)

1 Afghanistan
2 Bangladesh
3 Bhutan
4 Cambodia
5 Kiribati
6 Lao People's Democratic Republic
7 Myanmar
8 Nepal
9 Samoa
10 Solomon Islands
11 Timor-Leste
12 Tuvalu
13 Vanuatu
14 Yemen

Latin America and the Caribbean (1)

1 Haiti

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