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Measuring sustainability

UK wealth accounts for 25 years

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Abstract

What is sustainability and how do we measure it? Sustainability could be achieved through sustainable development and much of the literature on sustainable development has taken human well-being to be the object to be sustained. By constructing a very large and extensive National Accounts consistent database, this study develops an original set of UK wealth accounts for 25 years – 1988 to 2012 – to measure UK sustainability. While doing so, this research calculates the monetary value of UK natural capital and human capital which is then added into produced capital to develop a first comprehensive wealth account for the UK. This thesis argues that both wealth accounting approaches - "top-down[1]" and "bottom-up[2]" - are conceptually the same. They only differ empirically because of the methodologies employed to calculate natural capital, human capital and total wealth. This thesis shows how these both approaches can be combined together to measure UK sustainability.

This study concludes that since 2007 UK is not on a sustainable path. Despite a positive genuine savings, since 2007 UK wealth has a negative growth rate and wealth per capita is in decline. A positive genuine savings with a fall in wealth per capita shows that UK savings has not been sufficient to compensate for a fall in wealth and population growth. In order to reverse the trend, either UK has to reduce its population growth or it needs to reinvest in its capital asset bases. This thesis argues that an increase in population does not always decrease per capita wealth because an increase in population driven by a skilled work force increases the value of human capital and thus total wealth. This increase in wealth could offset an increase in population keeping per capita wealth intact. Furthermore, for UK, which is not a resource rich country, investment in human capital is needed to increase the rate of wealth growth.

[1] Total wealth calculated by the World Bank in "Where is the Wealth of Nations" (2006) and "The Changing Wealth of Nations" (2011) is based on theory developed by Hamilton and Hartwick (2005).
[2] Total wealth calculated by the "Inclusive Wealth Report" (2012) is based on theory developed by Arrow et al. (2012).

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Chapter 1

Measuring sustainability

1. Introduction

What is sustainability and how do we measure it? Sustainability is a complex concept and could be referred to everything we need for our survival and well-being. To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations. Sustainability could be achieved through sustainable development and the concept of sustainable development has been around for centuries with differing definitions. Neumayer (2013) argues that Sustainable Development is a vague concept with differing definitions and suggests that the likely economic definition of sustainable development accepted by most would be "*development is sustainable if it does not decrease the capacity to provide non-declining per capita utility for infinity*". Neumayer (2013) defines 'capacity' in terms of maintaining the capital that is necessary to provide non-declining future utility, not in direct utility terms. The capital is broadly defined as a stock that provides current and future utility.

Much of the literature on sustainable development has taken human well-being to be the object to be sustained. There are two alternatives views on sustainable development: the current generation's well-being and inter-generational well-being (Arrow et al. 2014). The determinants of current well-being are based on consumption, leisure activities and environmental amenity services. Solow (1974), Nordhaus and Tobin (1972), Hartwick (1977), and Jones and Klenow (2010) theoretical and empirical studies were in this vein. For example, Solow (1974) was concerned whether consumption of non-renewable resources imposes a limit on future well-being and Hartwick (1977) showed that constant consumption for ever can be achieved by following his rule. Studies in this vein formulated that a society's economic development would be said to be sustainable at a point in time if its *real income* were non-decreasing at that time.

In contrast, in the case of intergenerational well-being, the presumption is that at any given date social well-being is not only represented by the well-being of the current generation, but also the potential welfare of the generations that are to follow. Hamilton and Clemens

(1999), Dusgupta (2001) and Arrow et al. (2004) empirical work was in this vein. In their formulation a society's economic development would be sustainable at a point in time if its *wealth* were non-decreasing at that time after adjusting for discounting. Following Hamilton's approach, if wealth is non-declining, then future well-being will also be higher under certain conditions (Hamilton and Withagen, 2007).

The most modern day expression of sustainable development can be traced back to 1987 by the Brundtland Commission[3] in their report *Our Common Future.* In their landmark report the World Commission defined sustainable development as "development that meets the needs of the present without compromising the needs of future generations to meet their own needs".

Since their concern was about not only the well-being of present generation but future generation as well, the Commission's focus was not only on the environment but on the productive base of economies, which comprise the entire range of capital assets to which people have access. However, the report did not provide any guidance on how the productive base should be measured, which left countries with little choice but to continue using GDP to track progress of human well-being, or to develop a new set of sustainability indicators.

2. System of National Accounts

Over the last 50 years macro-economic policy has largely been based on information flowing from the System of National Accounts (SNA) framework. The SNA was introduced in 1953 as an international standard for measuring economic activity and it focused exclusively on measuring economic growth, in particular production in markets, for which prices were available. When the SNA was introduced, there was no perceived need for better treatment of natural resources and the environment than produced assets, as resources were considered abundant and the environment an inexhaustible sink. However, a significant increase in world population and the world economy has since put a stress on the natural environment, resulting in depletion and degradation of natural capital.

[3] In 1983, the Secretary General of the United Nations appointed a special commission to address the rapid deterioration of human and ecological environment. The commission known as the World Commission on Environment and Development published its report Our Common Future in 1987.

A full articulation of the SNA includes many measures of economic activities, one of which is Gross Domestic Product (GDP). An increase in GDP has led to job creation and improved well-being for many people. While economic growth has produced many benefits – raising standards of living and improving quality of life across the world – it has also resulted in the depletion of natural resources and the degradation of ecosystems. There has been much debate over whether or not it is possible to achieve economic growth without unsustainably degrading the environment, and a growing realisation that economic growth at the current rate of depletion and degradation of environmental assets cannot continue indefinitely.

3. Beyond GDP

There have been critiques since the early days of the SNA - some of the early welfare accounting proposals came from the 1960s; studies from Nordhaus and Tobin were in the early 1970s; and sustainability rationale for greener accounts is known from at least the late 1980s. The founding fathers of national accounting – Hicks, Kuznets, Samuelson, and Tinbergen – were also well aware of this. The SNA explicitly recognises the limitations of GDP as a measure of well-being[4]: "*Movements of GDP cannot be expected to be good indicators of changes in total welfare unless all the other factors influencing welfare happen to remain constant, which history shows is never the case".*

In an attempt to address these concerns and to broaden the perspective of well-being beyond economic growth and income, the Human Development Index (HDI) was developed. The HDI added literacy and mortality to the equation of income; however, HDI was not a perfect measure to capture sustainability. Sagar and Najam (1998) suggested that for the HDI to capture the sustainability dimension of human development, it would need to incorporate some mechanism for accounting overexploitation of natural resources.

Indeed, neither GDP nor the HDI give any indication of whether a country is on a sustainable path (Dasgupta, 2009). A number of theoretical works (for example, Kunte et al. 1998; Dusgupta and Maler 2000, 2001; Heal and Kristrom 2001; Arrow et al. 2003) have demonstrated that sustainable development requires non-declining per capita wealth, where wealth is defined in the broadest sense to include produced, natural and human

[4] Source: OECD (2013)

capital. Among the body of empirical work, one of the recent initiatives was the Commission on the Measurement of Economic Performance and Social Progress Report (Stiglitz et al. 2009), known as the "Stiglitz Report". The report identified the key dimensions of well-being to include health, education, social connection, political voice, unpaid household work, and present and future condition of the environment. The Commission notes that “all these dimensions shape people’s well-being and yet many of them are missed by conventional income measures.” This could be because GDP only measures activity within ‘the market’; however, much of what maintains and enhances well-being occurs outside of the market. Therefore, the Commission argued that applying a broader definition of wealth, to include natural capital, social capital and human capital, could provide a better understanding of well-being. Several institutions have incorporated these concepts in their conceptual frameworks (OECD, 2013).

Pioneering studies such as those by Kenneth Arrow and others, and the World Bank have provided a framework that provides a single indicator to measure wealth and the changes in wealth over time. The concept of comprehensive wealth is important as having a present day estimate of this wealth signals our future prospects for well-being and prosperity. In turn, the way in which this wealth is changing over time indicates how these future prospects are altering. There are some limitations in the comprehensive wealth framework, for example, it does not currently include factors such as cultural capital which is an important factor to determine well-being. However, despite its limitation, Stiglitz, Sen and Fitoussi (2009) recommended comprehensive wealth as one useful indicator of well-being.

4. Comprehensive wealth

Comprehensive wealth is the measure of an economy’s productive base, which comprises the entire range of capital assets to which people have access. Traditionally wealth has been defined as a stock of produced capital such as buildings, machinery, equipment and infrastructure. Economic theory tells us that there is a strong link between changes in wealth and sustainable development (World Bank, 2006). If a country is running down its assets, it is not on a sustainable path. For the link between changes in wealth and sustainability to hold, however, the notion of wealth must be truly comprehensive.

The publication *Where is the Wealth of Nations (World Bank, 2006)*, *The Changing Wealth of Nations (World Bank, 2011)* and *The Inclusive Wealth Report (2012)* are initiatives that have expanded the definition of wealth by including different capitals into a wealth framework. These reports rely on an economic welfare model for their theoretical foundation and measure sustainability and well-being by measuring changes in wealth, instead of economic growth and income.

The World Bank (2006, 2011) extends its wealth measures by accounting for exhaustible resources, renewable resources and agricultural land. They also include intangible capital, which encompassed raw labour, human capital (the knowledge, skills, competencies and attributes embodied in individuals), social capital and the quality of institutions.

The Inclusive Wealth Report (2012) is based on theory developed by Arrow et al. (2012) in their paper *Sustainability and the Measurement of Wealth.* The paper provides a theoretical framework based on social welfare theory to address the multiple issues which sustainable development attempts to address. The paper shows how expanding the asset boundary beyond produced and natural assets could increase the measures of income, savings and wealth enormously. The paper expands the definition of wealth by including 'health' and 'time' as an asset. However, The Inclusive Wealth Report[5] (IWR) treats health capital[6] separately from other forms of capital and does not include it in its Inclusive Wealth Index (IWI), as it argues that modest changes in health capital could outweigh any changes in the other three assets – produced, human and natural. The IWR also includes 'time' as an asset and argues that a country enjoys an expansion of its productive base simply by waiting and, therefore, time should be included in a society's productive base. Hence, the report defines wealth as the social worth of an economy's assets that includes reproducible capital, human capital, knowledge, natural capital, population, institutions, and time.

However, it opens up an interesting discussion on how to empirically measure these elements of wealth[7]. For example, Hamilton (2012) shows reservations on including health and time as an asset and pointed out that there is a need for further research. Hamilton is

[5] The Inclusive Wealth Report, published in June 2012, is a joint collaboration between the United Nations University International Human Dimensions Programme and the United Nations Environment Programme.

[6] IWR defines health capital as an increase in life expectancy that translates into an improvement in health. The value of health improvements is the value that people attach to the additional years of life that results from such improvements (Arrow et. al, 2012).

[7] See Symposium by Anastasios Xepapadeas (2012)

alarmed by the huge size of health capital and argues that the US value of statistical life (VSL) used in Arrow et al and Nordhaus (2002) merits careful consideration because it assumes that VSL can serve as the value of health or healthfulness, but it arguably includes everything that people value in life – consumption of goods, leisure, enjoyment of environmental amenities, relationship with friends, and so on, in addition of good health, which could end up in double counting. Solow (2012) is also alarmed by the huge size of health capital and shows concern that the whole exercise of including health as a capital is about increasing longevity. Solow (2012) also argues that it does not make sense to include time as a capital stock with its own rental rate or shadow price. This is because no decision is involved while waiting for capital gains on natural resources and one cannot choose to alter the stock of time, which simply marches on exogenously.

Arrow et al. (2014) clarify their methods and offered few observations in their paper '*Sustainability and the measurement of wealth: further reflection' (2014)*. They argue that what should be included on the list of capital assets is in part a matter of convenience and knowledge capital and institutional capital are common terms today. Arrow et al. (2014) also defended the huge size of health capital and argue that their results made use of the values of statistical life reported in the literature and are used in practice, for example, to set standards in air quality, and do not seem to have led to any absurd results. They also dismissed the views of double counting.

There is still an ongoing debate on what capital should be included in the comprehensive wealth; however, there is a broad agreement on including natural capital, human capital and social capital (though it has proved harder to value) in addition to produced capital in the comprehensive measure of wealth.

5. Sustainability indicators

A sustainable path is the one in which the present value of current plus future well-being is not decreasing (Hamilton and Hartwick, 2004). A large literature has shown that a comprehensive measure of the change in real wealth per capita plays a central role in determining whether current well-being can be sustained - for example see Pezzy (2004), Hamilton and Hartwick (2005), and Hamilton and Withagen (2006). In particular, current decline in real wealth per capita signals that future well-being can also decline (Hamilton and Hartwick, 2014). Therefore, it can be concluded that a change in wealth per capita over time suggests whether or not a country is on a sustainable path. To measure sustainability, Pearce and Atkinson (1993) introduced the concept of genuine savings based on the concepts of extended national accounts. This is because it provides a much broader indicator of sustainability by valuing changes in natural resources, environmental quality, and human capital in addition to the traditional measure of changes in produced assets provided by net savings. On the other hand, Arrow et al. (2012) measures sustainability by measuring a change in comprehensive wealth over time. Genuine savings and comprehensive wealth over time are published by the World Bank and the Inclusive Wealth Report respectively in their respective publications.

6. UK comprehensive wealth and sustainability

Both the World Bank (2006, 2011) and Inclusive Wealth Report (2012) measure UK wealth and its sustainability in their respective studies. These approaches are fundamentally similar to each other as they both are based on an economic welfare model and measure sustainability by measuring wealth instead of economic growth and income. Total wealth calculated by the World Bank (2006, 2011) approach is a comprehensive measure of the wealth which measures the discounted stream of consumption of produced goods and services over time. Whereas, total wealth calculated by the Inclusive Wealth Report (2012) is a comprehensive measure of wealth, which measures the productive base of an economy that comprises the entire range of capital assets to which people have access.

Empirically, one of the main similarities in both the World Bank and Inclusive Wealth Report is that both calculate UK natural capital directly (but with different methodologies) and do not include ecosystem services in their calculations. However, there are a few differences between them as well. Firstly, one of the main differences in these two approaches is the methodology used to calculate the total wealth. The World Bank calculates total wealth as a present value of future discounted consumption; whereas, Inclusive Wealth Report adds up the individual components of wealth - produced, natural and human capitals - to calculate total wealth (chapter 5 discusses this in detail). Secondly, the World Bank (2006, 2011) calculates natural capital using Net Present Value which is close to the System of National Accounts; although, National Accounts data are not used in all of its calculations. This is because World Bank has obtained data from those sources where it was readily available for most of the 120 countries for consistency purposes. On the other hand, the Inclusive Wealth Report (2012) uses a different approach to estimate the prices to value natural capital because it has a wider scope in terms of well-being and does not restrict itself to consumption based prices as defined by the System of National Accounts. Thirdly, The World Bank calculates human capital indirectly as an intangible capital; whereas, the Inclusive Wealth Report values human capital directly using average wage rate. Fourthly, the World Bank measures UK sustainability using genuine savings indicator; whereas the Inclusive Wealth Report measures sustainability by calculating a change in wealth over time.

7. Research objectives

This thesis contributes to the existing literature by calculating UK comprehensive wealth and measuring its sustainability for 25 years - from 1988 to 2012. A 25 year time period is selected because it is roughly equal to a human generation - from the birth of a parent to the birth of a child. This thesis develops an original set of comprehensive wealth accounts for the UK for 25 years, which are consistent with the System of National Accounts (SNA). By combining the World Bank and the Arrow et al. approaches, this thesis measures UK sustainability and analyses whether UK is on a sustainable path. In doing so, this thesis constructs an extensive database which has been obtained from various sources. Some of the data are held by public bodies, which are exclusively made available to the author for this research. Since the objective of this research is to develop comprehensive wealth estimates which are consistent with the national accounts, a large amount of data are also obtained from the UK National Accounts and where National Accounts data are not available, the author has worked with the UK Office for National Statistics (ONS) to estimate National Accounts consistent data. Where external data are used, the author has worked with the ONS to make it consistent with the National Accounts. Thus, this thesis has an advantage to all other existing studies that has measured UK comprehensive wealth and sustainability because its uses more accurate and timely data. This is an advantage relative to all other existing studies that have measured UK comprehensive wealth and sustainability, such as World Bank (2006, 2011), Inclusive Wealth Report (2012), McLaughlin et al. (2014) and Hamilton and Liu (2014).

The aim of this thesis is to develop an original set of UK wealth accounts for 25 years – from 1988 to 2012 – to measure UK sustainability. Therefore, the two main objectives of this research are to:

1. Develop UK comprehensive wealth accounts for 25 years from 1988 to 2012 which are consistent with the SNA;

2. Measure UK sustainability from 1988 to 2012 and assess whether UK is on a sustainable path.

In meeting the above objectives, this thesis makes the following original contributions to the existing literature:

I. Natural capital from 1988 to 2012 is calculated by following the System of Environmental Economic Accounting (SEEA) guideline, which is based on System of National Accounts. A new methodology based on SEEA is developed to value various components of UK natural capital. This is discussed in chapter 2 and 3.

II. For the very first time, this thesis estimates the monetary value of two ecosystem services - outdoor recreation and Greenhouse gas sequestration - and adds them into the value of UK natural capital. This is discussed in chapter 3.

III. UK human capital from 1988 to 2012 is calculated directly using the lifetime income approach, which is consistent with the System of National Accounts. This is discussed in chapter 4.

The structure of this thesis is as follows:

Chapter 2 provides a brief discussion on the purpose of measuring natural capital and how natural capital is calculated in an accounting context. It then provides an overview of UK natural capital estimates calculated by the World Bank (2006, 2011) and the Inclusive Wealth Report (2012) and discusses the additional contributions made in this thesis to extend the scope of UK natural capital. It then discusses the methodology employed in this thesis to estimate the asset value of UK natural capital. Chapter 3 applies this methodology to individual selected components of natural capital to estimate the total asset value of UK natural capital from 1988 to 2012.

Chapter 4 discusses different approaches to measuring human capital. It then discusses the lifetime income approach which is used in this thesis for valuing UK human capital and measures UK human capital for 25 years (from 1988 to 2012). It then discusses the results and provides an empirical analysis.

Chapter 5 presents UK's first wealth accounts from 1988 to 2012 that are consistent with the System of National Accounts. The chapter shows that how both World Bank and Inclusive Wealth Report approaches can be combined together to calculate not only the intangible capital (social capital and stock value of technological change) but also indicators that measures a country's sustainability. By using both wealth and genuine savings indicators, chapter 5 measures UK sustainability and discusses the results.

Chapter 6 concludes this thesis and discusses some of the strengths and weakness of this thesis and suggests future work.

Chapter 2

Natural capital

1. Introduction

Natural capital can be thought of as the stock of our physical natural resources and the ecosystem services that they provide. It includes both renewable and non-renewable resources such as oil and gas reserves, minerals, timber resources, water, fisheries and ecosystem services. The UK Natural Capital Committee's State of Natural Capital Report (2013) defines natural capital as: 'the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land minerals, the air and oceans, as well as natural processes and functions'. Therefore, natural capital comprises a number of components whose sum underpins not only all economic activity but life on earth itself. If properly managed, the living aspects of natural capital can continue to provide the ecosystem services and benefits indefinitely (State of Natural Capital Report, 2013).

This chapter starts with a brief discussion on the purpose of measuring natural capital. Section 3 discusses how natural capital is valued. Section 4 provides an overview of UK natural capital estimates calculated by the World Bank (2006, 2011) and the Inclusive Wealth Report (2012). Section 5 discusses the additional contributions made in this thesis to extend the scope of UK natural capital. The penultimate section discusses the missing natural capital from the estimates developed in this thesis. The final section discusses the methodology employed in this thesis to estimate the asset value of UK natural capital. Chapter 3 applies this methodology to individual selected components of natural capital to estimate the asset value of UK natural capital from 1988 to 2012.

2. Why measure natural capital?

Though our well-being is dependent upon the natural capital and the continued flow of the services (ecosystem services) that they provide, they are predominantly public goods with no markets and no prices, so are rarely detected by our current economic compass. There are growing concerns, for example, Repetto et al. (1989), Pearce and Atkinson (1993) and

Hamilton and Clemens (1999), that the current patterns of economic growth being experienced in many parts of the world are not sustainable because the practices of economic activity are depleting and degrading the available natural capital more quickly than they can regenerate themselves. These concerns have helped spawn a number of recent studies on "sustainable development". For example:

- In June 2011, The UK National Ecosystem Assessment (NEA) assessed the state and trends of UK natural environment and concluded that 30% of the environmental assets are in decline. This assessment complements other major international assessments such as The Economic of Ecosystem and Biodiversity (TEEB) which pointed out that globally the ecosystem loss from deforestation amounts to $2 – $4.5 trillion loss of capital value per annum

- A report into the state of England's wildlife sites 'Making Space for Nature' led by Professor John Lawton and published in September 2010, showed that England's wildlife sites are fragmented and not able to respond to the pressures of climate change and other pressures we put on our land

- In 2005 The Millennium Ecosystem Assessment (MEA) assessed the consequences of ecosystem change for human well-being and concluded that over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history. 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 Goal.

Therefore, it is argued that in addition to regulations to protect the natural environment, the contribution of the environment to society's overall well-being needs to be measured alongside its contribution to economic growth. A number of international initiatives have emphasized to take action to capture the values of natural capital and the services they provide in the nation's balance sheet. For example:

- In 2010 at Nagoya, 193 countries agreed to a strategic target to incorporate the values of biodiversity into national accounting and reporting systems by 2020. This followed the UN-led study, The Economics of Ecosystems and Biodiversity, which called for national accounts to be upgraded to include the value of changes in natural capital stocks and ecosystem service flows.

- The World Bank has recently stressed the importance of developing wealth accounting and through its “WAVES” project, is assisting a number of partner countries, with UK support, to implement natural capital accounting.
- Similarly, the recent Rio+20 UN Conference on Sustainable Development recognised “the need for broader measures of progress to complement GDP in order to better inform policy decisions” and requested the UN Statistical Commission to convene “a programme of work in this area building on existing initiatives.

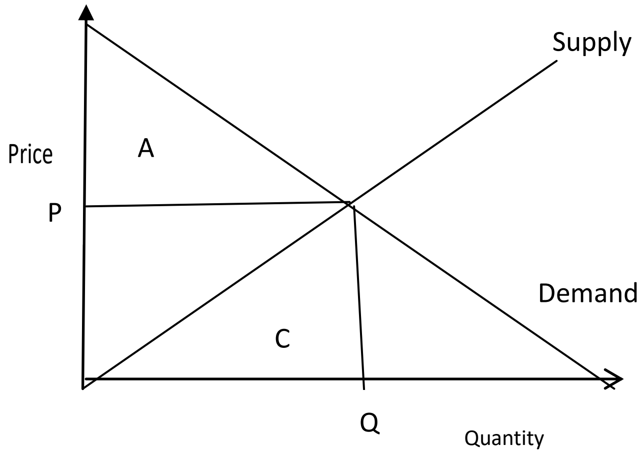
3. Valuing natural capital

The valuation of natural capital is quite complex because many ecosystem services are not traded in the market. Therefore, economic principles must be applied to estimate the value of those natural capital and the ecosystem services which are not traded in the market.

The value of a good or service is determined by the demand and supply of that good or service in a perfectly competitive market. However, the markets are not always perfect due to incomplete information or through some form of market power sellers may practice price discrimination (Day, 2013). For example, goods sold through an auction in which non-colluding buyers pay what they bid using consumer surplus.

Figure 2.1 shows a perfectly competitive market with demand and supply curves for a good traded in quantity ‘Q’ at a price ‘P’. In the figure, ‘A’ represents the consumer surplus, which is the gain obtained by consumers because they are able to purchase a product at a market price that is less than the highest price they would be willing to pay. Area ‘B’ is the producer surplus and area ‘C’ can be assumed to represent the production cost, which differs among producers.

Figure 2.1: Demand supply diagram



In the context of comparing values of natural capital with values of national accounts, the objective is to value the quantity of the natural capital at the market prices that would have occurred if it had been freely traded and exchanged. In the System of Environmental Economic Accounting (SEEA), as in the System of National Accounts (2008), market prices are defined as "amounts of money that willing buyers pay to acquire something from willing sellers. The exchanges should be made between independent parties on the basis of commercial considerations only, sometimes called 'at arm's length'" (Day, 2013). Defining in this way, in a perfectly competitive market, at a particular point in time, the same market price will be paid by all purchasers. The market price 'P' in figure 2.1 reflects consumers' marginal willingness to pay for the natural capital traded in the market at the market equilibrium quantity of Q. Therefore, PQ is the monetary value that is consistent with the National Accounts. In the case of natural capital not traded in a market, alternative approaches to establish a price for the natural capital, in line with SNA principles, need to be found.

The monetary value 'PQ' might not be the value of a natural capital used in welfare economics because it is based on exchange value principles. In figure 2.1, if the market price diverges from the equilibrium price 'P' and moves upwards to capture some element of consumer surplus, the resulting price known as *shadow price*, is the price commonly used in welfare analysis to value natural capital and ecosystem services. The shadow prices are not observable in the market and therefore are not used to value natural capital and ecosystem services if the purpose of the valuation is to compare natural capital values with national accounts.

4. Previous work on valuing UK natural capital

As discussed in chapter 1, both World Bank (2006, 2011) and Inclusive Wealth Report (2012) calculates UK natural capital as part of efforts to measure changes in aggregate wealth. Recently, McLaughlin et al (2014) calculate UK natural capital from 1760 to 2000 as part of historical wealth accounts by following the World Bank methodology. Empirically there are three major differences between the World Bank and the Inclusive Wealth Report approaches, other than the methodology[8], which has a bearing on the value estimates they generate:

1. In the World Bank approach some elements of marketed natural capital are embedded in intangible capital, and as a result, the value of natural capital has been underestimated.
2. Different components of natural capital are included in their value estimation.
3. The World Bank approach is more consistent with the System of National Accounts because it only looks at consumption; whereas, the definition of Arrow et al has a broader scope in terms of well-being.

The value of UK natural capital is estimated by both of these reports as part of the comprehensive wealth estimates; however, there are some shortcomings due to the first two differences given above. Table 2.1 shows the elements that are included in the World Bank, Inclusive Wealth Report (IWR) and McLaughlin (2014) calculations to estimate the value of UK natural capital.

World Bank

Since the World Bank estimates comprehensive wealth accounts for 120 countries in 'The Changing Wealth of Nations' (2011), only those elements are included for which the data are readily available for most of the countries. Hence the accounts omit many elements of natural capital for the UK. However, as mentioned above, the values of some omitted assets that are reflected in market values are implicitly included in the total wealth and are part of UK intangible capital. Additional assets, such as water resources, are missing altogether.

[8] The World Bank used a Net Present Value approach; whereas, the IWR estimates are based on quantity * price. The unit resource price calculations were different as well.

Table 2.1: Components of natural capital in other studies

World Bank (2006, 2011)	Inclusive Wealth Report (2012)	McLaughlin et al. (2014)
Oil & gas	Oil & gas	Oil & gas
Coal	Coal	Coal
Timber	Timber	Timber
Non-timber forest resources	Non-timber forest resources	
Agricultural land	Agricultural land	Agricultural land
Minerals[9]		Minerals (tin, copper, lead and zinc) and iron
Protected areas		

Source: World Bank, Inclusive Wealth Report, McLaughlin et al (2014)

The World Bank does not attempt to adjust the estimates for the values of externalities, for example, damage from pollution. However, damage from pollution is included in the World Bank's genuine savings indicator[10] (World Bank; 2006, 2011), though they are not measured correctly because the World Bank (2011) estimates the value of carbon in CO_2 emissions instead of estimating the value of total emissions emitted by CO_2. In their calculations, the World Bank (2011) multiplies the values of CO_2 by (12/44) to estimate the value of carbon in the emissions. This is because the atomic weight of carbon is 12 and of carbon dioxide is 44 and carbon is only (12/44) of the emissions. However, carbon on its own is not a greenhouse gas and does not emit emissions. It is CO_2 that emits emissions and therefore the overall CO_2 emissions value should have been deducted from genuine savings.

The non-provisioning ecosystem services, cultural and regulating, are not valued in the World Bank estimates and are therefore omitted from the total wealth calculations. The value of ecosystem services would only be picked up in total wealth estimates if they contribute to the production of consumption goods. Most of the provisioning services (with the exception of fisheries and some water services) are included explicitly in the wealth accounts in the form of values for agricultural and forest land values that provide food, fibre, timber, non-timber forest products, etc.

[9] World Bank includes those minerals - bauxite, copper, lead, nickel, zinc, silver, and iron ore - only for the year where data are available to them. Bauxite has been included only until 1990, copper until 1991, lead until 1990, nickel only from 1988 to 1990, zinc from 1989 to 1990, silver for 1980 and iron ore from 1982 – 1985 and 2005 and 2006.

[10] Genuine savings provides a broader indicator of sustainability by valuing changes in natural resources, environmental quality, and human capital, in addition to produced capital.

Protected areas are included in the World Bank's UK natural capital calculations; however, the calculated value is modest mainly due to data limitations. The value is also underestimated because it does not include the value of other ecosystem services that protected areas may provide, such as tourism, because this would have been picked up in the total wealth. Other studies such as Pezzy et al. (2006) have made some attempts to include these values for Scotland.

Using the World Bank methodology, McLaughlin et al. (2014) value the UK natural capital from 1760 – 2000 as part of measuring total capital or comprehensive wealth over the long run. As shown in table 2.1, for natural capital, forestry, oil and gas, coal, iron ore, other minerals (such as copper, lead, tin and zinc) and agricultural land are valued. The authors focus mainly on valuing non-renewable resources and therefore omit many types of natural capital, for example, fisheries and most ecosystem services.

Inclusive Wealth Report

Table 2.1 shows that, in addition to assets such as fisheries and water, minerals are also missing from UK natural capital calculations estimated by IWR. Non-provisioning ecosystem services are also not included and neither are they embedded in total wealth estimates because unlike the World Bank, IWR computes the individual elements of wealth to derive total wealth. However, Edward Barbier (2012) has progressed this discussion further in the IWR by suggesting that ecosystems should be included as an important asset in an economy, and, in principle, ecosystem services should be valued in a similar manner to any other form of wealth, regardless of whether a market exists or not.[11]

5. Extending the scope of UK natural capital estimates (1988 – 2012)

Both the World Bank (2006, 2011) and Inclusive Wealth Report (2012) have made important contributions in developing monetary estimates of the UK's natural capital assets; however, they inevitably fell short of capturing all elements, especially ecosystem services, as defined by the Natural Capital Committee's (NCC) State of Capital Report (2013). Ecosystems are defined as a dynamic complex of plant, animal and micro-organism communities, and their non-living environment interacting as a functional unit. The recent literature on ecological services, for example, Barbier (2011); Daily (1997); Daily et al.

[11] Chapter 8: Edward B. Barbier

(2000); Millennium Ecosystem Assessment (2005); National Ecosystem Assessment (2011); Pagiola et al. (2004); Polasky and Segerson (2009); The Economics of Ecosystems and Biodiversity (2009), implies that ecosystems are assets that produce a flow of beneficial goods and services over time. For example, as Daily et al. (2000) state, "the world ecosystems are capital assets. If properly managed, they yield a flow of vital services, including the production of goods and life fulfilling conditions." Barbier (2011) has further emphasised that if we need to view ecosystems as ecosystem assets, then it is helpful to be able to measure this form of "ecological wealth".

Ecosystem services are a central concept in the ecosystem accounting framework since they provide the link between ecosystem assets on the one hand and the benefits received by society on the other. People benefit from both the materials that ecosystems provide (such as the harvesting of timber from woodland) and from the outcomes of natural processes (such as the benefits from clean air that has been filtered by an ecosystem). Ecosystem services that contribute to human well-being can be classified into:

- Provisioning services – products such as: food (crops, meat and dairy products, fish and honey), water, fibre (timber and wool) and fuel;
- Regulating services – benefits such as: water purification, greenhouse gas sequestration, climate regulation, noise and air pollution reduction and flood hazard reduction;
- Cultural services - non-material benefits, for example: through cultural heritage, recreation or aesthetic experience;
- Supporting services – such as, soil function – these may not feature in the accounts to avoid double-counting, but information on these services will be needed in order to understand changes in the stock of ecosystem assets.

In spite of an increasing interest in the measurement of ecosystem services and ecosystem assets, there is still very limited experience with the integration of ecosystem services and ecosystem assets in the income and wealth accounts. However, recently Edens and Hein (2013) contributes to this development and the broader debate on ecosystem accounting by analysing potential solutions for four key challenges in ecosystem accounting, respectively defining ecosystem services in an accounting context, allocating ecosystem services to institutional sectors, recording ecosystem degradation, and valuing ecosystem services consistent with SNA principles. Barbier (2013) develops a methodology for including ecosystem services in a wealth accounting framework by following the approach developed by Dusgupta (2009) and further elaborated by Arrow et al. (2012). Barbier shows how the wealth accounting framework could be extended to incorporate ecosystems and their valuable goods and services and using the example of mangroves in Thailand, *Barbier* illustrated how such an approach might be applied.

This thesis takes the World Bank and Inclusive Wealth Report (IWR) work on UK natural capital estimates forward by addressing some of the shortcomings discussed above while recognizing that not all elements defined by the NCC's report - specifically the value of oceans and atmosphere - could be captured within the framework set by the System of National Accounts.

This thesis estimates the asset value of UK natural capital from 1988 to 2012 and extends the scope of UK natural capital estimates by:

- Including all the components of natural capital listed in table 1, except protected areas (see below), and adding additional components – minerals, fisheries and water - which are missing from the World Bank (2011) and IWR (2012) estimates.
- Going one step further by including the asset value of two non-provisioning ecosystem services - outdoor recreation and net greenhouse gas sequestration - in these estimates.

The asset value of the following components is estimated to calculate the monetary value of UK natural capital:

I. Non-renewable assets

- Sub-soil assets
    - Energy reserves
        - Oil and gas reserves , and Coal reserves
    - Mineral reserves
        - Silver, Limestone, Chalk, Salt, Sand and Gravel, Lead, and Peat as an extractive resource
- Agricultural land

II. Renewable assets

The following assets are categorised as renewable on the assumption that they can be harvested or extracted in a sustainable way:

- Timber
- Fisheries
- Water abstraction

The following ecosystem services are categorised as renewable ecosystem services on the assumption that there is no further depletion or degradation:

- Outdoor recreation (a cultural ecosystem service provided by natural environment)
- Net greenhouse gas sequestration (a regulating ecosystem service)

As shown in table 2.1, the World Bank includes protected areas in its estimates. However, this thesis excludes them to avoid double counting. This is because some of the other assets in the list above, such as agricultural land, water, outdoor recreation and net greenhouse gas sequestration, already capture important aspects of protected area values. Furthermore, in the UK, protected areas do not generally preclude agriculture and other production.

6. Missing natural capital

Due to data and methodology limitations the asset value of only a few elements of natural capital is calculated in this thesis. Some of the elements of natural capital that are included, for example, water, are partial values mainly due to lack of data. The most significant elements of natural capital missing from these monetary estimates are discussed below.

i. Water

Water resources provide a wide array of services from drinking water, agricultural irrigation and hydroelectric power to regulating and cultural services such as recreation. Only domestic and non-domestic water supply is valued in this research; therefore, this is likely to be an underestimate.

ii. Ecosystem services

As discussed in the opening sections, ecosystem services can be classified into four broad categories: provisioning, cultural, supporting and regulating services. Supporting services do not feature in the accounts to avoid double-counting as they support the functioning of all other services, but information on these services will be needed in order to understand changes in the stock of ecosystem assets.

a) Provisioning services

Most of the provisioning services are included explicitly in these monetary estimates, either directly through the value of the amounts entering the UK economy or indirectly in the form of the value of agricultural land used to produce food and fibre etc.

b) Cultural services

The UK natural environment is used by society for recreation, and this aspect of the value of natural capital is included in the estimates derived in this research. However, there will be other significant benefits from the aesthetic enjoyment of the countryside which are not included in these values. People are willing to pay higher prices for homes and, to some extent, for commercial properties in areas of great aesthetic beauty, such as coastal or woodland settings, or for the amenity benefits of urban green space and of the climate.[12] If the value of these ecosystem services were estimated and included in the monetary estimates of UK natural capital developed in this thesis, the total calculated value would have been much higher.

c) Regulating services

One regulating service, net greenhouse gases sequestration, is included in the monetary estimates derived in this thesis. Pollination and water filtration services are important regulating services and are already partially incorporated in the value of agricultural land. However, pollination services which impact on non-crop plant, for example, wild flower, are excluded. Furthermore, disentangling these values and isolating the value would make it clearer how the different components of natural capital contribute to the economy. Other important ecosystem services, such as, flood risk management (or hazard protection), air quality and noise protection, are also currently missing from these estimates due to data limitations.

[12] National Ecosystem Assessment, chapter 22

iii. Protected Areas

Much of the monetary value of terrestrial protected areas is already captured in other assets such as agricultural land, water, outdoor recreation and net greenhouse gas sequestration. Hence no attempt has been made to capture the value of protected areas separately in this thesis, because of the likelihood of double-counting. For similar reasons, values of marine protected areas are also excluded from these estimates.

7. Valuing UK natural capital - methodology

This section discusses the methodology employed in this thesis to estimate the asset value of UK natural capital. Chapter 3 applies this methodology to individual selected components of natural capital to estimate the asset value of UK natural capital from 1988 to 2012.

Natural capital is a collection of assets and therefore could be valued using environmental asset valuation principles. Environmental assets provide a series of benefits to individuals and to society; therefore, not only should the current benefits be valued, the future stream of benefits over the asset life should also be valued.

As discussed in section 3 above, observable market prices should be used to value all assets in order to be consistent with the National Accounts and the ideal sources of market price observations are values observed in markets in which each asset traded is completely homogeneous. This allows a comparison against other assets in order to assess relative returns, national wealth and similar types of analysis.

The System of Economic and Environmental Accounts (SEEA) Central Framework states that an important principle in the valuation of environmental assets is to value the asset in situ – the asset itself as it is in the ground rather than after its removal. For environmental assets which are extracted, the price of the output from extraction can normally be found in the market, but the market price of environmental asset in the ground is not common. Since environmental assets in the ground are often not traded in the market, an attempt should be made to estimate its value using the market prices that are observable. When market prices for assets are missing, SEEA suggests two approaches that estimate the prices of the assets in the absence of any regular markets:

1) Written down replacement cost

The value of an asset declines over time from when it was purchased, commonly known as depreciation. Theoretically, the value of an asset at any given point in time in its life is equal to the current purchase price of an equivalent new asset less the cumulative depreciation over its life. When reliable market prices are not available, this approach gives a reasonable approximation of what the market price would be if the asset was offered for sale.

2) Discounted value of future returns

This approach, commonly known as Net Present Value (NPV), uses projections of the future returns of an asset and discounts them in today's money to reflect the value an investor would be prepared to pay for the asset in the current period. This approach provides reasonable proxies for observable market prices and is consistent with the System of National Accounts.

The written down replacement cost method does not appear to estimate the prices for environmental assets due to two reasons. First, there is no current purchase price of an equivalent environmental asset and, secondly, the value of sub soil assets, such as, oil & gas, does not depreciate.

The NPV method, recommended by the SEEA, provides reasonable estimates for observable market prices for environmental assets which are extracted, as it uses projections of the future rate of extraction of the asset together with projections of its price to generate a time series of expected returns. These streams of expected returns are discounted to reflect the value an investor would be prepared to pay for the asset in the current period. The NPV method is used in this thesis to value UK natural capital from 1988 to 2012.

Net Present Value (NPV)

There are five key aspects of NPV that are crucial to estimate the value of natural capital:

i. Resource rent
ii. Pattern of expected resource rent
iii. Asset life
iv. Choice of discount rate
v. Deflating – constant prices

A detailed discussion and methodology of NPV to derive the asset value of UK natural capital estimates is given below.

i. Resource rent

The resource rent represents one accounting price for a natural capital asset (Lange, 2004). Once market-based asset values have been estimated it is important to isolate the benefits that are generated by the natural capital itself. The overall value of the service from a product typically includes a number of other elements, such as wages and returns to the investment made by investors that do not stem from the value of the natural capital. Once these costs and normal returns are deducted from the market price, the resulting element or net benefit is known as resource rent.

This thesis applies the resource rent approach to value UK natural capital, as this provides an estimate of the value added stemming from natural capital itself – once all human inputs have been removed. This is shown in table 2.2 below.

Table 2.2: Derivation of resource rent[13]

<u>Equation 2.1</u>

Resource rent *= Gross Operating Surplus (SNA basis) – specific subsidies on extraction + specific taxes on extraction – user cost of produced assets*

Where:

Gross operating surplus = Output (sales of extracted environmental assets at basic prices) – Operating costs (intermediate consumption + compensation of employees + other taxes on production plus other subsidies on production)

User cost of produced assets = consumption of fixed capital (depreciation) + Normal returns on produced assets (net capital stock * rate of return)

Resource rent is thus derived from standard SNA measures of gross operating surplus by deducting specific subsidies, adding back specific taxes and deducting the user cost of produced assets.

[13] Source: System of Environmental Economic Accounting – Central Framework, Page 153

Normal returns on produced assets

A rate of return on produced assets is required to estimate the user cost of the produced assets used in the extraction of the environmental assets. If this cost is not deducted the resulting estimates of resource rent will be overstated. The rate of return estimates the return that investors would make if they invest their capital elsewhere, instead of investing it in an environmental asset. Ideally, an industry specific rate of return should be used, for example, the interest rate on bonds issued by UK resource companies can be a proxy for estimating returns on capital. However, the issue of bonds by the private sector (for example, oil & gas companies or other extraction industries) is not common in the UK. SEEA suggests that a realistic approach could be to use an economy wide rate of return based on government bond rates. The government bond rates may not include an adequate risk premium for specific industries, but it provides a reasonable reflection of a normal return.

This thesis uses the ten year real government bond yield from the Bank of England to calculate the "return on produced assets" for all components of natural capital. The data are taken from the Bank of England. It is recognised that this rate is historically low for the last few years compared to those expected in certain markets, such as, oil abstraction and water supply and may well have the effect of overstating the resulting resource rent estimates. Nevertheless, overall this provides an indication of a return that an investor is willing to accept if the capital was invested elsewhere.

ii. Pattern of expected resource rent

A critical factor in the valuation of natural capital is determining the expected pattern of the resource rent. Future resource rent paths are not observed and hence assumptions concerning the flows must be made. In the absence of any forecast data, a simplified way to determine the expected resource rent is to assume that the current flow is constant over the asset life, but this might not be the case.

Another way to determine the expected extraction is to project the rate of future extraction (production) and prices. Based on the projection the resource rent for each future year can be calculated. This method is preferable because it takes into account forecasted changes in prices, costs and extraction rates.

Due to data limitations, this chapter follows the System of Economic and Environmental Accounts (SEEA) Central Framework guideline[14]and assumes constant projected resource rents throughout the asset life based on latest five year extraction data. The exceptions are for oil and gas reserves, timber and net greenhouse gas sequestrations for which future extraction data are available. The pattern of expected resource rent (RR) is calculated as:

Equation 2.2

$$\overline{RR}_t = \frac{RR_{t-4} + RR_{t-3} + RR_{t-2} + RR_{t-1} + RR_t}{5},$$

where: t = Year

iii. Asset life

The asset life is the expected time over which an asset can be used in production or the expected time over which extraction from a natural resource can take place[15]. It is important to estimate the asset life in the NPV model because it determines the expected time over which an asset should be discounted.

For non-renewable assets, the asset life could be determined as the time it takes for the projected cumulative production to equal the reserves. The asset life for a particular year depends upon the reserves in that year; therefore, it could be assumed that the extraction stops exactly at the point when the cumulative production equals the reserves of that year. For renewable assets, the asset life could be infinite if they are harvested or extracted sustainably.

The World Bank (2006, 2011) derives the asset life of non-renewable assets by computing the reserve-to-production ratios for all the countries included in their calculations. They choose to cap exhaustion time at 25 years for all the resources and countries. The resulting estimates of asset values are conceived as a 'generational account' - the wealth enjoyed by the current generation (Hamilton and Liu, 2014). The World Bank (2011) argues that it is unlikely that companies or governments will develop reserves to cover more than 25 years of production. For timber resources, the World Bank (2006, 2011) uses an asset life of 25 years if the forest is sustainably harvested - if roundwood harvest is smaller than net annual

[14] SEEA Central Framework – page 143
[15] Source: SEEA Central Framework

increment. If forest is not sustainably harvested, the time to exhaustion is calculated and the smaller of 25 years and the time to exhaustion is then used as resource life. For other natural capital - non-timber forest, crop land, pasture land and protected areas- the World Bank uses 25 years as an asset life.

In the UK, for non-renewable assets, reserves data are available only for Continental oil & gas and therefore the asset life for UK Continental oil & gas reserves in this thesis is determined as the time it takes for the projected cumulative production to equal the reserves (This is calculated in next chapter). However, the data on UK mineral reserves are not available. One option is to use 25 years based on World Bank methodology, but it could be argued that 25 years is a short time period and if the reserves are in abundance, human could potentially be consuming them infinitely (until all humans die). Similarly, for UK renewable assets, there is no information on sustainable management of these resources. Unlike non-renewable assets, renewable assets can be infinite if managed sustainably[16]. However, to assume an infinite asset life is not appropriate because of lack of information on the sustainable management of renewable resources. Furthermore, if an infinite asset life is assumed, non-negligible discounting would render future values relatively immaterial.

Generally, an average rotation period for timber resources is 50 years and therefore it is reasonable to assume a 50 years asset life for timber resources. Due to lack of data and limited information on reserves and management practices of other non-renewable and renewable assets valued in this chapter, a 50 years asset life is assumed throughout for consistency purposes.

iv. Choice of discount rate

A discount rate is required to convert the expected stream of resource rents into a current period estimate of the overall value. A discount rate expresses a time preference - the preference for the owner of an asset to receive income now rather than in the future. It also reflects the owner's attitude to risk. The use of discount rates in NPV calculations can be interpreted as an expected rate of return on the environmental assets.

There has been an ongoing debate on what discount rate to apply for the valuation of environmental assets. Though there is a vast literature on selecting discount rates, most of the debate only focuses on the social discount rate. There is no real debate on what

[16] SEEA Experimental Ecosystem Accounting

discount rate should be selected for accounting purposes. The choice of discount rate can make a significant difference to accounting values, and there is a need to be transparent about the basis for selecting an appropriate discount rate.

This sub-section discusses the issues surrounding the selection of a discount rate and concludes by suggesting a discount rate that should be used to value natural capital. This discount rate is then used in this thesis to value UK natural capital from 1988 to 2012.

What is discounting?

Discounting is based on the principle that, generally, people prefer to receive goods and services now rather than later. This is known as 'positive time preference'. For individuals, time preference can be measured by the real interest rate on money lent or borrowed in a perfect market. Amongst other investments, people invest at fixed low risk rates, hoping to receive more in the future to compensate for the deferral of consumption now. These real rates of return give some indication of their individual pure time preference rates. Society, as a whole, also prefers to receive goods and services sooner than later, and to defer costs to future generations. This is known as social time preference – the rate at which society values the present to the future.

Although a relatively simple concept in economic theory, the issue of discounting is something that the environmental economics literature has wrestled with. The literature is far from a consensus on which discount rate to apply. One of the reasons of differences in opinion is because of a big difference between normative and behavioural approaches to the choice of discount rate. Despite the controversy, most participants in the debate about what constitutes an appropriate discount rate for environmental valuation acknowledge that a good starting point is the so-called Ramsey formula given in equation 2.3 below.

Equation 2.3

$$r = \rho + \mu . g \, ,$$

where:

r = Social time preference rate (Discount rate)

ρ = Pure rate of time preference

μ = Elasticity of the marginal utility of consumption

g = Consumption growth rate

Equation 2.3 shows that the discount rate should be equal to the sum of two factors - the pure rate of time preference and the product of the growth rate of consumption and the elasticity of the marginal utility of consumption. Most of the literature has not included a catastrophic risk rate or have mixed this with the pure time preference rate as part of the Ramsey formula. A catastrophe risk is the likelihood that there will be some event so devastating that all returns from policies, programmes or projects are eliminated, or at least radically and unpredictably altered[17]. For example, technological advancements that leads to premature obsolescence, or natural disasters, major wars etc. The scale of this risk is, by its nature, hard to quantify. In the UK, the HM Treasury Green Book (2003) has included the catastrophic risk rate in addition to a pure time preference rate to derive the discount rate.

The main source of contention regarding at what level the discount rate should be set is the pure rate of time preference, though there are some disagreement on the elasticity parameter (for example see Weitzman 2013). The pure rate of time preference measures the extent to which future welfare is discounted. Most of the literature and empirical studies have assumed social time preference as opposed to individual time preference to derive the discount rate. This is because social discount rates place a higher relative importance on income earned by future generations and is the rate that the government would choose in allocating resources across generations. On the other hand, market discount rates are typically higher than social discount rates, as individuals (or enterprises) tend to demand a quicker return from their ownership of an asset. The use of a market discount rate also provides a stronger comparison across different types of assets and the trade-off between assets can be considered.

UK experience

The Stern Review (2006), the first major official economic report to give climate change a prominent place among global problems, used a pure time preference rate of 0.1% and an elasticity of marginal utility of consumption of one. When combined with an assumed per capita growth rate of 1.3%, Stern arrived at a relatively low discount rate of 1.4%. One way

[17] Source: HMT Green Book (2003)

to judge discount rates is to compare the assumptions made with observable market variables, for example, interest rates and saving behaviour. Nordhaus (2007) notes that the resulting discount rates set out in the Stern Review do not match the observed market interest rates. Similarly, Dasgupta (2006) argues that the values of the pure time preference rate and the elasticity of marginal rate of consumption assumed by Stern would not be compatible with observed savings rates.

However, Sterner and Persson (2008) dismisses these arguments on two points. First, real market complexities make it far from obvious which values the discount rate should match. The market rate used should be the risk-free rate and an average rate over a very long time period should be used, especially if the discount rate is to be used over an extremely long time period. As noted by Cline (1999), this could well imply a discount rate that is close to zero, matching that of the historical real rate of return on treasury bills. Secondly, Sterner and Persson (2008) argues that using observable real market rate variables as a benchmark is not appropriate because a discount rate should be based on an ethical or normative judgement, not on simply observing the markets.

In the UK, the HM Treasury Green Book (2003) provides guidelines on what discount rate to use when applying the NPV method. The Green Book recommends using a pure time preference rate of 0.5%. In addition, it has allowed for an exogenous catastrophic risk of 1%[18]. This risk relates to typical public expenditure projects and includes unforeseen changes in social and political objectives and priorities and to possible wider changes in the economy, society and technology, which are not part of the endogenous risk assessment. The Treasury Green Book also assumes the marginal utility of consumption as 1.0[19] as assumed by the Stern Review and uses a growth rate of 2.0%[20] to derive the social time preference rate of 3.5%. Hence, the Green Book recommends using 3.5% as a discount rate to convert all future costs and benefits to present values.

[18] Newbury (1992) estimates this as 1.0%; Kula (1987) as 1.2%; Pearce and Ulph (1995) as 1.2%; OXERA (2002) as 1.1% currently and 1% in the near future.
[19] Pearce and Ulph (1995) estimate a range from 0.7 to 1.5 with 1.0 being considered defensible; Cowell and Gardiner (1999) estimate μ as being just below or just above one; OXERA (2002) estimate a range from 0.8 to 1.1.
[20] Based on work by Maddison (2001) on the 1950-1998 UK average growth rate.

International experience

The World Bank in its reports, *Where is the Wealth of Nations (2006)* and *The Changing Wealth of the Nations (2011*), use 1.5% as the pure time preference rate. However, to estimate the value of natural capital, by using 1.0 as the marginal elasticity of consumption and 2.5% as the growth rate, the World Bank applies 4% as the social discount rate in their wealth accounts[21]. The recently published *Inclusive Wealth Report (2012)* utilises a 5% discount rate for a number of worked examples of natural capital valuation – including for agricultural land, fish and timber. The report also uses a discount rate of 10% to value coastal protection in Thailand (Chapter 8: Barbier; Inclusive Wealth Report 2012). International organisations, such as, the OECD[22] suggests that discount rates should be based on long-term bonds and has provided 5% as an example. On the other hand, Eurostat uses a consultation of forest experts to ascertain a discount rate and has found an admissible range of 0.5% to 3.5% [23] as appropriate discount rates.

Other reports such as *The Economics of Ecosystem and Biodiversity (TEEB, 2010)* recommend that zero or negative discount rates could also be applicable when valuing environmental assets. This is because a zero percent discount rate could have the perverse effect of favouring over-investment in the present and thus spur further environmental and natural resource degradation. The perversity is that this would enhance what zero percent discount rate proponents aim to avoid: the reduction of the stock of natural capital available to future generations[24].

System of Environmental Economic Accounting (SEEA)

In contrast to the social discount rate, the SEEA Central Framework recommends the use of market discount rates in order to align the valuation with the System of National Accounts. However, the SNA does not deal with discount rates in respect to environmental assets directly. For instance, the SNA 2008 discusses discount rates briefly in terms of financial assets, though it uses the term *suitable* discount rate without elaborating what *"suitable"* actually means. SNA 2008 states that *"... for some financial assets, particularly those with a face value applicable at some point in the future, the present market value is established as*

[21] Chapter 5 of this thesis discusses why World Bank uses two different discount rates.
[22] OECD, 2001, P16
[23] Eurostat, 2000
[24] Source: New Economic Foundation - Discounting and time preference (2013)

the face value discounted to the present by the market interest rate. In principle, therefore, if a reasonably robust estimate of the stream of future earnings to come from an asset can be made, along with a suitable discount rate, this allows an estimate of the present value to be established". As an example, SNA 2008 uses a 5% discount rate for illustrative purposes.

Eurostat (2011) suggests that the International Accounting Standards aim for 'high-quality corporate bonds' as the ideal discount rate[25]. It suggests that where such markets are underdeveloped, government bond yields should be used. This might suggest that Eurostat provides some indication of using a social discount rate in the absence of any high quality information on a market discount rate. In relation to pensions, Eurostat recommends using a 3% real discount rate (5% nominal) across Europe, which is based on European government real bond yields over a 10 year period. If these principles are applied to environmental assets, it could be argued that they should also be discounted using a social discount rate.

The SEEA CF highlights that the discount rate can be seen as an expected rate of return on non-produced assets and in a perfectly competitive market, these two should align and simply reflect businesses' time preference for receiving returns. However, it also recognises that social discount rates can be supported regarding environmental assets (SEEA CF, 2013, p145).

What discount rate is used in this thesis?

The above discussion shows that there is little consensus on the discount rate that should be used for valuation of environmental assets. However, there could be a consensus if the objective of the whole exercise could be established because the threat comes from confusion about the purpose of the exercise. If the purpose of the exercise is sustainability of natural capital and ecosystems, the discount rate used will be different to the one that is used for accounting purposes – where the objective is to extend national accounting to incorporate environmental considerations.

The objective of this thesis is to measure sustainability while remaining consistent with national accounting. This complicates things because there is no single discount rate that combines the both options together - sustainability and national accounting. This is because the social discount rate is normally used if the purpose of the exercise is

[25] Eurostat, 2011, p45

sustainability; whereas, the market discount rate is normally used if the purpose is to extend the national accounts. The market discount rate is suggested by the SEEA because of its consistency with the principles of SNA. However, it is not clear what market discount rate should be applied for individual assets.

In the UK, the Treasury Green Book recommends a social discount rate of 3.5%, which is not too low compared to other studies that uses social discount rate and lies close to a market discount rate of 3.0% to 5% (as illustrated by the SNA and the Eurostat). It is a possibility that a uniform discount rate of 3.5% as suggested by HMT Green Book could be used for both sustainability and accounting purposes. This approach makes sense because there is no single market discount rate that could be used across all the natural capital and ecosystems. Using different market discount rates could cause an inconsistency across natural capital and could cause a real challenge in choosing the discount rate. This is because capital markets may exhibit imperfections which may distort interest rates and also that the individuals (and investors) are myopic and might not make the right decisions.

Therefore, this thesis uses a declining discount rate set out in the HM Treasury Green Book (2003, page 100) to value UK natural capital[26]. A declining discount rate is chosen mainly because of uncertainty about the future. This uncertainty can be shown to cause declining discount rates over time[27]. Most of the natural capital valued in this thesis has an asset life of 50 years; therefore, to capture the uncertainty about the future, this paper uses a declining discount rate throughout the calculations to estimate the value of individual components of natural capital.

v. Deflating – constant prices

Natural capital calculated in this thesis is in 2012 prices. All prices and data used for the resource rent calculations are deflated using the GDP deflator to convert them into 2012 prices. There are some issues with using a GDP deflator, such as the general inflation level

[26] In November 2013, the author presented a paper (Khan, Greene; 2013) on selecting discount rates for natural capital accounting at the valuation for natural capital accounting seminar organised by the UK Office for National Statistics (ONS) in London. Based on the recommendations and subsequent discussions in the seminar, the ONS now uses declining discount rates to value UK natural capital.

[27] Weitzman (1998, 2001) and Gollier (2002)

(from the GDP deflator) includes the price movements of the resources of interest, so some part of the relevant price changes will still be removed. Nevertheless, GDP deflators are good indicators of the absolute change in the value of money as opposed to industry specific deflators. Therefore, a general GDP deflator has been applied throughout due to an interest in the overall change in value – for both quantity and price changes.

Chapter 3

Valuing UK natural capital - application

1. Introduction

Chapter 2 has discussed the Net Present Value (NPV) methodology employed in this thesis to estimate the asset value of UK natural capital. This chapter applies this methodology to individually selected components of natural capital to estimate the asset value of UK natural capital from 1988 to 2012. This chapter starts with discussing the NPV equation that is used to value natural capital. It then values the individual components of natural capital selected in this thesis and provides the results. The next section provides the total asset value of UK natural capital and the final section provides a comparison with international studies.

2. Net Present Value

The following Net Present Value (NPV) formula is used to calculate the monetary asset value for each natural capital component:

Equation 3.1

$$\textit{Value of component of natural capital} = \sum_{t=0}^{n} \frac{\text{resource rent in year t}}{(1+r)^t},$$

where:

N = total number of periods (typically 50 years - discussed in chapter 2)

t = year

r = declining discount rate

3. Building the individual components

a) Non-renewable assets

Table 3.1 lists the non-renewable assets that are included in this thesis to calculate the asset value of UK natural capital.

Table 3.1: Non-renewable assets

Sub-soil assets		Agricultural land
Energy reserves	**Mineral reserves**	
Oil & gas reserves	Silver	
Coal reserves	Limestone	
	Chalk	
	Salt	
	Sand and gravel	
	Lead	
	Peat - as an extractive resource	

Sub-soil assets

The first component of natural capital in these monetary estimates is sub-soil assets, which consists of energy and mineral reserves.

<u>*3.1) Energy Reserves*</u>

3.1.1) Oil & gas reserves

The System of Environmental Economic Accounting (SEEA) categorises known oil & gas reserves into three classes:

- Class A: Commercially Recoverable Resources;
- Class B: Potentially Commercially Recoverable Resources and;
- Class C: Non-Commercial and Other Known Deposits.

The scope of the monetary asset account for oil & gas reserves is limited to Commercially Recoverable Reserves (Class A). According to the System of National Accounts, the market value is assumed to be zero if the extraction and sale have not yet been confirmed to be economic. Since Class B and Class C have a certain degree of uncertainty regarding the expected extraction profiles and incomes, they are not included in the monetary asset valuation. However, SEEA suggests if Class B and Class C need to be valued, the values of each class should be clearly distinguished. It could be argued that if price rises over time, or extraction costs fall, then Class B and Class C reserves could become economical. If these reserves become economical due to an increase in price or fall in cost, they would be reclassified as Class A and thus will be included in the monetary asset valuation.

In the UK, the discovered oil & gas reserves are categorised as proven[28], probable[29] and possible[30] depending upon their commercial viability to be extracted. In addition to these three classes, there are estimates of undiscovered reserves which have not been discovered but are potentially recoverable. The UK Continental Shelf's reserves categorisation is different to SEEA Central Framework; however, Class A reserves could broadly be categorised as proven and probable reserves. Therefore, this chapter values only the estimates of proven and probable reserves within the UK Continental Shelf.

Ideally, oil & gas reserves should be valued separately; however, oil & gas reserves are often extracted jointly and it is therefore not possible to identify the extraction cost of each resource. Therefore, these reserves are valued together in this chapter.

Methodology

The methodology to estimate UK Continental Shelf oil & gas reserves from 1988 to 2012 is given below. It is based on the methodology developed by Khan et al. (2013)[31] to estimate the monetary value of UK Continental Shelf oil & gas reserves for 2011. This chapter extends the methodology to value the oil & gas reserves from 1988 to 2012.

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[28] Proven reserves are known reserves which have a better than 90 per cent chance of being produced

[29] Probable reserves are known reserves which are not yet proven but which are estimated to have a greater than 50 per cent chance of being technically and commercially producible

[30] Possible reserves are those reserves which at present cannot be regarded as 'probable' but are estimated to have a significant but less than 50 per cent chance of being technically and commercially producible

[31] http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/publications/monetary-valuation-of-uk-continental-shelf-oil-and-gas-reserves.pdf

Chapter 2 discussed that subsoil assets should be valued in situ – the asset itself as it is in the ground rather than after its removal. The price in situ is not available for UK Continental Shelf oil & gas reserves; however, it is possible to estimate the value in the ground by subtracting all the extraction costs from the total output of oil & gas reserves. This is known as resource rent, which is explained in the previous chapter.

i. Resource rent

The chapter uses equation 2.1 (*Resource rent = Gross Operating Surplus (SNA basis) – specific subsidies on extraction + specific taxes on extraction – user cost of produced assets)* given in chapter 2 to estimate the resource rent for UK Continental oil and gas reserves from 1988 to 2012. The data for Gross Operating Surplus (GOS) for oil & gas are not available in the UK national accounts and therefore need to be calculated. This chapter calculates the GOS for oil & gas reserves in situ from 1988 to 2012 based on the SEEA principles. This methodology also takes into account the decommissioning cost which is associated with the dismantling of the production facilities. Therefore, GOS is calculated by deducting operating expenditures and decommissioning cost from total income. Hence, based on equation 2.1, the resource rent for oil & gas reserves is calculated as:

Equation A

Resource rent = Total income – Operating expenditures – Decommissioning cost – User cost of produced assets

Where:

- *GOS = Total income - Operating expenditures - Decommissioning cost*
- *User cost of produced assets = Consumption of fixed capital (depreciation) + Normal returns on produced assets*.

Decommissioning cost

An important but challenging component of the costs of extracting oil & gas reserves is the eventual decommissioning costs (DC) associated with the dismantling of the production facilities. Both World Bank (2006, 2011) and Inclusive Wealth Report (2012) do not include the DC; however, this chapter includes DC to calculate the resource rent for oil & gas. There are three main approaches to dealing with DC in an accounting framework:

1. The total remaining DC could be divided by the remaining years of projected production. However, this method is not appropriate, as the DC is accumulated towards the end of the production period, which results in an increasingly large DC in the future.

2. Allocating the DC paid in a year to that specific year. However, this will overstate the cost of that specific year because the cost realised in any given year is predominantly related to past production.

3. The DC in a year could be apportioned appropriately to past production. This method is then applied to every subsequent year, while assuming that all DC allocated to previous years is considered as a sunk cost.

This chapter uses the third approach to allocate the DC to UK Continental Shelf oil and gas production. The DC for each year is related to past production. For example, the 1988 DC is related to 1966[32] to 1987 production and 2012 DC is related to 1966 to 2011 production and so on. Since DC for a year, for example 2012, relates to past production, this cost needs to be spread out over this production period (from 1966 to 2011). The following steps show how 2012 and future years DC is apportioned to 2011 production:

In the first instance, DC per unit for 2012 is calculated. It is calculated by dividing 2012 DC by cumulative production from 1966 to 2011. The resulting DC per unit is then multiplied by 2011 production to estimate DC proportion for 2011

- Then, a DC per unit for future years (from 2013 to 2040 for which data are available from Office for Budget Responsibility) is also calculated by using the above method and then multiplied with the 2011 production to estimate decommissioning cost proportion for 2011. These future years decommissioning cost is related to previous production including 2011; therefore, 2011 proportion needs to be calculated for each year until 2040 and added to 2011 decommissioning cost.

- These proportions are then added up to calculate the total DC for 2011.

- The DC allocated to 1966 to 2010 is assumed as sunk cost

[32] The start of significant [offshore] production of oil & gas in the UK

Using the above methodology, decommissioning cost for 1988 to 2012 is calculated. For 1988, the decommissioning cost allocated to 1966 to 1987 is assumed as sunk cost and for 1989; cost allocated to 1966 to 1988 is assumed as a sunk cost and so on.

Data sources

The data for total income and operating expenditures from 1988 to 2012 are taken from Department for Energy and Climate Change (DECC). The data for decommissioning cost from 2004 to 2012 are also taken from DECC. Since the data for decommissioning cost from 1988 to 2003 are not available, they are kept constant at 2004 level. The data from 2013 onwards are taken from the Office for Budget Responsibility (OBR) forecast. These data are then adjusted to apportion the decommissioning cost (discussed above).

The user cost of produced assets is not provided by these data sources and is therefore calculated separately. To calculate the user cost of produced assets, the net capital stock and the consumption of fixed capital data for 1997 to 2012 are taken from the ONS. Capital stock and consumption of fixed capital data from 1988 to 1996 are not available; therefore, the 1997 values are kept constant to 1988. A ten year real government bond yield from the Bank of England is used to estimate the return on produced assets by multiplying the rate with the net capital stock invested in the oil & gas sector.

ii) Pattern of expected resource rent and asset life

The data for forecast of oil and gas extraction, prices, income earned, expenditures occurred from this extraction and decommissioning cost are taken from Office for Budget Responsibility (2014). An average of last ten year real government bond yield from the Bank of England is used from 2014 onwards to estimate the return on produced assets. The projected OBR data for capital expenditure are used to estimate the future capital stock and consumption of fixed capital. This is estimated by the ONS using Perpetual Inventory Model. The data are available from 2013 until 2040. Since data for projection of extraction are available from the OBR, a constant extraction for oil & gas is not assumed and, therefore, the asset life is not 50 years as considered for other components of natural capital in this paper (explained in chapter 2). However, it is assumed that proven and probable reserves are always extracted first. The asset lives are calculated as years to depletion of reserves based on actual and projected extraction. For example:

1988 reserves asset life

Reserves as at 31 December 1988 = 2,433 million tonnes of oil equivalent (mtoe)

The cumulative production reaches the reserves (2,433 mtoe) in 2000. This gives an asset life of 13 years[33].

2012 reserves asset life

Reserves as at 31 December 2012 = 1,323 million tonnes of oil equivalent (mtoe)

The cumulative production reaches the reserves (1,323 mtoe) in 2032. This gives an asset life of 21 years[34].

Only proven and probable reserves are valued in this paper. Therefore, the resource rent in the last year (the 13th year and 21st year for 1988 and 2012 respectively) is adjusted to ensure that the extraction stops exactly when the sum of the future production reaches the estimated reserves. This approach is different to the World Bank (2006, 2011) approach which uses reserve to production ratio to estimate the asset life of oil & gas reserves.

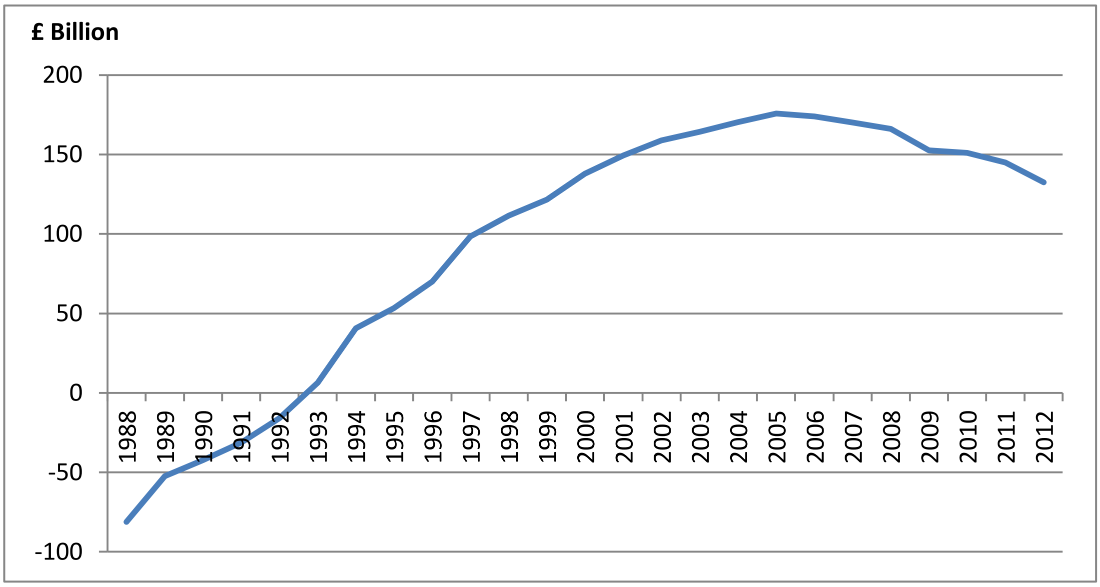
Results

Using equation 3.1 and applying a declining discount rate (discussed in chapter 2), the asset value of UK Continental Shelf oil & gas reserves from 1988 to 2012 is shown in figure 3.1. The figure shows that although the values of UK oil & gas reserves were increasing from 1988, they were in negative territory between 1988 and 1992. From 1993, the values were in positive territory and continued to increase sharply before the values started to decline from 2006.

[33] This figure is inclusive of 1988

[34] This figure is also inclusive of 2011.

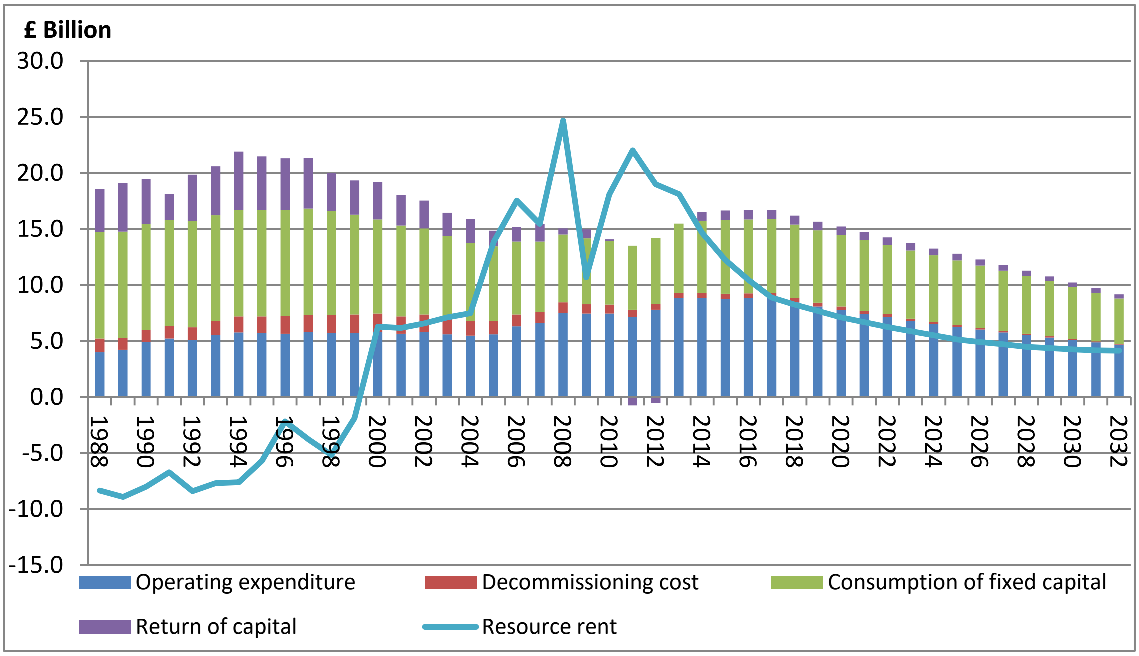
Figure 3.1: Asset value of UK Continental Shelf oil & gas reserves, 1988 to 2012 -2012 prices



The negative asset values between 1988 and 1992 are due to negative resource rents from 1988 to 1999, which is due to lower income and higher expenditures. Since the asset value for UK Continental oil & gas reserves in a particular year is calculated by adding up the resource rents for the reserves until it depletes, the negative resource rents until 1999 have pushed down the asset values of the reserves between 1988 and 1992. The resources rents and components of resource rent are shown in figure 3.2. The figure shows that the negative resource rent is due to higher operating expenditure and the depreciation of capital stock. This higher depreciation is mainly due to higher capital stock invested in the oil & gas industry during the early years of oil & gas production in the UK.

Figure 3.1 shows that the asset value of UK Continental oil & gas reserves has increased sharply in 90s. This is due to an increase in the oil & gas reserves and in their unit cost, which has increased sharply during the 90s and early twenties because of an increase in demand. Since mid-twenties, the asset value of UK Continental oil & gas reserves has started to decline. This is due to both depleting reserves and a fall in price, which has lowered the resource rent projected for future years (figure 3.2).

Figure 3.2: The components of resource rent from 1988 to 2032



3.1.2) Coal reserves

Methodology

i. Resource rent

Resource rent for coal is not calculated by using the equation 2.1 given in chapter 2. This is because equation 2.1 can only be applied if resource rent can be calculated in the first place. In other words, data for Gross Operating Surplus (GOS) should be available or could be calculated by deducting costs and expenditures from total income. However, the data for GOS are only available for sector class 'mining and quarrying' and therefore resource rent for coal reserves cannot be calculated by standard resource rent method. Furthermore, data on total income and cost are also not available to calculate the GOS.

To overcome this issue, a general resource rent ratio is calculated for 'mining and quarrying' sector. This resource rent ratio is then applied to calculated market values of coal production (flows) to isolate the resource rent. The resulting flow value is then capitalised for 50 years to calculate the asset value of UK coal reserves.

A resource rent (RR) ratio is calculated as:

Equation 3.2

$$RR\ ratio = \frac{Resource\ rent\ of\ the\ sector}{Total\ output\ of\ the\ sector}$$

Resource rent ratio

A resource rent for the sector 'mining and quarrying' is calculated in the first instance using equation 2.1. The data for total income, operating cost, net capital stock and consumption of fixed capital on 'mining and quarrying' are from the ONS. The data are only available from 1997 to 2012 and therefore 1997 data are kept constant from 1988 to 1996. A ten year government bond yield from Bank of England is used to estimate the return on produced assets by multiplying the rate with the net capital stock invested in the 'mining and quarrying' sector.

The resulting resource rent is then divided by the total output of the sector 'mining and quarrying' to derive the resource rent ratio from 1988 to 2012 (Equation 3.2). This resource rent ratio is then applied to calculated market values of coal extraction (flows) for each year to isolate the resource rent.

Market value

To calculate the market values of coal extraction, data on quantity and prices are required. The data for production from 1988 to 2012 are from British Geological Survey[35] (BGS). The data on prices are only available from 1998 to 2012, which are also from the BGS. The data are based on export values and volume. The unit price of coal is derived by dividing coal export values of a year by export volumes of that year. Since data on prices prior to 1998 are not available, the data for 1998 is assumed to be constant from 1988 to 1997. The prices for all the years are deflated by using GDP deflators to obtain the values in 2012 prices. The market value from 1988 to 2012 is then multiplied by the resource rent ratio to derive the resources rent for coal production for each year.

---

[35] Data for production and prices for coal are extracted from the following BGS publications: United Kingdom Minerals Yearbook 1998, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013.

ii. *Pattern of expected resource rent and asset life*

To calculate the pattern of expected resource rent of coal extraction, data on future extraction and prices are required; however, projected data on coal production and prices are not available. Therefore, a constant extraction and real prices are assumed from 2013 based on a five year average of production and prices between 2008 and 2012. This is illustrated below.

Extraction

The projection of coal extraction after 2012 is based on a five year average of production between 2008 and 2012. The following formula is used to calculate future extraction (S):

Equation 3.3

$$\overline{S_t} = \frac{S_{t-4} + S_{t-3} + S_{t-2} + S_{t-1} + S_t}{5} \ ,$$

where: t = Year

This 5 year average is then applied throughout as the standard projection for each year after 2012.

Prices

Forecasted prices are assumed constant based on a 5 year average between 2008 and 2012. The following formula is used to calculate future prices per unit (P):

Equation 3.4

$$\overline{P_t} = \frac{P_{t-4} + P_{t-3} + P_{t-2} + P_{t-1} + P_t}{5} \ ,$$

where: t = Year

These data are then used to forecast future extraction and prices for 50 years. The projected production and prices are multiplied to derive the market value of UK coal production from 2013 to 2061. The resulting market price is then multiplied with the resource rent ratio to derive the resource rent from 2013 to 2061. However, data on resource rent for 'mining and quarrying' are only available until 2012 and therefore resource rent ratio from 2013 onwards needs to be projected. Following the projection method discussed in equations 3.3 and 3.4, the resource rent ratio (RRR) for coal production is assumed constant based on a five year average of resource rent ratio between 2008 and 2012. This is shown in equation 3.5 below.

Equation 3.5

$$\overline{RRR_t} = \frac{RRR_{t-4} + RRR_{t-3} + RRR_{t-2} + RRR_{t-1} + RRR_t}{5} \;,$$

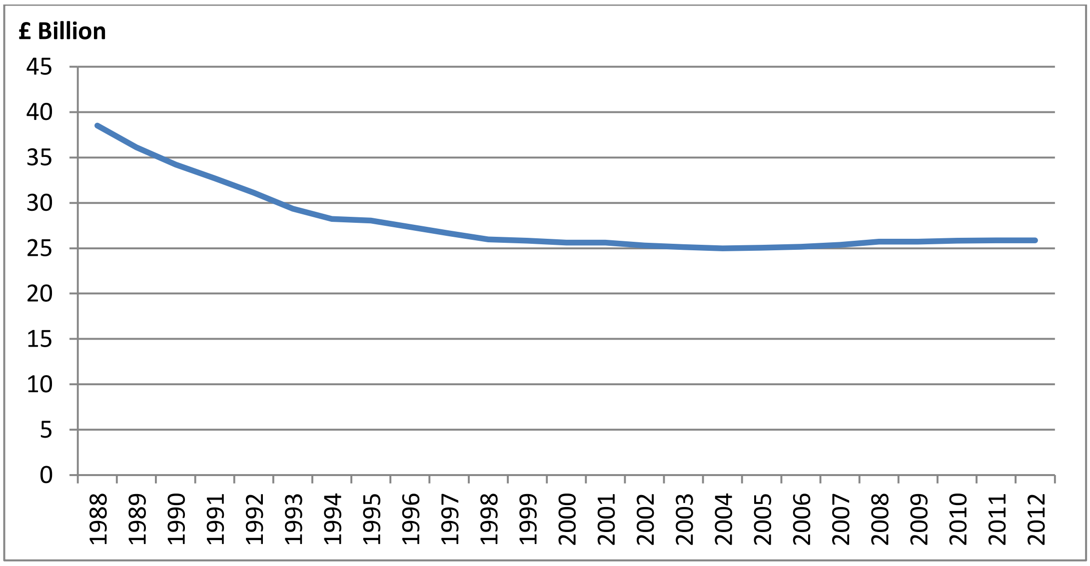
where: t = Year

The resulting resource rent ratio is then multiplied with the projected market price to derive the projected resource rent for coal production for each year from 2013 to 2061.

Results

Using equation 3.1 and applying a declining discount rate, the flow values of UK coal reserves from 1988 to 2012 are capitalised for 50 years. The asset value of UK coal reserves from 1988 to 2012 is shown in figure 3.3 below.

Figure 3.3: Asset value of UK coal reserves, 1988 to 2012 - 2012 prices



3.2) Mineral Reserves

As shown in table 3.1, seven minerals - lead, silver, peat, salt, sand and gravel, limestone and chalk - are selected for valuation purposes. The methodology used to value these reserves is given below.

Methodology

i. Resource rent

Due to data limitations, as for coal reserves, resource rent for minerals is not calculated by using the equation 2.1 given in chapter 2. Hence, the same general resource rent ratio calculated for "mining and quarrying" sector (as discussed in coal section) is used to isolate the resource rent from the market prices of minerals because minerals are also a part of "mining and quarrying" sector.

Market values

To calculate the market values of mineral production (flows), data on extraction and prices are required.

- Extraction

Silver

The data for silver extraction from 1988 to 1991 and from 2007 to 2012 are from the British Geological Survey[36] (BGS). The data from 1992 to 2006 for silver production are not available. This could be due to a very low silver production in the UK. For example, in 1990 and 1991, silver production was only 2695 kilograms and 565 kilograms respectively in the UK. The latest data show that in 2007 silver production was only 212 kilograms, all of which were from Northern Ireland. Since silver production had been very low historically, data for 1992 to 2006 have been assumed constant at 1993 level.

[36] Data for production and prices for all minerals are extracted from the following BGS publications: World Mineral Production (various publications) and United Kingdom Minerals Yearbook 1998, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013.

Peat

The data for peat extraction from 1991 to 2012 are from the BGS. The data from 1988 to 1990 are not available; therefore, the data for 1988 to 1990 have been assumed constant at 1991 level.

Limestone, chalk, lead, salt, and sand and gravel

The data for limestone, chalk, lead, salt, and sand and gravel extraction from 1988 to 2012 are also from the BGS.

- <u>Prices</u>

The data on prices for all minerals are available from 1988 to 2012, which are taken from the BGS. The data are based on export values and volume. The unit price of a mineral is derived by dividing the export values of a year by export volumes of that year. The prices for all the years are deflated by using GDP deflators to obtain the values in 2012 prices.

The market values for these minerals from 1988 to 2012 are then multiplied by the resource rent ratio to derive the resources rent for these minerals for each year.

ii. *Pattern of expected resource rent and asset life*

To calculate the pattern of expected resource rent of minerals, data on future extraction and prices are required; however, projected data on extraction and prices for all these minerals are not available. Therefore, a constant extraction and prices are assumed from 2013 based on a five year average of production and prices between 2008 and 2012. The five year average is calculated using the equations 3.3 and 3.4 given above.

In practice this standard projection might not be applicable to all mineral reserves. For example, UK lead extraction dropped from 2,000 tonnes in 1997 to 61 tonnes in 2012. However, due to lack of data on future extraction, this chapter has followed the SEEA Central Framework guidelines of assuming constant extractions.

Peat areas are now under various and increasing forms of legal protection or designation. Furthermore, the National Planning Policy Framework states that no new planning permissions for peat extraction shall be granted. As a result, extraction of peat is likely to continue to decrease. Therefore, it is ideal that future peat production should be estimated based on a function that estimates peat production to fall continuously at a diminishing rate over the 50 years asset life. Therefore, instead of using equation 3.3, this chapter estimates future production of peat with an exponential function based on trends in previous production data. The exponential function used to estimate future peat production in given in equation 3.6 below.

Equation 3.6

Peat future extraction = Extraction in 2012 x Exp (-0.063 x n)

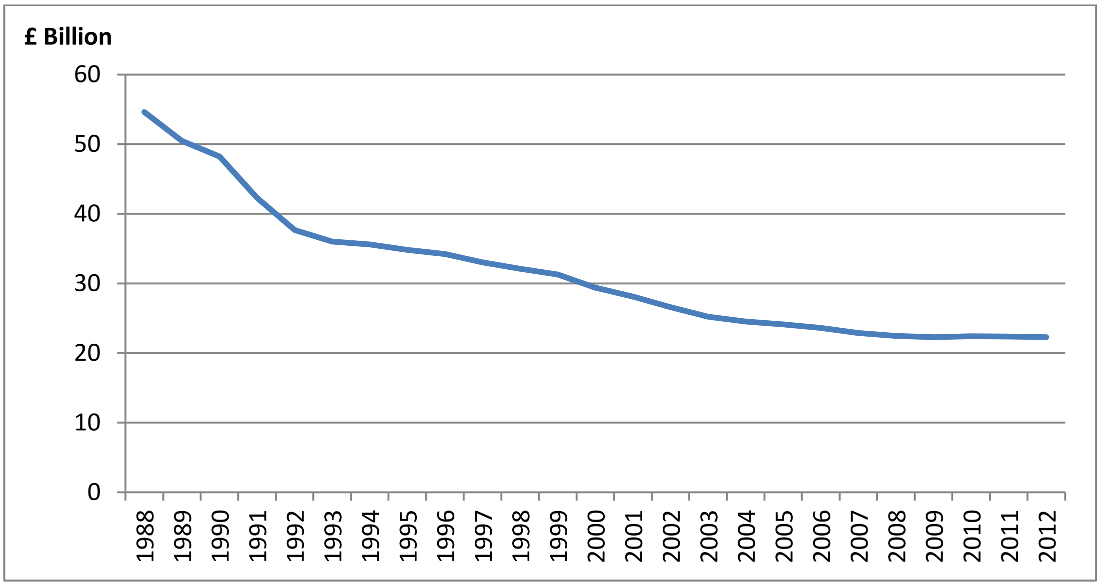
Where n = Current year (e.g. for 2013, n=1 and 2004, n=2 and so on)

The projected data are then used to forecast future extraction and prices for 50 years. The projected production and prices are multiplied to derive the market value of UK mineral production from 2013 to 2061. The resulting market price is then multiplied with the resource rent ratio (RRR) to derive the resource rent from 2013 to 2061. However, data on resource rent for 'mining and quarrying' are only available until 2012 and therefore RRR from 2013 onwards is projected using equation 3.5. The resulting RRR is then multiplied with the projected market price to derive the projected resource rent for all minerals for each year from 2013 to 2061.

Results

Using the equation 3.1 and applying a declining discount rate, the flow values of UK mineral reserves from 1988 to 2012 are capitalised for 50 years. The asset value of UK mineral reserves from 1988 to 2012 is shown in figure 3.4 below.

Figure 3.4: Asset value of UK mineral reserves, 1988 to 2012 - 2012 prices

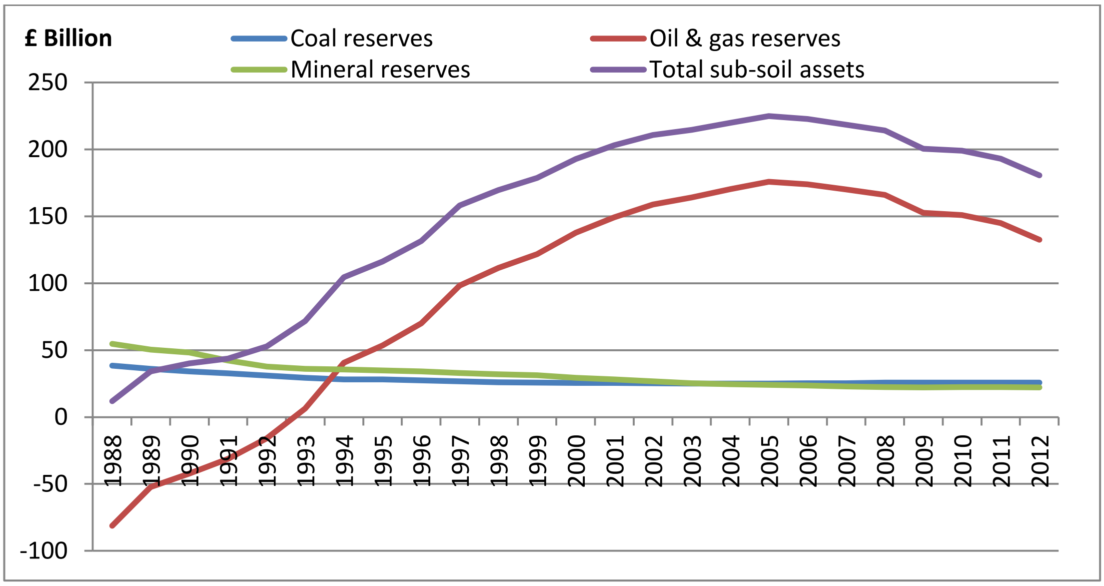


UK total subsoil assets (Oil & gas reserves, coal and minerals)

Figure 3.5 shows UK sub-soil assets from 1988 to 2012. The figure shows that oil & gas reserves are the largest component of sub-oil assets and are driving the trend of sub-soul assets. The figure shows the value of UK sub-soil assets has increased substantially between 1988 and 2005. This is mainly due to an increase in the asset value of UK Continental oil & gas reserves which has increased until 2005 (discussed in the earlier section). This increase has been partly offset by a fall in the asset values of UK coal and mineral which have been in a continuous decliner since 1998. The majority of this fall reflects depleting reserves.

Since 2005, the overall asset value of UK sub-soil assets is in decline. Much of this decline is due to a fall in the value of oil & gas reserves which is due to both depleting reserves and a fall in prices. The value of UK sub-soil assets in 1988 was £12 billion, which has increased to £225 billion in 2005 before decreasing to £181 billion in 2012. A fall in value in sub-soil assets between 2005 and 2012 is mainly due to a 25% fall in the monetary value of UK Continental Shelf oil and gas reserves. There is a general decline in UK oil and gas reserves, from 1,582 million tonnes of oil equivalent (mtoe) in 2005 to 1,323 mtoe in 2012. Oil and gas production has also declined from 181.0 mtoe in 2005 to 83.5 mtoe in 2012.

Figure 3.5: UK sub-soil assets, 1988 to 2012 - 2012 prices



3.3) Agricultural land

The second category in non-renewable assets is agricultural land. The following methodology is employed to estimate the asset value of UK agricultural land from 1988 to 2012.

Methodology

i. Resource rent

Equation 2.1 is used to estimate the resource rent for UK agricultural land from 1988 to 2012. Due to data limitations, Gross Operating Surplus (GOS) data for industrial classification "crop and animal production, hunting and related services" is used to estimate the resource rent for agricultural land. It is assumed that this classification is mainly related to agriculture and, hunting and related agricultural services are negligible.

The data for GOS are from the ONS. The data are available from 1988 to 2012; however, data from 1988 to 1996 are not on comparable basis with the rest of the data. Therefore, data from 1997 to 2012 are used in this chapter and the 1996 values for GOS are calculated by taking a five year average of 1997 to 2001 data and are kept constant to 1988. It is assumed that the GOS includes all wage costs in addition to other operating costs.

An added complication in this sector, which has been ignored at present, is the presence of owner-occupier farms whose 'wages' would not necessarily be recorded under compensation of employees. So, the resource rent applied here may be overestimated as it has not taken these notional 'wages' (essentially paid out of the profit of the farm) out of the calculation.

As mentioned in chapter 2 and in equation 2.1, specific taxes related to an environmental asset needs to added back and subsidies need to be deducted from the GOS. The data for subsidies and taxes are available from ONS for industrial classification "crop and animal production, hunting and related services". Therefore, the GOS has been adjusted for these changes.

The GOS is then adjusted for user cost of the produced assets to derive the resource rent for agricultural land. The data for net capital stock and consumption of fixed capital for industrial classification "crop and animal production, hunting and related services" are from the ONS. The latest data were published by the ONS in July 2014 and are from 1997 to 2012. Capital stock data are not available from 1988 to 1996; therefore, the 1996 values for net capital stock are calculated by taking a five year average of 1997 to 2001 data and are kept constant to 1988. A ten year government bond yield from Bank of England (see chapter 2) is used to estimate the return on produced assets by multiplying the rate with the net capital stock invested in the "crop and animal production, hunting and related services" sector.

Similar to net capital stock, data for consumption of fixed capital are also from the ONS. Consumption of fixed capital data are also not available from 1988 to 1996; therefore, the 1996 values for consumption of fixed capital are calculated by taking a five year average of 1997 to 2001 data and are kept constant to 1988. The user cost of produced asset for each year is deducted from the GOS to derive the resource rent for agricultural land for each year from 1998 to 2012.

ii. *Pattern of expected resource rent and asset life*

Since data on future production and GOS are not available, the pattern of expected resource rent of agricultural land is calculated using equation 2.2[37] discussed in chapter 2.

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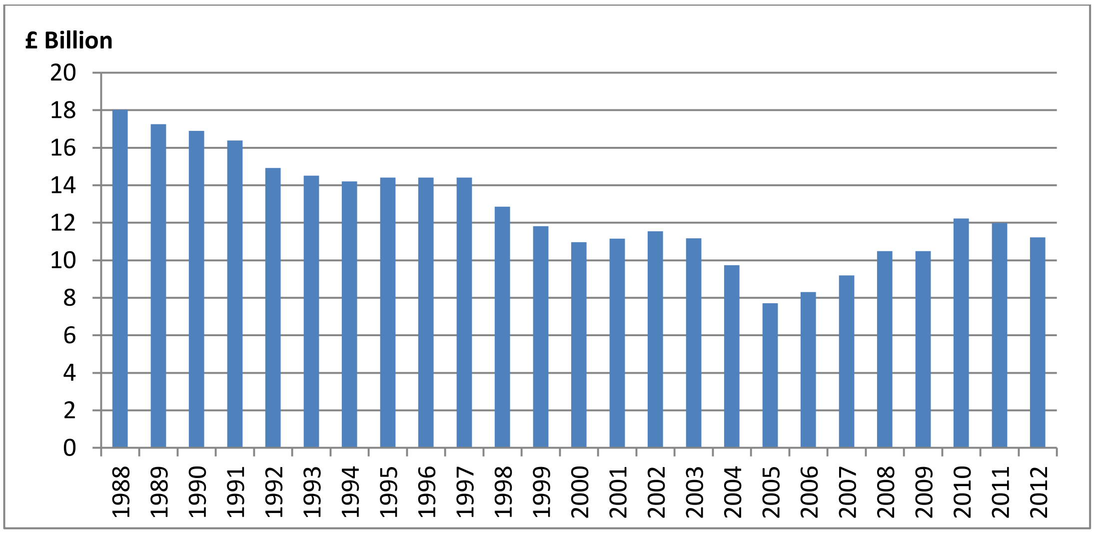
[37] $\overline{RR}_t = \frac{RR_{t-4} + RR_{t-3} + RR_{t-2} + RR_{t-1} + RR_t}{5}$

Hence, a constant resource rent is assumed from 2013 onwards based on five year average of 2008 to 2012 agricultural resource rent data to estimate the resource rent for 50 years.

Results

Using equation 3.1 and applying a declining discount rate, the flow values of UK agricultural land from 1988 to 2012 are capitalised for 50 years. The asset value of UK agricultural land from 1988 to 2012 is shown in figure 3.6 below. The figure shows that the asset value of UK agricultural land has fallen for most of the years between 1988 and 2012. This is because of lower Gross Operating Surplus, which could be due to over harvesting of agricultural land and the competitive nature of the market. Furthermore, there is a low and in some cases a negative resource rent due to the existence of higher agricultural subsidies and higher net capital stock.

Figure 3.6: Asset value of UK agricultural land, 1988 to 2012 - 2012 prices



b) Renewable assets

Table 3.2 lists the renewable assets and ecosystem services that are included in this thesis to calculate the asset value of UK natural capital. As mentioned in chapter 2, these assets are categorised as renewable on the assumption that they can be harvested or extracted in a sustainable way and there will be no further depletion or degradation to the ecosystem services.

Table 3.2: Renewable assets and ecosystem services

Renewable assets	Renewable ecosystem services
Timber	Outdoor recreation
Fisheries	Net greenhouse gas sequestration
Water abstraction	

3.4) Timber resources

The first category in non-renewable assets is UK timber resources. The monetary value of UK timber resources is the value of the timber resources that are located in the UK woodlands. In the UK, all timber resources can be regarded as available for wood supply. Therefore, this chapter values all the timber resources within UK woodland. By assuming all timber is available for wood supply, this chapter is not making an assumption that woodland in the UK is only managed for timber. The focus of this chapter is to value the timber resources as an asset regardless of whether they provide other ecosystem services.

The methodology to estimate the asset value of UK timber resources from 1988 to 2012 is discussed below. It is based on the methodology developed by Khan et al. (2013)[38] to estimate the monetary value of UK timber resources. This chapter extends the methodology to value UK timber resources from 1988 to 2012.

As discussed in chapter 2, the timber resources in this chapter are valued in situ and theoretically the value of the timber resource is the discounted future stumpage price paid by the buyer to the owner of the forest for standing timber. The average price of coniferous standing sales[39] (per cubic metre over bark) by the UK Forestry Commission is available for Great Britain. Coniferous species account for over 90% of all timber harvested in the UK, and the Forestry Commission accounts for around half of all coniferous timber sold. Assuming that broadleaved species, which are not traded as regularly, have the same stumpage price as coniferous species, this chapter has used the average price of Forestry Commission coniferous standing sales as the average stumpage price for all timber.

[38] http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/publications/monetary-valuation-of-uk-timber-resources.pdf

[39] Average prices for Forestry Commission sales of coniferous standing timber are published in the Forestry Commission's National Statistics release "Timber Price Indices"

Methodology

i. Resource rent

Resource rent could be estimated by using the equation 2.1 by deducting the user cost of produced assets from gross operating surplus after adjustment for any specific subsidies and taxes. However, unlike agricultural land, data on gross operating surplus are not available and in the absence of data, a number of assumptions are required. Alternatively, as suggested by SEEA, the resource rent for timber resources could be estimated more directly by using estimates of the stumpage price. However, using stumpage price as the resource rent presents a risk that the management cost and normal return is not deducted. This chapter uses the stumpage price as the resource rent of timber resources to value the UK timber resources for 2011. The data for natural growth and removals of timber are then used to estimate the value of UK timber resources from 1988 to 2010 and 2012.

The stumpage price, as discussed above, is used in this paper as the unit resource rent (URR) of UK timber resources. The URR is assumed to be constant over the asset life, so the volatility of the URR could affect the expected resource rent. To smooth out these URR fluctuations, the following five year average is applied:

Equation 3.7

$$Adjusted\ URR = \frac{URR_{t-2} + URR_{t-1} + URR_{t} + URR_{t+1} + URR_{t+2}}{5} ,$$

where: t = current time period

Using equation 3.7, an adjusted URR of £13.21 is derived. The adjusted URR is used to estimate the expected resource rent for the timber resources for 2011.

ii. Expected pattern of resource rent

There are a number of ways to determine the patterns of the expected resource rent for timber resources:

1) One way is to project the future extraction. However, in the absence of information on future cost, prices and extraction rates it is not possible to estimate a reliable extraction projection.

2) A second way is to assume that the current extraction rate and the natural growth rate are constant. In the absence of any information, SEEA Central Framework has also suggested assuming constant extractions. However, if this option is chosen, the possibility of over-exploitation and afforestation may not be captured in the value.

3) A third way is to consider the age structure of the timber resources. Generally, timber resources have different growth rates – higher growth rates when they are young, constant rate close to harvesting, and declining growth rate after maturity. Considering these growth patterns, an optimum harvesting age can be derived using either the Faustmann rule or the maximum mean annual increment concept. The Faustmann rule gives the present value of the income stream of the forest rotation and provides the optimal harvesting age; whereas, the mean annual increment is the average annual increase in the volume of a tree at a certain age.

This chapter uses the third option to determine the expected resource rent for timber resources by using the maximum mean annual increment concept. This is because the Faustmann rule requires a number of assumptions and information on the value of forests, expected prices and associated costs, which are not readily available.

The maximum mean annual increment concept is based on different growth rates in timber resources throughout its life span. However, the average age of the maximum mean annual increment is currently not available for UK timber resources. As discussed in chapter 2, average rotation period of timber is 50 years; therefore, this chapter assumes that the harvesting age is 50 years and falls in the 41-60 age class[40]. Since timber grows until it is harvested, the expected volume of standing timber for each age class is assumed to be fixed at the harvesting age. There are timber resources in the UK that are older than the harvesting age - known as overdue timber. This additional volume is not considered in the valuation of the timber resources.

iii. Asset life and discount rates

A midpoint for all the age classes is calculated to obtain the asset life corresponding to each age class. As discussed earlier, the harvesting age is assumed to be 50 years. To estimate

[40] The age classes are: 0-20, 21-40, 41-60, 61-80, 81-100 and 100+

the asset life of timber resources in each age class, the midpoint of each age class is subtracted from the harvesting age. For example, for class 0-20 the midpoint is 10, which is subtracted from the harvesting age of 50 years to obtain an asset life of 40 years. Timber resources above 50 years are valued at their expected volume of 50 years instead of their actual volume.

A declining discount rate is then applied to discount the future receipts to estimate the value of timber resources at each age class. Since the harvesting age is set between the 40 and 60 age class, the future receipts from 60+ age classes are not discounted, as these trees could (by assumption) be harvested now. The total receipts from all age classes of timber resources give the total value of UK timber resources.

Monetary value of UK timber resources for 2011

Using the equation 3.1, the monetary value of UK timber resources at 31 March 2011 is estimated at £7.2 billion. The valuation of timber resources is undertaken on all standing timber. All the standing timber stock is being valued as if it is used solely as timber without considering the other ecosystem services they provide. Therefore, the value derived is an asset value of timber resources when they are being removed and used as timber products. The value of ecosystem services, other than removal, provided by UK woodland are not captured over here.

The above valuation includes those timber resources that are above 60 years of age (above the harvesting age of 50) and are valued around £2.2 billion. This value is based on the assumption that the timber is overdue and could be harvested at any time. This approach is consistent with SEEA Central Framework and the System of National Accounts (SNA), which states that any asset which is used for economic production has an economic value. The timber resources above 60 years are available for wood supply and therefore they need to be valued.

Monetary value of UK timber resources for 2012

Flows between 2011and 2012

To estimate the monetary value of UK timber resources for 2012, data for addition to stock and reduction in stock are required. The value of additions to stock consists of natural growth from the existing timber stock and the new planting and restocking. The reductions in stock consist of removals, felling residues, natural losses and catastrophic losses. The data for addition to stock between 2011 and 2012 are from the Forestry Commission. The data for UK timber removals and felling residues[41] are from the Forestry Statistics 2012. An estimate for natural losses has been obtained from the Forestry Commission's submission to Forest Europe for the State of Europe's Forests 2011 (SoEF 2011). There are currently no data available for catastrophic losses and therefore they have not been calculated. However, it is expected that such losses are very small.

Prices used to value flows

SEEA suggested that the valuation of flows of timber resources (including removals, natural growth and new planting) should be undertaken using the price in situ. Therefore, an average discounted price of timber resources, also known as the price in situ, is calculated. This is derived by dividing the discounted total value of timber resources by the total current volume of timber resources at 31 March 2011 (Price in situ = £7,189 million / 585.31 million cubic metres overbark = £12.28 per cubic metre overbark).

Asset value of UK timber resources for 2012

The price in situ, £12.28, is applied to each of the categories in the additions to and reductions in stock. The value of the net change is then added to the 2011 timber resources value. This provides the monetary value for 2012. The monetary value for UK timber resources for 2012 is estimated to be £7.4 billion.

Asset value of UK timber resources from 1988 to 2010

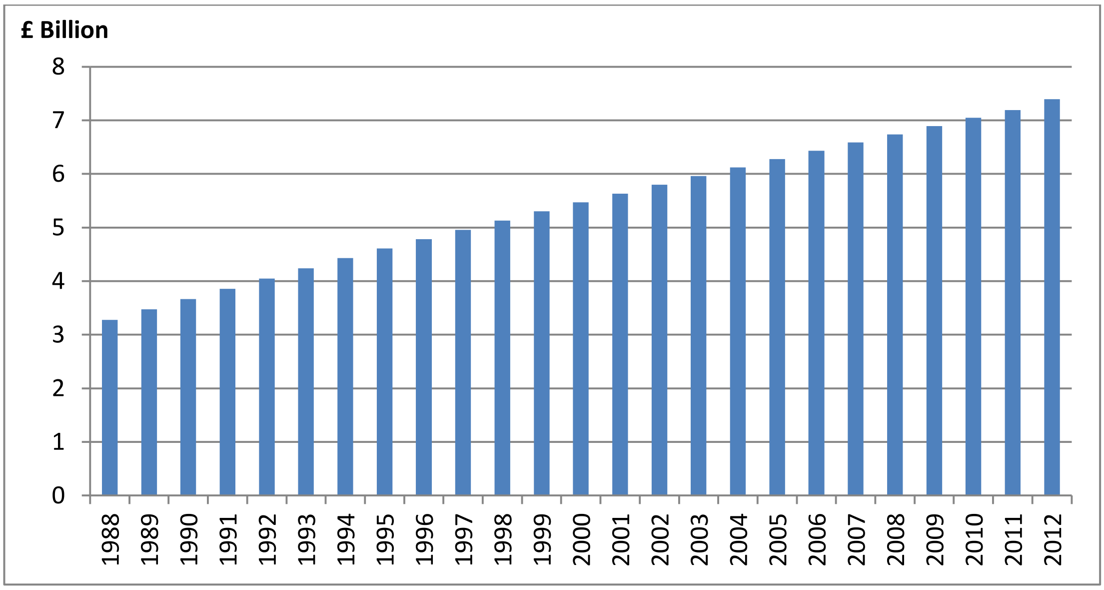
To estimate the monetary value of UK timber resources from 1988 to 2010, data for addition to stock and reduction in stock are required. However, data are not available for addition to stock, and for reduction in stock data are only available for removals. Therefore, only removals data are used for reduction in stock, and for addition to stock, it is assumed that natural growth remains at the same level for every year between 1988 and 2010 as it is between 2011 and 2012. The data for removals of timber from 1988 to 2010 are from the Forestry Statistics.

[41] The data for removals and fellings relates to calendar years. For simplicity, it is assumed that felling activity id similar throughout the year and that the figures for financial years are similar to those for calendar years.

A non-monetary net change is calculated for every year from 1988 to 2010, which is then multiplied by the price in situ (£12.28). The resulting net change value of 2010 is subtracted from the asset value of 2011 to obtain the monetary value of timber resources for 2010. This step is repeated for every year to obtain the value of timber resources from 1988 – 2010.

Following the above methodology, the asset value of UK timber resources from 1988 to 2012 is given in figure 3.7 below.

Figure 3.7: Asset value of UK timber resources, 1988 to 2012 - 2012 prices



3.5) Fisheries

The second category in non-renewable assets is fisheries. The following methodology is employed to estimate the asset value of UK fisheries from 1988 to 2012.

Methodology

i. Resource rent

Equation 2.1 from chapter 2 is used to estimate the resource rent for UK fisheries from 1988 to 2012. The data for Gross Operating Surplus (GOS) for industrial classification "fishing and aquaculture" are used to estimate the resource rent for fisheries. Similar to agricultural land, the data for GOS are available from 1988 to 2012; however, data from

1988 to 1996 are not on comparable basis with the rest of the data. Therefore, 1996 values for GOS are calculated by taking a five year average of 1997 to 2001 data and are kept constant to 1988. The GOS is then adjusted for user cost of the produced assets to derive the resource rent for fisheries.

User cost of produced assets

Similar to agricultural land, the GOS is then adjusted for user cost of the produced assets to derive the resource rent for fisheries. The data for net capital stock and consumption of fixed capital for industrial classification “fishing and aquaculture” are taken from the ONS. Capital stock data for fisheries are also not available from 1988 to 1996; therefore, the 1996 values for net capital stock are calculated by taking a five year average of 1997 to 2001 data and are kept constant to 1988. A ten year government bond yield from Bank of England is used to estimate the return on produced assets by multiplying the rate with the net capital stock invested in fisheries sector. The consumption of fixed capital for fisheries is calculated in a similar way. The user cost of produced asset for each year is deducted from the GOS to derive the resource rent for fisheries for each year from 1988 to 2012.

As with agricultural land, the wages of the owners who are running their own boats are currently not accounted for in the GOS. Therefore, the resource rent derived from the GOS might be overstated. However, the resource rent could be underestimated as well because of overcapacity in the fishing fleets, the existence of fisheries subsidies and the competitive nature of the market.

ii. *Pattern of expected resource rent and asset life*

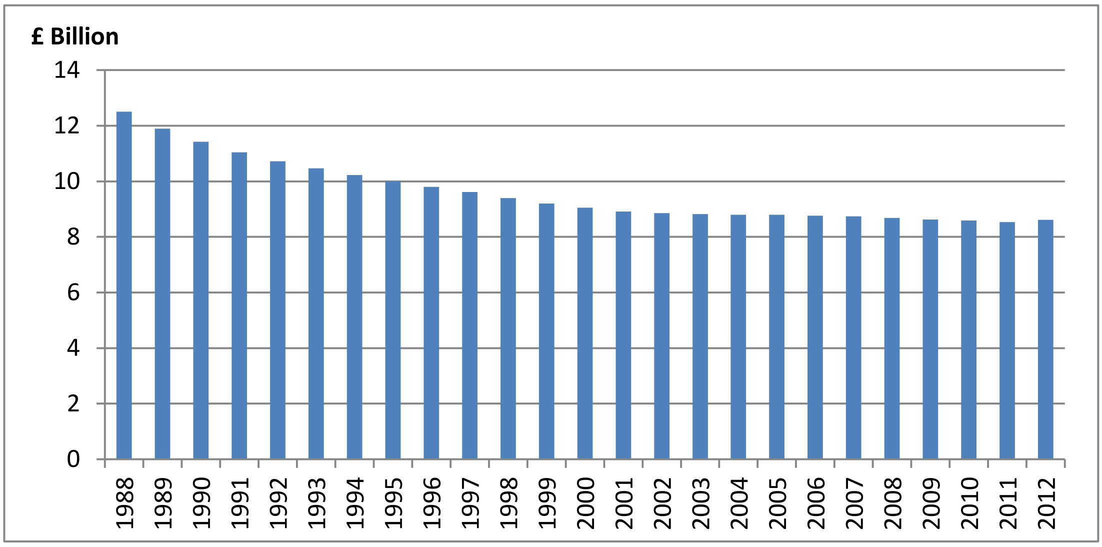
The pattern of expected resource rent for fisheries is calculated using equation 2.2 given in chapter 2. Hence, a constant resource rent is assumed from 2013 onwards based on five year average of 2008 to 2012 resource rent data to project the resource rent for 50 years.

Results

Using equation 3.1 and applying a declining discount rate, the flow values of UK fisheries from 1988 to 2012 are capitalised for 50 years. The asset value of UK fisheries from 1988 to 2012 is given in figure 3.8 below. The figure shows that the asset value of UK fisheries is quite low and is falling between 1988 and 2000 and then almost similar every year until

2012. The low asset value of UK fisheries is due to lower resource rent which is due to lower Gross Operating Surplus (GOS), existence of subsidies and higher net capital stock invested in fisheries sector. The lower GOS is because of over fishing and competitive market of the nature. In 1992, Common Fisheries Policy review determined that there had been an overinvestment in vessels and due to overfishing the numbers of fish landed were decreasing. In 1995, a permit system was introduced with specific guidelines on when and where boats were allowed to fish. This would have helped to stabilise the resource rent. Another likely reason for a stabilised resource rent is the assumptions used in calculating the resource rent and the asset value of UK fisheries. For example, as discussed above, due to limited data availability on net capital stock and GOS, data have been estimated for a few years, which could have given a constant trend.

Figure 3.8: Asset value of UK fisheries, 1988 to 2012 - 2012 prices



3.6) Water abstraction

The third category in non-renewable assets is water abstraction for public water supply. The following methodology is employed to estimate the asset value of water abstracted in the UK from 1988 to 2012.

Methodology

i. Resource rent

The resource rent calculations for water abstraction is very challenging. It can be derived following the same methodology as fisheries. The alternative is to collect the price data for various uses, such as irrigation, drinking water and electricity generation, and apply them to the quantity of water abstracted. The second option is preferable but due to data limitations, it is currently not possible to employ this method. As such, similar to agricultural land and fisheries, equation 2.1 is used to estimate the resource rent for water abstracted for public supply from 1988 to 2012. The data for Gross Operating Surplus (GOS) for industrial classification "water collection, treatment and supply" are used to estimate the resource rent for water supply.

Similar to fisheries, the data for GOS are available from 1988 to 2012; however, data from 1988 to 1996 are not on comparable basis with the rest of the data. Therefore, data from 1997 to 2012 are used in this paper and the 1996 values for GOS are calculated by taking a five year average of 1997 to 2001 data and are kept constant to 1988.

User cost of produced assets

The GOS is then adjusted for user cost of the produced assets to derive the resource rent for water supply. The data for net capital stock and consumption of fixed capital for industrial classification "water collection, treatment and supply" are from the ONS. Capital stock data for water supply are also not available from 1988 to 1996; therefore, the 1996 values for net capital stock are calculated by taking a five year average of 1997 to 2001 data and are kept constant to 1988. A ten year government bond yield from Bank of England is used to estimate the return on produced assets by multiplying the rate with the net capital stock invested in fisheries sector. The consumption of fixed capital for water supply is calculated in a similar way. The user cost of produced asset for each year is deducted from the GOS to derive the resource rent for water supply for each year from 1988 to 2012.

A complication in valuing water supply is that it is currently not clear whether water companies are investing in water infrastructure. It is argued that either government is currently paying for capital investment or subsidising the water companies to invest in the infrastructure. There is also no evidence that water companies are setting aside funds for capital depreciation. In these circumstances, it might be the case that the resulting resource rent of water supply is underestimated. Furthermore, the values for water derived in this chapter for 1988 to 2012 are for public water supply only, which accounts for around a quarter of water abstraction. Therefore, the value for water derived is likely to be an underestimate.

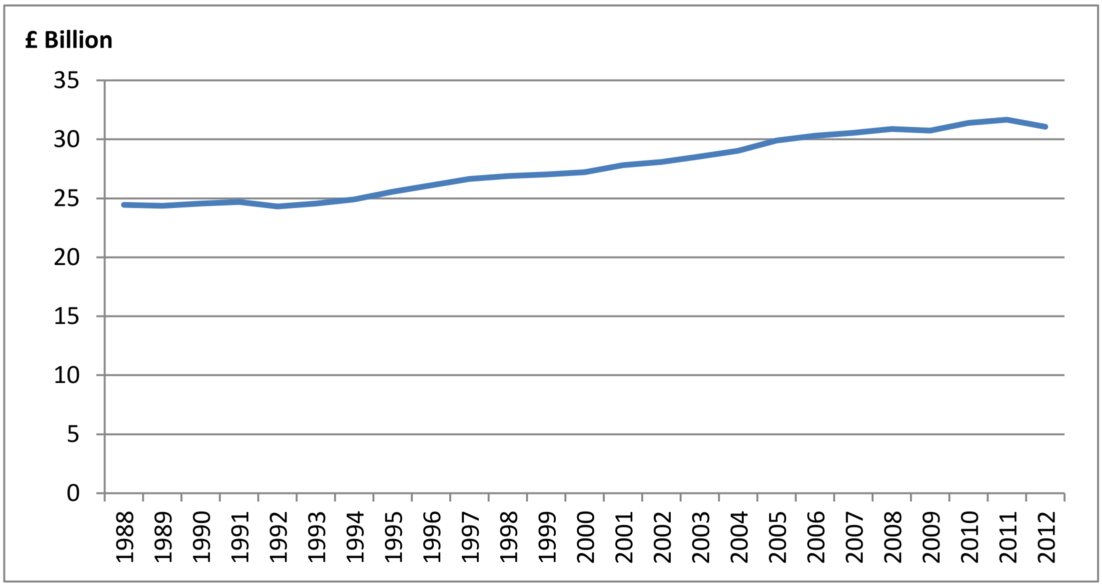
ii. *Pattern of expected resource rent and asset life*

Similar to agricultural land and fisheries, the pattern of expected resource rent of water supply is calculated using equation 2.2. Hence, a constant resource rent is assumed from 2013 onwards based on five year average of 2008 to 2012 water supply resource rent data to estimate the resource rent for 50 years.

Results

Using equation 3.1 and applying a declining discount rate, the flow values of UK public water supply from 1988 to 2012 are capitalised for 50 years. The asset value of UK public water supply from 1988 to 2012 is shown in figure 3.9 below.

Figure 3.9: Asset value of UK public water supply, 1988 to 2012 - 2012 prices



3.7) Outdoor recreation - a cultural ecosystem service

The first category in renewable ecosystem services is the outdoor recreation provided by natural environment in the UK. Outdoor recreation forms one of the major leisure activities for the majority of the population and is one of the most important cultural ecosystem services provided by the natural environment. People visit the natural environment, for example, woodlands, for walking and other recreation related activities and receive numerous non-material benefits. Since the recreational benefits of most natural areas cannot be enjoyed without travelling to the site, a lower bound price for outdoor recreation can be imputed. In turn, an asset value for the recreational sites can be estimated.

Travel Cost Method

Travel Cost Method (TCM) is a well-used indirect method in estimating the economic value of the recreational sites in a non-market environment, like valuing ecosystem services associated with recreational sites. This is a revealed preference method because it looks at actual human behaviour to try to define the value people place on something. Through the analysis of the travel costs and the behaviour of the visitors, a demand function could be defined by collecting related data on the demand (number of travel) and the price (for example transport costs, admission fee, travel time and visiting time). This is based on the understanding that to enjoy the recreational site one has to pay the cost of getting to that site and remaining on the site.

Travel Cost Method assumes that there is a relation between the value of the recreational site and the travel expenditure, which includes both monetary costs and opportunity cost as well, (Pearce et al, 2006). When the total cost increases, the number of visitors or the visitation rate decreases. Based on that, a demand function could be estimated and by modelling and regression the economic value of recreational site could be computed.

It is quite complex to value the ecosystem services that stem from recreational sites in an accounting context using TCM. This is because of the inclusion of cost of time (travel time and visit time) in the TCM. Though, Hynes et al (2009) concluded that a general consensus in the literature is that some recognition of the opportunity cost of time should be included in the Travel Cost Method, there are arguments that the inclusion of cost of time is not consistent with the System of National Accounts as no transactions have actually taken place.

This thesis argues that the cost of time spent at recreational sites could be included in the calculations without being inconsistent with the System of National Accounts. If the concepts of travel time and visit time (time spent at recreational site) can be separated, there could be an argument of including the visit time to a recreational site in the accounts. The threat of not including the cost of time visiting a recreational site in TCM in accounting context comes from the inclusion of travel time, which could cause some challenges due to data limitations, for example, the travel time could be used for visiting a single site or multisite and most data do not provide this differentiation. The inclusion of travel time in the calculations needs further research.

To understand the above concept of time spent at recreational sites, one needs to think how a hypothetical market for recreation would work in practice. If the hypothetical market is constructed carefully, one would feel that it is just like a normal market. If there were a real market, one has to pay for the time spent at the recreational sites. In real markets, for example, a theme park, an individual buys a ticket for a theme park for one day and enjoys all the rides or the individual can buy the tickets for two days (and pay extra for that) and enjoy the same rides. For theme parks, the individual is not paying for the rides (of course the individual enjoys the rides), but for the time spent at the theme park and that is the reason, the individual is paying extra just to remain at the theme park (for 2 days). There is a price for the extra time that individual is spending at the theme park. This cost of time is not an opportunity cost of time. This ends up in the National Accounts. Similarly, if an individual is visiting a recreational site to enjoy the activities and the price to enjoy these activities is the time spent at the sites (same concept to theme park). If there were a regular market, this individual would have paid a price. One could argue that admission fee covers this, but it is not true as most of the recreational sites are open access sites.

Another example could be parking in car parks. An individual goes to a car park and uses the parking space by paying for the time his car is in the car park. He is charged by the hour and pays the price to park his car for certain time. A service is provided in this case and he is charged for the time spent in the car park. Similarly, recreational sites provide a service and an individual would have been charged for the time spent at the sites, if there were a regular market.

The above discussion shows that there could be a mechanism by which visitors could be charged a price for visiting the recreational sites and the price is the value of time spent at these sites - the same concept as the theme park. Since there is no real market in the case of recreational sites, proxies are used to estimate the time. If the pricing of theme park is consistent with the National Accounts, the recreational sites have to be as well.

Methodology

To obtain an estimate of the value of recreation that stems from the natural environment in the UK, this chapter uses a simple travel cost method[42]. This chapter estimates the following components of travel cost:

- Visit time – time on the recreational sites (excluding travel time)
- Travel expenditures – private transport fuel costs, public transport expenditures and parking fees

As discussed above, it is assumed that there is a price to visit the recreational sites and the price is the travel cost and the time spent on the site. At this price, the quantity demanded is the actual number of visits to the site. To derive the demand curve, due to data limitations, it is also assumed that all visitors have the same average willingness to pay and would pay this price. This might not be the case but by making this assumption this chapter makes an implicit judgement about the demand curve.

This method is based on the assumption discussed above that there could be some mechanism whereby visitors might be charged their average willingness to pay if a market did exist. This is based on SEEA Central Framework and SEEA Experimental Ecosystem Accounting principles that when there are no observable prices because the items in question have not been purchased or sold on the market in the recent past, an attempt has to be made to estimate what the prices would be if a regular market existed and the assets were to be traded on the date to which the estimate of the asset relates[43].

i. Resource rent

To estimate the resource rent of outdoor recreational services the values of visit time and travel cost are calculated as follows:

Value of the visit time spent at recreational sites

To estimate the value of visit time at recreational sites, the data on the number of people visiting recreational sites and the price for visiting these sites is required.

[42] TCM by modelling and regression is an extensive research on its own, which is beyond the scope of this thesis.
[43] Source: SEEA Central framework and SEEA Experimental Ecosystem Accounting

Number of visits

The data on number of visits to UK recreational sites are challenging to obtain. There is lack of data for the required time period and even for those years where the data are available; they are not on comparable basis. For example, data on people visiting recreational sites are only available from 2009 for England and from 2004 for Scotland. Data for Wales and Northern Ireland are not available, though Wales has recently started a comparable survey but data for most of the required years are not available. This poses a huge challenge as without the number of visits, the value of visit time to recreational sites cannot be calculated. There are two ways to overcome this challenge:

- Impute the data for the missing years for all the countries; however, due to large data gaps for England and Scotland, and non-availability of data for Wales and Northern Ireland, a number of assumptions need to be applied, which might not provide credible results.
- Use the data for one of the countries with large representation and upscale them to UK level using population data to get comparable results for the UK. However, using this approach would still require to estimate data for the missing years. But this approach is still preferable because it could provide comparable results for the whole UK.

This chapter uses the second approach to estimate the number of visits to UK recreations sites. The data for number of visits to recreation sites in England are used to estimate the data for the UK because it has the largest weighting and the required data for this thesis are available. However, the data on the number of people visiting recreational sites in England are only available from 2009 to 2012. These data are estimated by Monitoring Engagement with the Natural Environment (MENE) survey, which began in 2009 and is conducted by Natural England on an annual basis. Natural England defines the natural environment as the "green open spaces in and around towns and cities, as well as the wider countryside and coastline" (Natural England, 2012). Since the MENE survey started in 2009, the data on the number of visitors for 1988 to 2008 need imputing. There are two ways to impute the data:

1. Take an average value for 2009 to 2012 and then assume it constant between 1988 and 2008.
2. Calculate a ratio of change in population in England for every year between 1988 and 2008 and apply the ratio to the number of visits to recreational sites in England for these years.

It is recognised that both of the above methods have some limitations in providing an accurate estimation of the annual number of visits, but in the absence of any reliable data they do provide an indication of the number of annual visits to recreational sites in England. To cross check, this chapter uses both approaches to estimate the annual number of visits to recreational sites in England from 1988 to 2008. As the visitor data relates to England only, they are scaled up to the UK level using population data from the ONS from 1988 to 2012. The numbers of annual visits by both approaches are shown in tables 3.3 and 3.4 below.

Table 3.3: Number of annual outdoor visits to UK recreational sites from 1988 to 2012 (billions) - 1988 to 2008 are average values for 2009 to 2012

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
No.	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
No.	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**		
No.	2.73	2.73	2.73	2.86	2.49	2.73	2.85		

Table 3.4: Number of annual outdoor visits to UK recreational sites from 1988 to 2012 (billions) - values derived by applying the ratio of change in population

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
No.	2.74	2.74	2.74	2.74	2.74	2.74	2.74	2.74	2.74
Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
No.	2.74	2.74	2.74	2.74	2.74	2.75	2.75	2.75	2.75
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**		
No.	2.75	2.75	2.75	2.86	2.49	2.73	2.85		

Tables 3.3 and 3.4 show that the annual number of visits to UK recreational sites are almost similar regardless of the approach used. This provides some degree of confidence in the approach used to impute the number of visits. Since table 3.3 is a less conservative estimate than table 3.4, this chapter uses the number of visits derived by the first approach as shown in table 3.3.

Travel cost

Travel cost is calculated by adding the value of time spent at recreational sites to the expenditures incurred to access these sites, i.e. the cost of petrol and diesel, public transport and parking fee. The data on expenditures on petrol and diesel, public transport and parking fees for 2009 to 2012 are from the MENE survey. Similar to the imputation of number of visits above, these expenditures are imputed from 1988 to 2008 by taking an average value for 2009 to 2012 and then assuming it constant between 1988 and 2008. The estimation of value of time spent at recreational time is discussed below.

Value of visit time

To estimate the value of time spent at recreational sites, the annual number of visits from 1988 to 2012 is multiplied by the time spent at recreational sites (duration) in each year. The data on time spent are from the MENE survey. This is then multiplied by the average wage rate – a proxy used for the cost of time spent at recreational sites. The value of time spent at recreational site is very sensitive to the wage rate as a marginal change in wage rate could have a significant impact on the overall value of the UK outdoor recreation. This poses a challenge as to what wage rate to use to value the time spent at recreational sites. There are arguments on what wage rate to use for valuing the time spent at recreational sites, for example, Freeman III et al. (1993) suggests using an after-tax rate; whereas, the latest research by Fezzi et al (2013) suggests using ¾ of the hourly wage rate.

Since the wage rate could have a significant impact on the overall value of UK outdoor recreation, this chapter provides the lower and upper range values of outdoor recreation by using 1/3 and 3/4 of the hourly wage rate. The data for the average wage rate are taken from the ONS Annual Survey of Hours and Earnings.

The value of visiting time is then added to the private transport fuel costs, public transport expenditures and parking fees to obtain the yearly flow of benefits from the outdoor recreation provided by natural capital. Due to lack of data on capital inputs and other related costs, gross benefits of outdoor recreation are calculated and are assumed as resource rent. However, it is recognised that there are a number of costs related to outdoor recreation that should be deducted, for instance the roads and car parks which allow visits to take place.

ii. Pattern of expected resource rent and asset life

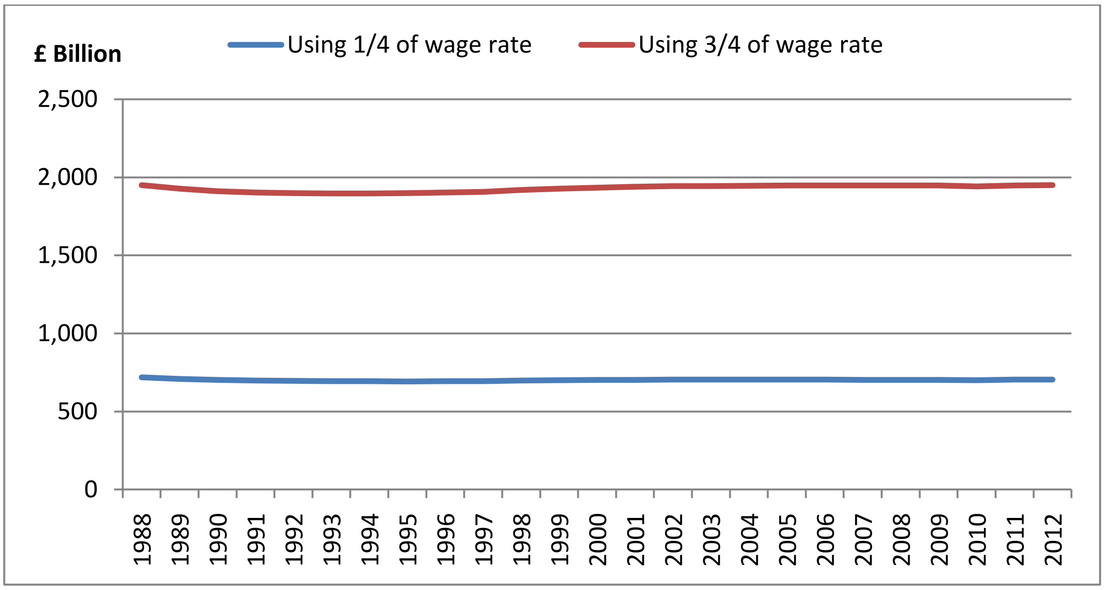
Since the asset life is assumed to be 50 years, due to lack of data the gross benefits are projected from 2013 to 2061 based on five year average of 2008 to 2012 (equation 2.2).

Results

Using equation 3.1, applying a declining discount rate and using 1/4 and 3/4 of the hourly wage rates, the flow values of UK outdoor recreation from 1988 to 2012 are capitalised for 50 years. The asset value of UK outdoor recreation from 1988 to 2012 is shown in figure 3.10 below. The figure shows the lower and upper bound values of UK outdoor recreation. Both of these approaches have some shortcomings. Using 3/4 of the hourly wage rate could overestimate the value because some of the visitors might be non-working people, such as retirees; whereas, using 1/4 of wage rate could underestimate the value of outdoor recreation because a number of people, such as doctors and lawyers, earn more than the average hourly wage rate. Furthermore, the latest research by Fezzi et al (2013) argues that commonly implemented assumptions of ¼ of the wage rate produces downward biased results and suggests using 3/4 of the hourly wage rate. Therefore, it is not unreasonable to assume that the value of UK outdoor recreation lies above the lower bound value.

Since this chapter excludes a number of ecosystem services from natural capital calculation due to data gaps (see chapter 2) and the purpose of this thesis is to estimate the total wealth of the UK, this chapter uses the upper bound value of outdoor recreation in the valuation of natural capital.

Figure 3.10: Asset values of UK outdoor recreation ecosystem services, 1988 to 2012, (2012 prices)



3.8) Net greenhouse gas sequestration - a regulating ecosystem service

The second category in renewable ecosystem services is the net greenhouse gas (GHG) sequestration in the UK. Net GHG sequestration refers to the net annual change in the stock of greenhouse gas (GHG) in the "Land Use, Land Use Change and Forestry" (LULUCF) sector. In essence, it shows how much GHG has been taken out of the atmosphere by terrestrial ecosystems in a particular year. GHG storage (i.e. carbon currently locked away in ecosystems in various forms) is not considered in the calculations. This chapter considers six GHG - carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons, per-fluorocarbons, and sulphur hexafluoride to value UK net GHG sequestration from 1988 to 2012.

Methodology

i. Resource rent

The non-monetary data on net GHG sequestration are from the Department for Energy and Climate Change (DECC) LULUCF publication. The data are available from 1990 to 2012. The data show negative net GHG sequestration between 1990 and 1997, which could be due to more GHG released from the terrestrial ecosystems into atmosphere than taken out of the atmosphere because of full capacity. Due to the negative net GHG sequestration between

1990 and 1997, this chapter calculates the asset value of UK net GHG sequestration from 1998 to 2012.

Due to a lack of data on all GHG sequestration, the data on cost of carbon are used to value all terrestrial physical net GHG sequestration. There are large variations in the estimates of the unit costs of climate change from carbon emissions (McLaughlin et al, 2014). For example, Tol (2008) has used $23 / tonnes and Stern (2006) has used a range from £68.2 per tonne to £201.2 per tonne. In order to be consistent with the national Accounts, market prices should be used to value net GHG Sequestration; however, the data on the market price of carbon are not available. In the UK, DECC publishes carbon prices as traded and non-traded because they both attract different prices. The EU Climate and Energy Package (December 2008) has introduced separate emissions reduction targets for the traded sector (those emissions which are covered by the EU Emission Trading System - EU ETS), and for the non-traded sector (those emissions not covered by the EU ETS). The presence of separate targets in the traded and non-traded sectors implies that emissions in the two sectors are essentially different commodities. Changes in emissions which occur in the traded sector are valued at the traded price of carbon, whereas changes in emissions in the non-traded sector are valued at the non-traded price of carbon. These traded and non-traded carbon prices are different in the short-term, but are projected to converge, becoming equal in 2030 and remaining so in further years. This is based on the assumption that there will be a fully functioning global carbon market by 2030[44]. Traded carbon prices can be considered as market prices but since non-traded carbon prices are not derived from the market, they are not market prices. However, they are a close proxy to market prices. Since net GHG sequestration is not traded in the market, this chapter uses non-traded market prices to value net GHG sequestration. The data for the cost of carbon are from the DECC. The data are available from 2009 to 2050. The price data from 1998 to 2008 are assumed constant at 2009 level. A central price estimates for non-traded price is used. For example, for 2012, £53 per tonnes is used for non-traded carbon to value net GHG sequestration.

The non-monetary net GHG sequestration is multiplied with the prices to obtain the gross benefits. Similar to outdoor recreation, due to data limitations on costs, gross benefits of

[44] Source: Department for Energy and Climate Change https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483278/Valuation_of_energy_use_and_greenhouse_gas_emissions_for_appraisal.pdf

net GHG sequestration are calculated and are assumed as resource rent for every year from 1998 to 2012.

ii. Pattern of expected resource rent and asset life

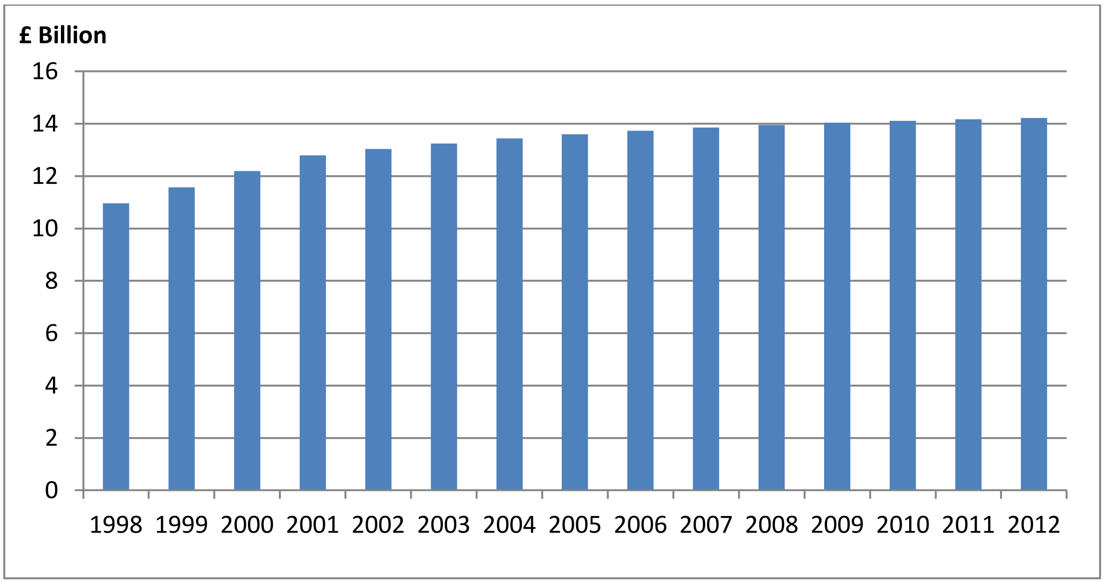
To estimate the pattern of expected resource rent (gross benefits), the data on future net GHG sequestration are assumed constant from 2013 based on a five year average of net GHG sequestration between 2008 and 2012 (equation 3.3). The data on prices for non-traded carbon are available until 2050 and beyond 2050 the data are assumed constant based on five years price average between 2046 and 2050 (equation 3.4).

The projected non-monetary net GHG sequestration is then multiplied with the actual and projected prices to obtain the gross benefits, which are assumed as the resource rents for every year from 2013 to 2061.

Results

Using equation 3.1 and applying a declining discount rate, the flow values of UK net GHG sequestration from 1998 to 2012 are capitalised for 50 years. The asset value of UK net GHG sequestration from 1988 to 2012 is shown in figure 3.11 below.

Figure 3.11: Asset value of UK Net GHG Sequestration, 1988 to 2012 - 2012 prices



4. Total asset value of UK natural capital

By applying the Net Present Value to the below components, the asset value of UK natural capital from 1988 to 2012 is given in figure 3.12 below.

- Sub-soil Assets
- Agricultural land
- Timber
- Fisheries
- Water abstraction
- Outdoor recreation
- Net greenhouse gas sequestration

The figure shows that the value of UK natural capital has increased from £2,020 billion in 1988 to £2,202 billion in 2012. This is mainly due to an increase in the value of non-renewable assets, which has increased from £30 billion in 1998 to £192 billion in 2012. The value of non-renewable assets was the highest in 2005 at £233 billion before falling to £192 billion in 2012. Between 1998 and 2012, the value of renewable assets has increased by £20 billion – from £1,991 billion to £2,011 billion. The figure shows renewable assets have a larger share of total natural capital. However, the share of renewable assets as total natural capital has decreased slightly from 98.5% to 91.3% between 1988 and 2012; whereas, the share of non-renewable assets has increased from 1.5% in 1988 to 10.4% in 2005 before falling to 8.7% in 2012. The increase in the share of non-renewable asset is due to high extraction of sub-soil assets combined with an increase in oil prices because of an increase in economic growth in nineties and early twenties. However, a fall in demand in sub-soil assets and oil prices because of the recent financial and economic crisis has reduced the share of non-renewable assets by around 15% between 2008 and 2012. On the other hand, though the share of renewable assets as total natural capital has fallen between 1988 and 2012, the value of these assets have remained pretty stable because of the outdoor recreation which accounts for almost 86% of all renewable assets.

Figure 3.12: Asset value of UK natural capital, 1988 to 2012 - 2012 prices

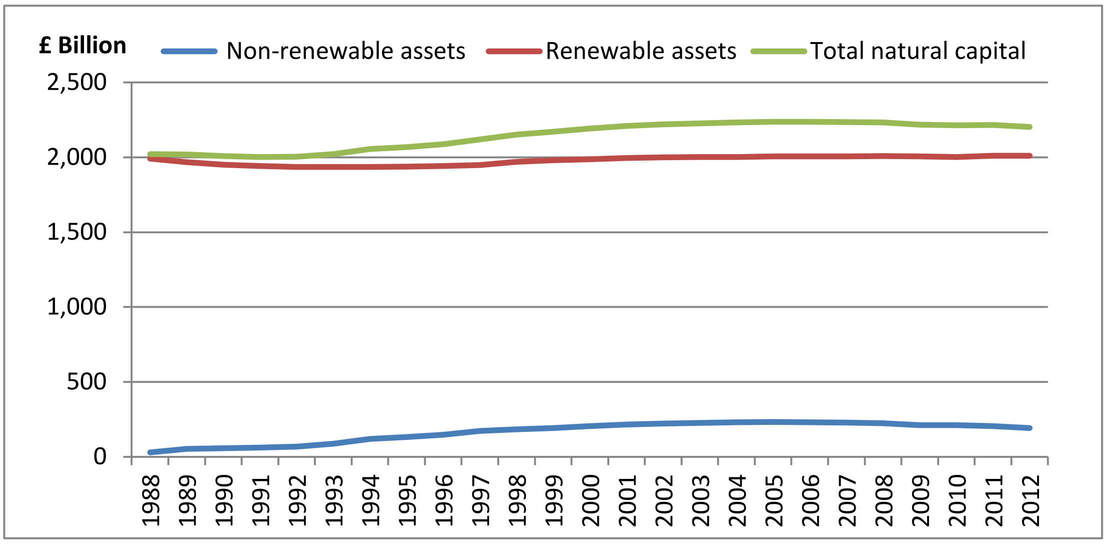
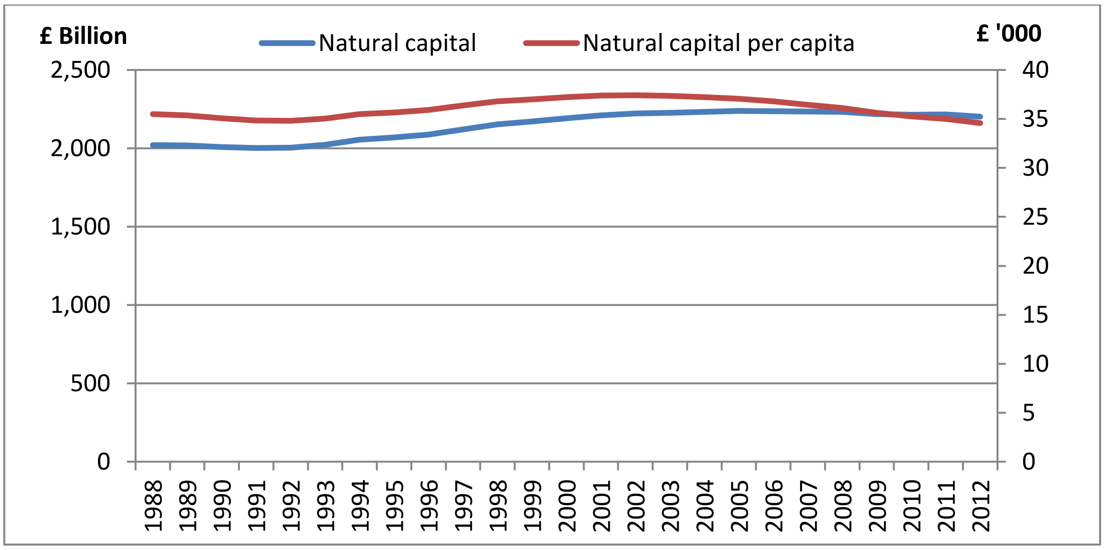


Figure 3.13 shows UK natural capital and per capita natural capital from 1988 to 2012. The value of average natural capital per capita between 1988 and 2012 is £33,378. Between 1988 and 2002, the asset value of UK natural capital has increased by 9.9%; however, natural capital per capita has increased by 5.4% only. This is because the UK population has increased by 4.3% during this period. On the other hand, between 2002 and 2012, the asset value of UK natural capital has decreased by 1%; whereas, natural capital per capita has decreased by 7.6% because of a 7.3% increase in the UK population between 2002 and 2012.

Figure 3.13: UK natural capital and per capita Natural capital, 1988 to 2012 - 2012 prices



5. Comparison with international studies

This section compares the UK natural capital results with other publications. As discussed in the earlier section, the World Bank (2011) and the Inclusive Wealth Report (2012) have published monetary estimates of UK natural capital in their respective publications. These publications focus different time periods, therefore, for comparison purposes, those time periods are selected for which the results are available in both of these studies. Table 3.5 provides a comparison of these monetary estimates with the estimates derived in this chapter. Since the World Bank and the IWR do not include ecosystem services in their calculations, table 3.5 shows the results derived in this chapter with and without the inclusion of ecosystem services.

The asset value of UK natural capital derived in this chapter, excluding the ecosystem services, is different to the values derived by the World Bank and the IWR. The only exception is the value of natural capital for 2005, which is close to the value estimated by the World Bank. Though this chapter uses the Net Present Value method as used by the World Bank, there are a number of differences in applying this methodology which are discussed in the above sections. For example, more robust and accurate data sources on quantity and prices, a 50 year asset life to calculate the resource rent and a declining discount rate etc. Due to all these differences the results obtained in this chapter are different to the results obtained by the World Bank. On the other hand, the differences in the results between the IWR and this chapter are due to the use of different methodologies. The IWR uses a different approach to estimate the prices because it has a wider scope in terms of well-being and does not restrict itself to consumption based prices as defined by the System of National Accounts.

Table 3.5: Comparison of World Bank and IWR natural capital estimates with the monetary estimates developed in this study[45]

	Year	World Bank (2011)	IWR (2012)	This chapter – without recreational and GHG sequestration services	This chapter – with recreational and GHG sequestration services
Total Natural capital, £billion	**1995**	285	123	171	2,069
	2000	319	107	246	2,192
	2005	272	92	278	2,238
	2012	-	-	239	2,203

[45] The World Bank and IWR values are given in USD prices and have been deflated using the US GDP implicit price deflator up to the estimate base year (2012). They are then exchanged into Pound Sterling using the 2012 average exchange rate taken from the Bank of England.

Chapter 4

Human Capital

1. Introduction

As discussed in chapter 1, to measure sustainable development, the notion of wealth must be truly comprehensive. This should not only include traditional capitals (manufactured and financial capital), but other non-traditional capital such as natural capital, human capital and social capital should also be included. Chapters 2 and 3 have discussed natural capital in detail and have provided a monetary valuation of UK natural capital and ecosystem services from 1988 to 2012. This chapter values the stock of UK human capital which is also relevant for discussions on how to measure sustainable development.

Economists have a long history of recognising that human capital is an important component of the wealth of nations (Petty, 1690; Smith, 1776; Farr, 1853; Engel, 1883; Shultz, 1961; Becker 1964 and Mincer 1974). Despite the wide use of the human capital concept, different people define human capital in different ways. For example, Shultz (1961) classifies *skills and knowledge* that people acquire as a form of human capital. Thurow (1970) defines human capital as an individual's productive *skills, talents and knowledge*[46]. Behrman and Taubman (1982) define human capital as "the stock of economically productive human capabilities." Laroche et al (1999) further extends the notion to include 'innate abilities'. Recently, the concept of human capital has been extended to incorporate non-market activities (Le et al, 2003), and a broader definition of human capital is "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2001). This is a broad definition that has many dimensions (knowledge, skills, competencies and health) and can be acquired in various ways, including at home, at school, at work, and so on.

The paper starts with a brief discussion on the purpose of measuring human capital. Section 3 then discusses the approaches to measuring human capital. Section 4 discusses the

[46] See Stroombergen et al (2002) for detailed discussion on the various definitions of human capital

approach that is used in this chapter to value the stock of UK human capital. Section 5 provides a detailed review of lifetime income approach. Section 6 provides a brief overview of UK human Capital calculated by other studies and discusses the additional contribution made in this paper to extend the scope of UK human capital. Section 7 discusses the methodology employed in this paper to valuing UK human capital for 25 years (from 1988 to 2012). Sections 8 and 9 discuss the results and provide comparisons with other studies. Section 10 provides an empirical analysis of the results and the final section concludes this chapter.

2. Why measure human capital?

The most important and most common use of human capital measure is in understanding economic growth[47]. Most researchers such as Denison (1967), Barro (1991), Gundlach (1995), and Hanushek and Kimko (2000) have recognised the importance of human skills in raising GDP per capita. A number of growth theory economists such as Romer (1986, 1989), Lucas (1988), and Aghion and Howitt (1998) have argued that human capital rather than physical capital has a decisive role in determining a country's economic prosperity.

One of the key findings from the World Bank report *The Changing Wealth of Nations* (2011) is that intangible capital - the unexplained capital that comprises human, social and the stock of technological changes - constitutes a large share of total wealth, an estimated 60-80 per cent, in most countries covered. To better understand the composition of this residual, it is important to disentangle the intangible capital into main components. Ferreira and Hamilton (2010) found that, by treating human capital as a function of years of schooling (adjusted by survival rates), human capital is the most important component of intangible capital for all countries and especially for high-income countries. In their most recent paper, Hamilton and Liu (2014) argue that since income is the return on wealth, the total wealth of any given country should be in the order of 20 times its Gross Domestic Product. However, the average observed ratio from the balance sheet accounts of the System of National Accounts (SNA) is a factor of 2.6 – 6.6, depending on whether commercial natural resource stocks are included in the balance sheet[48]. Hamilton and Liu

[47] The other two main areas where human capital is relevant are economics of education and employability. For a detailed discussion see (Stroombergen et al, 2002)
[48] See Hamilton and Liu (2014) and The Changing Wealth of Nations (World Bank, 2011)

(2014) concludes that the clear implication is that the SNA accounts are incomplete, with the most obvious omission being human capital.

There is also an ongoing debate on weak sustainability, which is based on the work by Solow (1974, 1986, and 1993) and Hartwick (1977, 1978). The debate on weak sustainability suggests that depleting natural capital can be compensated by increases in a country's other assets such as investing in human capital or in factories, for example, Hamilton and Atkinson (2006). The concept of weak sustainability attracts a lot of criticism and there are arguments for strong sustainability which assumes that human and manufactured capitals are complementary to natural capital. They are not interchangeable. However, it is widely believed that human and manufactured capitals are substitute for each other. This is discussed in chapter 5.

Due to its importance in relation to total wealth, there is a growing interest by economists and policy makers in not only understanding human capital but also how to measure this form of intangible capital.

3. Measuring human capital

Human capital is intangible, the stock of which is not directly observable. It can be measured either directly or indirectly. A detailed discussion of these both methods is given below:

a) Indirect measure of human capital

The indirect way to measure human capital is to measure it as a residual, an approach adopted by the World Bank in its comprehensive wealth accounts (World Bank, 2006, 2011). In these calculations, human capital was part of intangible wealth (it implicitly includes measures of human and social capital), which was measured as a residual - the difference between total wealth[49] and produced, natural capital and net foreign assets. A similar indirect approach to measuring human capital is also applied by Statistics Norway (Liu and Greaker, 2009).

However, an indirect measure of human capital has some shortcomings. As a residual, intangible capital includes other assets which, for lack of data, could not be accounted for

[49] Calculated as present value of future consumption - see chapter 5 for a detailed discussion

in the wealth estimates. Furthermore, the intangible capital residual also includes any errors and omissions in the estimation of produced and natural capital (for example fisheries, water and marketed ecosystem services). Therefore, an indirect approach does not provide a true picture of how human capital has changed in any year or evolved over time.

b) Direct measure of human capital

There are generally three approaches to measuring human capital in a direct way that is documented in the literature. The three approaches are cost based approach, income based approach and the educational stock based approach (Le et al., 2003; Liu, 2011).

The educational stock based approach

The educational stock based approach, common in the economics literature, measures human capital through various types of characteristics in the population, such as adult literacy rates, school enrolment ratios and average years of schooling of the working population. (e.g. Barro and Lee, (2001, 2010), Ederer, et al (2007), and Wöbmann (2003)). This approach is also known as an indicator approach (Liu and Greaker, 2009).

Limitations

- This approach measures human capital in non-monetary terms and due to lack of common unit of measurement does not provide an aggregate measure. This creates two problems: first, it does not allow a cross-country and over time comparison of the value of human capital and secondly it does not allow comparing the stock of human capital with other types of capital such as economic and natural capital. There are recent developments in human capital theory (see Bowles et al, 2001) that suggest that meaningful monetary aggregate measures are feasible. However, Stoorbergen et al. (2002) suggests that due to market related characteristics and a broader definition of human capital, it will be a problem of attaching a price to individual characteristics and non-market related skills and attributes.

- It is argued that poor proxies are used to measure the stock of human capital due to their over reliance on data availability instead of empirical growth studies[50]. For example, adult literacy rates misses out most of the educational investment made on

[50] See Wöbmann (2003) for a detailed discussion.

top of the acquisition of basic literacy and school enrolment ratios are flow variables and may not accurately represent changes in the human capital stock, especially during periods of rapid educational and demographic transition.

- The most common used proxy, educational attainment and average years of schooling[51], has also been criticised due to two reasons: First, it implicitly gives the same weight to any year of schooling acquired by a person. There is no allowance for diminishing returns to education which disregards the findings of a whole micro-econometric literature on wage differentials which shows that there are decreasing returns to schooling (Wöbmann 2003, Psacharopoulos 1994). Secondly, instead of giving different weight to the quality of education, it gives the same weight to a year of schooling in any schooling system at any time despite of different education system quality of teaching, and educational infrastructure.

The cost based approach

The cost based approach has its origins in the cost of production method of Engel (1883), who estimated human capital based on child rearing cost to their parents[52] (Le et al., 2003). More recently, Machlup (1962) and Schultz (1961) augmented Engel's approach to create what is now commonly known as cost based approach. This approach measures human capital by looking at the stream of past investments, including investments coming from the individual, family, employer and governments (Shultz, 1961; Kendrick, 1976; Eisner, 1985; Liu, 2011). This approach relies on information on all the costs that are incurred when producing the human capital. Since the cost based approach focuses on past investment, it is also known as "backward looking" approach (Le, et al., 2003). This approach provides a measure of the current flow of resources invested in the education and other human capital related sectors, which can be very useful for cost benefit analysis. The cost based approach estimates human capital based on the assumption that the depreciated value of the dollar amount spent on those items defined as investment in human capital is equal to the stock of human capital. Kendrick (1976) and Eisner (1985) have provided seminal examples of this approach. Recently, the World Bank (2006, 2011) has used cost based approach to include human capital in its genuine savings calculations.

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[51] For a detailed discussion on the methods used to measure educational attainment in the form of average years of schooling see (Wöbmann (2003).

[52] Engel computed the cost of rearing a person as the total cost required to raise him/her from conception to the age of 25, since he considered a person to be fully produced by the age of 26.

Limitations

There are several limitations with this method:

- This approach does not provide an accurate cross-sectional comparison because human capital is basically determined by the demand for it, not by the cost of production (Le, et al., 2003). Therefore, this approach could overestimate the human capital of a less able and less healthy child while underestimating well-endowed children who incur fewer rearing and educational expenses.

- This approach arbitrarily allocates spending between investment and consumption (Liu, 2011). Some of the educational expenditures go into paying for food and clothes, which are not investment but consumption, and therefore it is hard, if not impossible, to separate the expenditures from the investment made in human capital.

- Like physical capital, human capital depreciates over time due to long term unemployment, inability to keep up with technological innovations, illness or organisational change. The two main methods used to calculate depreciation in the literature are straight-line method and double declining balance method. In the cost based approach, both of these methods set the rate of depreciation arbitrarily (Liu, 2009).

- The appreciation that is evident in human capital utilisation especially in early years is usually ignored, despite empirical evidence showing that human capital appreciates at younger ages (Mincer, 1974; Graham and Webb 1979).

- This approach ignores the long time lag between the current outlays of educational inputs and the emergence of human capital embodied in their graduates – a large share of educational investment goes to individuals who are still enrolled in school and whose human capital is yet to be realised.

The income based approach

The income approach is to measure human capital by looking at the stream of future earnings that human capital investment generates over the lifetime of a person (Farr 1853;

Weisbrod, 1961; Graham and Webb, 1979; Jorgenson and Fraumeni, 1989, 1992). In contrast with the cost based approach, which focuses on input side, the income based approach measures the stock of human capital by looking at the output side. This approach is also known as "forward looking" or prospective because it focuses on the total discounted values of all the future income streams regarded as returns to investments into human capital, which all individuals expect to earn throughout their lifetime (Le, et al. 2003). By focusing on the earning power of each person, the income based approach values human capital at market prices, under the assumption that labour market to a certain extent accounts for the many factors including ability, professional qualifications and technological structures of the economy. Since this approach values the stock of human capital at market prices using lifetime earnings, this approach is consistent with the System of National Accounts.

Limitations

The income based approach is not free from drawbacks. There are a few limitations with this method:

i. This method is quite sensitive not only to discount rate, but also to retirement age (in some countries compulsory retirement age has been abolished, for example, The UK and New Zealand) and future real income growth. This method also relies upon accurate data on earnings, life tables and employment rate, which are not widely available for developing countries.

ii. The valuation method could imply that differences in wages reflect differences in productivity. However, wages may vary for other reasons; for example, trade union may be able to command a premium wage for their members. Hence, the wage rate used as a proxy for earning power is not always equal to the marginal value of a particular type of human capital. This could lead to bias estimates of human capital.

iii. Another issue with the income based approach is the treatment of maintenance cost. On the one hand, some authors, such as Eisner (1988) have argued that human capital should be measured net of maintenance cost just like the physical capital. On the other hand, it is argued that maintenance cost should not be deducted because net productivity is a more relevant measure of a person's value to others (Graham and Webb, 1979). Even those who have argued for including maintenance cost have found it challenging to measure human capital net of maintenance cost. For example, Weisbrod (1961) attempted to account for maintenance cost, but found it difficult because of the challenges involved in identifying what types of expenditures should be classified as maintenance.

4. Approach used in this thesis to value UK human capital

Both direct and indirect methods have their advantages and disadvantages. The three approaches – indirect, cost based and income based – refer to monetary measures. One common advantage of these measures is that they combine many different aspects that contribute to human capital in a single monetary unit. For example, estimates based on the income-based approach allow for comparing the importance of demography (age, gender), educational factors (enrolment rates, the number of people with different level of educational attainment) and labour market factors (employment probabilities and earning by educational characteristics). Similarly, the cost-based approach allows for comparing the relative importance of the expenditures incurred by different sectors (public, household, firms) and non-market inputs (for example, time devoted to educational related activities by students, parents). However, these single measures may also hide some of the important information. For example, monetary values of human capital may increase when underlying volume of human capital population is falling.

The indicator or educational stock based approach, though appealing for its simplicity, cannot on its own adequately measure the various dimensions of skills and competence (OECD, 2001), and sometimes poorly specifies the relationship between education and the stock of human capital (Wobmann, 2003). Therefore, only a wider definition can provide useful clues about where investment is most needed and where the benefits go. Furthermore, applying a single indicator as a proxy for human capital is not consistent with the System of National Accounts and wealth accounts. In the SNA, produced capital is accounted using the perpetual inventory method, in which the stock of capital is measured as the sum of depreciated flows of investment, and commercial natural resources are valued as the present value of future resource rents. Both methods are consistent with standard economic theory (Hamilton and Liu, 2014). Therefore, to serve the purpose of directly accounting for human capital within the wealth accounting framework, a monetary measure based on sound economic theory is needed. Given the role of the System of

National Accounts in official statistics, monetary approaches, in particular the cost based and the income based approaches, are most likely to be used to construct human capital measures consistent with the accounting framework.

The cost based approach is considered to be relatively easy to apply because of the ready availability of data on both public and private expenditures in formal education as human capital investments. However, the main problem with this approach is that it focuses on inputs instead of outputs, which explicitly assumes that human capital is basically determined by cost of production, not by the demand of it. Furthermore, this method not only needs to assume an arbitrary rate of deprecation, but also arbitrarily allocate educational expenditures between consumption and investment.

The lifetime income approach leads to an accounting system that includes values, volumes, and prices as basic elements. It is more consistent with the System of National Accounts. This approach brings together, through a consistent accounting structure, a broad range of factors that shape the stock of human capital of the population living in a country – total population, age, gender, expected life-span to reflect health conditions, educational attainment, labour market experiences in terms of both their employment probabilities and the earning they gain. This method also does not need to assume an arbitrary rate of depreciation because it uses life time income approach where deprecation is implicitly accounted for in the model due to the concave parabola shape of the lifetime income as income first rises then steadily declines well into zero at retirement (Le et al., (2003). The parabola shape indicates that human capital appreciates at younger ages followed by straight-line depreciation. In this way the income-based framework implicitly allows for depreciation so there is no need to assume an arbitrary depreciation rate.

Another advantage of using lifetime income approach is that changes in the stock of human capital during each accounting period can be described in terms of investment. For example, how much is spent of formal and informal education, or how much human capital has depreciated due to death and net emigration.

Since lifetime income approach provides the most reliable results, if necessary data are available, it has been used in this chapter for valuing the stock of UK human capital from 1988 to 2012.

5. Lifetime income approach – a review

The lifetime income based approach, advocated by Jorgenson and Fraumeni (1992), has its origins since Petty (1960) estimated human capital stock in England and Wales by capitalising the wage bill at a 5% interest rate for the whole of the work force (Le, et al., 2003). However, the very first scientific work to measure human capital was undertaken by Farr (1853), who calculated the monetary value of human capital by estimating the capitalised value of earning capacity by calculating the present value of an individual's future earnings net of personal living expenses by using a discount rate of 5%. The underlying assumption of Farr's approach is to value the human capital embodied in individuals as the total income that could be generated in the labour market over their lifetime after adjusting for survival rates.

Farr's approach is considered a benchmark in measuring the stock of human capital using income based method. A number of early empirical studies (for example, Fisher, 1908; and Woods and Metzger, 1927) have estimated the value of human capital by following Farr's approach. For example, Dublin and Lotka (1930) followed Farr's method but allowed for unemployment, rather than assuming full employment (Le et al., 2003). Weisbrod (1961) used a modified version of Dublin and Lotka's (1930) approach to estimate human capital by using cross-sectional data for earnings, employment rates and survival rates. For example, Weisbrod estimated the present value of expected income of a 25 year old individual in 20 year time as the current income of a 45 (25 +20) years old person, adjusted for survival probabilities and discount rate. The retirement age was set at 75, at which earnings were zero. As discussed earlier, Weisbrod (1961) attempted to account for maintenance cost, but found it difficult because of the challenges involved in identifying what types of expenditures should be classified as maintenance. Hence, Weisbrod (1961) did not deduct the maintenance cost.

Graham and Webb (1979) adjusted Weisbrod's (1961) model to incorporate economic growth and education in the model. For example, they estimated the present value of expected income of a 25 year old individual with a Degree level qualification in 20 year time as the current income of a 45 (25 +20) years old person with the same educational qualification, adjusted for survival probabilities and discount rate. The present value of expected income of a 35 year old in 40 years was assumed to be zero because at retirement age earnings were considered as zero.

One of the most comprehensive studies using the income based approach to measuring human capital was presented by Jorgenson and Fraumeni (1989, 1992) by augmenting Graham and Webb's (1979) method. They suggested a model that included both market and non-market economic activities. They also simplified the procedure for discounting future income streams by showing that the present value of lifetime labour income for an individual of a given age is just their current labour income plus the present value of their lifetime income in the next period weighted by employment and survival probabilities (Le et al., 2003). For example, for 74 years old individual, the present value of his lifetime labour income is just his current labour income (retirement age is assumed to be 75). The lifetime labour income of a 35 year old individual is equal to the value of his current income plus the lifetime labour income of 36 years old, adjusted for survival rate and discount rate.

A variation on the income based approach is presented by Mulligan and Sala-i-Martin (1997), who calculated an index measure of human capital by dividing the total labour income per capita divided with the wage of the uneducated. However, this model has been criticised because it assumes that zero-schooling workers are identical always and everywhere and those workers with different level of schooling are perfectly substitutes (Wachtel, 1997). Furthermore, this method neglects the contribution to human capital by factors other than formal schooling, such as informal schooling, on the job training and health.

Mulligan and Sala-i-Martin (1997) method have been modified and applied in a number of empirical studies. For example, Jeong (2002) modified Mulligan and Sala-i-Martin's model by using industrial labourer, as classified by the International Labour Office, rather than the workers with on schooling to measure the human capital across 45 countries. Laroche and Merette (2000) accounted for working experience in addition to formal schooling to estimate Canada's human capital from 1976 to 1996.

6. Valuing UK Human capital, 1988 – 2012

A few studies have applied lifetime income approach to value human capital; however, most of these studies focused on countries other than the UK (for example, Jorgenson and Fraumeni, 1989, 1992a, 1992b; Ahlroth et al., 1997, Greaker and Liu, 2009; Wei, 2004 and 2007; Le et al., 2006). The first comprehensive project to estimate the monetary value of human capital for 16 countries[53] using lifetime income approach was undertaken by the OECD (Liu, 2011) based on Jorgenson and Fraumeni (1989, 1992) methodology. Due to data limitations, OECD estimated human capital stock for the UK only for the years 1997 – 2001 and 2003 – 2007. Applying the OECD methodology, the UK Office for National Statistics has estimated the stock of human capital from 2001 – 2009 and more recently from 2004 – 2013 by using data from the Labour Force Survey and Annual Population Survey respectively. Using Rodriguez-Clare (1997) method that builds on the earlier work of Mincer[54], the Inclusive Wealth Report (2012) calculates human capital for 20 countries, including UK, from 1990 – 2008. The report estimates human capital by measuring the population's educational attainment and the additional compensation over time of this training, which is assumed to be equivalent to interest rate (8.5 per cent in this case). The IWR calculates the shadow price of human capital by dividing the total real wage bill by the stock of human capital. McLaughlin et al. (2014) calculates UK human capital from 1760 to 2000 as part of historical wealth accounts by following Jorgenson and Fraumeni (1989) and Le et al. (2006) methodology. The authors did not consider educational attainment and did not make any adjustments for mortality and earnings growth. Recently, Hamilton and Liu (2014) uses the OCED (Liu, 2011) estimates for human capital for 13 selected countries (including UK) for 2005 only and makes some adjustments to combine them with the World Bank's comprehensive wealth accounting. For the UK, the authors found that in 2005 UK human capital per capita was around £292,400.

Since the purpose of this thesis is to develop human capital estimates to measure sustainable development within the framework of comprehensive wealth while being consistent with the System of National Accounts, the Hamilton and Liu (2014) approach, which is based on Jorgenson and Fraumeni (1989, 1992), is used in this chapter to estimate the stock of UK human capital. This chapter takes Hamilton and Liu (2014) work forward and extends the scope of measuring UK human capital for 25 years - from 1988 to 2012. It also provides the results of UK human capital by age, gender and educational level for this time period. In addition, a number of following adjustments are made:

[53] Australia, Canada, Denmark, France, Israel, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Poland, Romania, Spain , the United Kingdom, and the United States.

[54] Mincer (1974) ran a regression of worker log wages on worker years of schooling and experience. Rodriguez-Clare (1997) combined this with data on schooling attainment and estimates of school quality to produce measures of human capital for 98 countries.

(i) The scope of population

OECE (Liu, 2011), and Hamilton and Liu (2014) distinguish between three stages in the life cycle of an individual of working age (15 – 64):

1. Study and work (15-40)
2. Work only (41-64)
3. Retirement (65 and above)

This thesis distinguishes human capital between three stages in the life cycle of an individual (from birth until retirement instead of his/her working life only):

1. School but no-work (aged between 0 and 15)
2. School and work (aged between 16 and 64)
3. Retirement (65 and above)

The lifetime income for the first and the third group is set to be zero. This is because it is assumed that individual in the group aged 0-15 are not available to join the labour market. It is recognised that there is potential human capital embodied in these individuals, but to be consistent with other capitals - manufactured and natural - which are calculated based on System of National Accounts, individuals who are not part or available to join the labour market are excluded from the calculations. For the third group, though there is currently no compulsory retirement age in the UK, this research sets a retirement age of 65 based on the assumptions that most individuals who were working from 1988 to 2012 would choose to retire at age 65[55] and withdraw fully from the labour market. However, it is recognised that people in this class make important contribution to the economy through non-market activities, which are worth billions of pounds.

For the second group (school and work), OECD (2011), and Hamilton and Liu (2014) divide it into 'study and work' (15 – 40) and 'work only' (41 – 64). The cut-off date at age 40 for 'study and work' was due to the fact that information on the number of students enrolled in different educational levels from the OECD database was available until age 40. However, they acknowledged that many countries, including UK, have witnessed in recent years a quite significant increase in the number of adults (over 40 years old) attending colleges for

[55] Before the abolition of compulsory retirement age in 2011, the retirement age in the UK was 65 and 60 years respectively for men and women.

further education. Therefore, this chapter assumes that all individuals in the UK until the age of 64 can enrol in further education to enhance their skills.

Most of the researchers have valued human capital of those people who are employed in the labour market. The human capital of unemployed people has been valued at zero because they are not participating in any market activity. However, by definition, unemployed people are those individual who are looking for jobs and are available to join the labour market. They have skills embodied in them, which has an economic value. Therefore, they should be part of the human capital calculations. This approach is consistent with the System of National Accounts, which states that any asset which could be used for economic production has an economic value. Furthermore, OECD guidelines on physical capital states that only those assets should be measured that are present at production sites and capable of being used in production or that are available for renting by their owners to producers (OECD, 2001). Therefore, this research focuses on full human capital – individual who are employed (employees and self-employed) and unemployed – of UK working-age population (aged 16 – 64). However, this research also provides separate results for employed human capital – individuals who are in work – for analysis purposes. The data on number of employees, self-employed and unemployed in the UK from 1988 to 2012 are from the Labour Force Survey (LFS). The data are computed for every gender, age and educational level group (see below).

This chapter also estimates human capital per capita as calculated by Hamilton and Liu (2014), which is different to OECD (Liu, 2011) approach. Human capital per capita is defined as total human capital of the whole population divided by the corresponding whole population (donated as HCP_{real}). It could also be approximated as (Hamilton and Liu, 2014) either human capital of working age population divided by the corresponding working age population (denoted as $HCP_{working}$) or by the whole population (donated as HCP_{whole}). Most of the empirical work, including OCED (2011), calculates human capital per capita as $HCP_{working}$. However, Hamilton and Liu (2014) uses HCP_{whole} to calculate human capital per capita because they argue that this measure does not overestimate human capital per capita and using $HCP_{working}$ human capital per capita could be overestimated or underestimated depending on a country's demographic structure. If the population of elderly people (65 and above) is very small, then $HCP_{working}$ could be less than HCP_{real} because in HCP_{real} the lifetime income of young people (aged 0-14) is also included and their lifetime income will be larger than lifetime income of working people (aged 15 – 64).

This is due to the fact younger people have longer remaining working years and thus more lifetime incomes than elder counterparts. However, if the elderly population is large enough, then $HCP_{working}$ could be greater than HCP_{real}. In the UK, the population of aged 65 and over was 11.1 million (17.4 per cent of the UK population) in Mid-2013[56]. This is a large population which could overestimate human capital per capita by using $HCP_{working}$.

This chapter considers the whole population while estimating wealth per capita (see chapter 5) and therefore human capital per capita is also calculated on the same basis. The above discussion shows that $HCP_{working}$ would provide higher estimates for UK human capital per capita; whereas, HCP_{whole} would not overestimate it. Therefore, similar to Hamilton and Liu (2014), this chapter also calculates UK human capital per capita as HCP_{whole} to avoid overestimation. The data used in this chapter for UK population from 1988 to 2012 are from the Office for National Statistics.

(ii) Annual labour income growth rate

OECD (2011) uses 2.14 per cent annual real income growth rate for the UK in estimating the stock of human capital for OECD countries. This is based on historical data and short and medium term projections are based on assumptions about the growth of potential output in UK. The Office for Budget Responsibility forecasts that the average earnings growth in 2015 is expected to be 2.5 percent. This is in line with the UK long term trend growth, which is estimated to be between 2.5 percent and 2.75 percent (HM Treasury, 2006). Therefore, this research uses 2.5 percent as the annual growth rate of labour income.

(iii) The choice of discount rates

There is no standard discount rate that has been used to value human capital. The OCED (Liu, 2011), and Hamilton and Liu (2014) use a uniform discount rate of 4.58 per cent for all countries to discount future earnings. This discount rate was originally used by Jorgenson and Fraumeni (1992) to estimate the US human capital. A number of studies that have applied the lifetime income approach to measuring human capital have found that the estimated stock are very sensitive to the choice of these rates (for example, Wei, 2004; Liu and Greaker, 2009; Liu, 2011; World Bank, 2011). The discount rates used by these studies vary from as low as 3.5 per cent (Ervik et al. 2003; Liu and Greaker, 2009) to as high as 8.5 per cent (Arrow et al. 2012).

[56] Source: Office for National Statistics

Chapter 2 of this thesis provides a detailed discussion on the issues that arise in selecting a discount rate. Based on the discussion in chapter 2 and to be consistent with the discount rate selected for measuring UK natural capital (chapter 3), a declining discount rate should be used to value UK human capital. However, it is very challenging to apply a declining discount rate to human capital model that calculates the lifetime income of an individual (the model is discussed in the next section). Therefore, this paper uses a uniform discount rate of 3.5% as set out in the HMT Treasury Green Book (2003). The results are not much different to using a declining discount rate, which uses 3.5% rate for the first 30 years and then 3% from year 31 to year 75. A sensitivity analysis is provided in section 7 using different discount rates.

7. Methodology

This section discusses the methodology that is employed to value the stock of UK human capital from 1988 to 2012 by using the lifetime income approach. The implementation of lifetime income approach usually requires three steps:

Step 1

The first step is to construct a database containing the economic value of labour market activities for various categories of people. The database contains information on the number of people, their earnings (when employed), and probability to gain higher qualification, employment rates, and survival rates. All these data should, ideally, be cross-classified by gender, age, and the highest level of educational attainment achieved. However, in practice, most data on survival rates do not distinguish between different categories of educational attainment (i.e. survival rates differ only according to the age and gender of each person).

The main data set constructed for calculating the stock value of UK human capital is from the Labour Force Survey (LFS). The LFS is the largest regular social survey in the United Kingdom. The Office for National Statistics conducts the survey in Great Britain. The Central Survey Unit of the Northern Ireland Statistics and Research Agency conducts the survey in Northern Ireland. The designs of both the Great Britain and Northern Ireland surveys are similar.

The LFS is a survey of households living at private addresses in the UK. Its purpose is to provide information on the UK labour market which can then be used to develop, manage, evaluate and report on labour market policies. The first LFS in the UK was conducted in 1973. The survey was carried out every two years from 1973 to 1983 in the spring quarter and was used increasingly by UK Government Departments to obtain information which could assist in the framing and monitoring of social and economic policy. Between 1984 and 1991 the survey was carried out annually covering over 50,000 households across the UK. In 1992, quarterly LFS was launched in Great Britain and in 1994 in Northern Ireland. The sample was increased to cover over 63,000 households every quarter enabling quarterly publication of LFS estimates.

This research uses the LFS annual data from 1988 to 1991 and quarterly data from 1992 to 2012 to construct the main database for calculating the stock of UK human capital. The quarterly data for each year is added up to obtain the annual data for the years 1992 to 2012. This is further discussed below.

Educational attainment

The data on the number of people by the highest education attainment completed from 1988 to 2012 are also from the LFS. For this research, the educational qualifications reported in the LFS are consolidated into six following categories:

- Degree or equivalent
- Higher education
- GCE A - level or equivalent
- GCSE grade A* - C or equivalent
- Other qualifications (includes missing qualifications)
- No qualification

Gaining higher qualifications

Using the longitudinal dimension of the LFS, this research estimates the annual probability of gaining higher educational attainment for every gender, age and educational level group.

Annual earnings

Annual earnings for employees by gender, age groups and educational attainment from 1988 to 2012 are calculated using the gross weekly earnings data from the Labour Force Survey. It is calculated separately for men and women of each age group. The data on earnings are only available from 1993. For earlier years, earnings are imputed based on wage regression model on a set of characteristics in 1993 to obtain parameters that are used to predict earnings from 1988 to 1992. To calculate the earnings from 1993 to 2012, as a first step, an average of gross weekly earnings[57] by gender, age and educational attainment is calculated. A wage regression model is used to smooth the age-profile of the average earnings of older workers because there are only a few observations for this age group and using the average of observed value could result in imprecise and volatile estimates average earnings[58]. A log of gross weekly earnings is modelled as a function of gender, age (first and second order), educational attainment and occupation[59]. An exponent of the fitted value is calculated and multiplied by 52 to derive annual gross earnings. It is assumed that on average, weekly gross earnings do not change over the year. The annual gross earnings are then used to compute the average annual gross earnings by gender, age and educational level. The calculated average annual gross earnings are multiplied with the number of employees to estimate the value of human capital embodied in people who are in paid employment.

Since data on gross weekly earnings are only available for people who are in paid employment, proxies are used to estimate the gross weekly earning for self-employed and unemployed people. For these groups, earnings are imputed by using average annual gross earnings of individuals who are in paid employment and who share the same characteristics (gender, age and educational level) with self-employed and unemployed as a proxy for annual earnings. This is based on the assumption that at a given age, gender and educational qualifications, self-employed and unemployed would have the same earnings as employed people if they were employed. There are some advantages and disadvantages of using this approach. One of the advantages is to get around the issue of whether the income of self-employed should be categorised as labour or capital income because it is not possible to distinguish between returns to skills and returns to physical capital. The

[57] Earnings from both primary and secondary jobs are used.
[58] The fit of this model is 0.4885 for 2012 data.
[59] Occupation is included in the model because it is a strong predictor of earnings and the profile of occupations is likely to differ across age groups.

disadvantages are that this approach could overestimate the value of human capital of the unemployed people due to two reasons. First, the unemployed may differ from employed people in terms of characteristics other than gender, age and educational qualifications that are related to productivity. Secondly, unemployed could have lower human capital due to scarring effect of unemployment, for example, through skills depreciation. Nevertheless, this approach provides a reasonable estimate of the human capital embodied in unemployed people.

Employment rate

Data on employment rate and labour force participation by gender and educational level from 1988 to 2012 are also from the LFS. Employment rates are calculated as the ratio of the number of employed persons to that of total population in each group classified by gender, age and educational attainment. Labour force participation (to calculate full human capital) is calculated as the ratio of the number of employed and unemployed persons to that of total population in each group classified by gender, age and educational attainment.

Survival rates

The survival rate is the conditional probability that a person who is alive in year *t* will also be living in year *t+1*. Information on survival rates, by gender and individual year of age, from 1988 to 2012, is derived from ONS' interim life tables.

Step 2

The second step is to construct an algorithm for calculating the lifetime income for a representative individual in each category in the database. The key assumption applied here is that an individual of a given age, gender and educational level will have in year *t+1* the same labour income (adjusted by the real income growth rate expected in the future and by the survival rate) as a person who, in year *t*, is one year older but has otherwise the same characteristics (for example, gender and educational level).

As discussed above, this paper distinguishes human capital between three stages in the life cycle of an individual:

- School but no-work (aged between 0 and 15) – the lifetime labour income for this group is set to be zero because they are not available to join the labour market

- Retirement (above 64) – the lifetime labour income for this this group is also set to be zero because, by assumption, these people will not receive earnings after withdrawing from the labour market.

- School and work (aged between 16 and 64) – the lifetime labour income (LIN) for this group is estimated by using equation A given below:

Equation A

$$LIN_{age}^{edu} = EMR_{age}^{edu} \quad AIN_{age}^{edu} + \sum_{i=1}^{6} \Pr(EDU_{age+1} = i \mid EDU_{age}) \, SUR_{age+1} LIN_{age+1}^{edu} \frac{(1+r)}{(1+\delta)},$$

where:

LIN_{age}^{edu} = present value of lifetime labour income of an individual with educational attainment level of *edu* at the age of *age*

EMR_{age}^{edu} = the employment rate of this individual with educational level of *edu* at the age of *age*

AIN_{age}^{edu} = the current annual labour income of this individual with educational level of *edu* at the age of *age*

$\Pr(EDU_{age+1}$= i $|EDU_{age})$ = probability of having the highest qualification *i* at age *age+1 (*given the qualification held at previous year)

SUR_{age+1} = the probability of surviving one more year given that this individual is at the age of *age*

r = annual growth rate of labour income (in real terms)

δ = annual discount rate

This model assumes that:

- Returns to skills (qualification and experience) are stable over time.

- Individuals can only move to a higher educational level than the one they have already completed.

- No further enrolment is allowed for people having already achieved the highest educational level.

Equation A states that during the "school and work" stage, a representative individual in the next year can either continue his/her work, holding the same educational level as before, or gain higher qualification to improve his/her educational attainment level to receive higher income with the probability of $\Pr\ (EDU_{age+1}$= i $|EDU_{age})$.

The empirical implementation of equation A is similar to the methodology employed by Jorgenson and Fraumeni (1989, 1992). This is based on backward recursion, which means that the lifetime labour income of a person aged 64 – one year before retirement – is simply his/her current labour income (the first term in equation A) because his/her lifetime income in at 65 is zero by construction. Similarly, the lifetime labour income of a person aged 63 is equal to his current labour income plus the present value of the life time income of a person aged 64, or the lifetime labour income of a 35 year old individual is equal to the value of his current income plus the lifetime labour income of 36 years old, adjusted for survival rate and discount rate, and so forth.

Step 3

The third step is to apply the measures of lifetime income per capita estimated through equation A to all individuals in each age, gender and educational category to compute the human capital stock for that category from 1988 to 2012. Summing up the stock of human capital across all categories in each year yields an estimate of the aggregate value of the human capital stock for that year. The total stock of UK human capital (HC) for each year from 1988 to 2012 is computed as:

Equation B

$$\text{HC} = \sum_{age} \sum_{edu} LIN_{age}^{edu} NUM_{age}^{edu} \ ,$$

where:

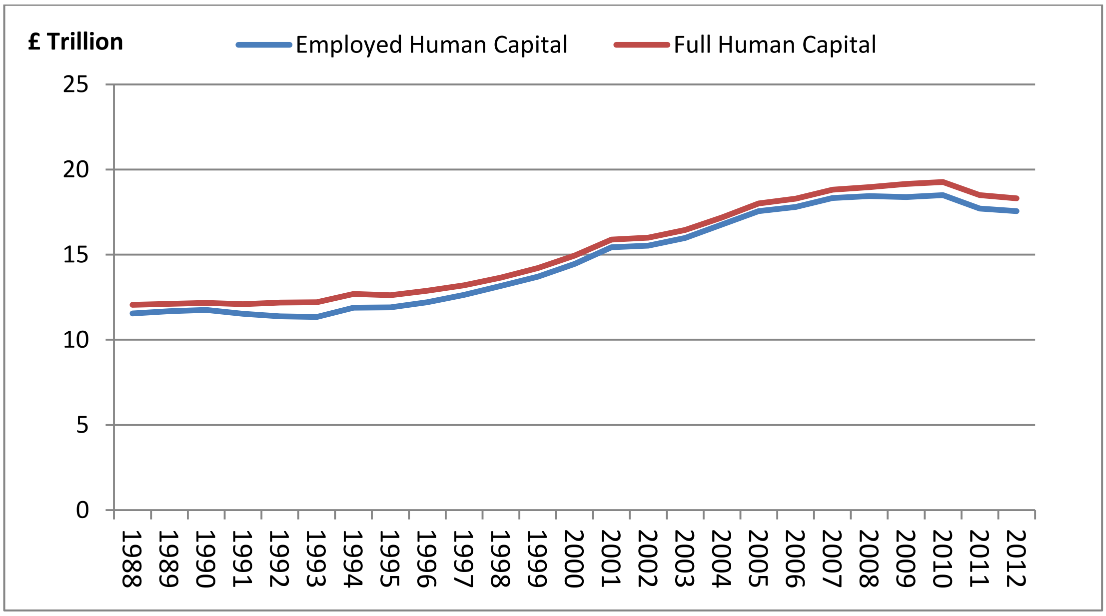
NUM_{age}^{edu} = number of persons in the corresponding age/educational category.

Equation A and B are applied separately to both men and women to estimate the stock of UK human capital by gender from 1988 to 2012. Human capital calculated in this chapter is in 2012 prices. All values from 1988 to 2011 are deflated using the annual Consumer Price Index data which are taken from the ONS.

8. Empirical results

This section provides the results of the UK human capital from 1988 to 2012. Using the equations A and B, applying a 3.5% discount rate as set out in the HM Treasury Green Book, and using income growth rate of 2.5 per cent, the values of UK full human capital stock for 1988 and 2012 are £12.1 trillion and £18.3 trillion respectively. As mentioned earlier, this research also provides separate results for employed human capital – individuals who are employed and self-employed – for analysis purposes (these are only shown in figure 4.1, the rest of the analysis focuses only on full human capital). The values of UK employed human capital stock for 1988 and 2012 are £11.5 trillion and £17.6 trillion respectively. The stock values of UK human capital from 1988 to 2012 are given in figure 4.1 below. An empirical analysis is provided in section 10.

Figure 4.1: UK human capital, 1988 to 2012 - 2012 prices



Sensitivity Analysis

Table 4.1 shows how UK full human capital for 2012 changes with a change in a discount rate and labour income growth rate. The table shows that by holding everything else constant an increase of 1.0% in the discount rate decreases the value of UK human capital by £2.4 trillion; whereas, a decrease of 1.0% in the discount rate increases the value of UK human capital by £3.0 trillion. On the other hand, by holding everything else constant an increase of 1.0 % in labour income growth rate increases the value of UK human capital by £3.0 trillion ; whereas, a decrease of 1.0% in the labour income growth rate decreases the value of UK human capital by £2.4 trillion. Table 4.1 also shows how the value of UK human capital changes with a simultaneous change in both discount rates and labour income growth rates.

Table 4.1: Impact of various discount rates and labour income growth rates on the 2012 value of UK full human capital – (2012 prices - £ Trillion)

Discount rates	Labour income growth rates		
	1.5%	**2.5%**	**3.5%**
2.5%	18.3	21.3	25.1
3.5%	15.9	18.3	21.3
4.5%	14.0	15.9	18.3

9. Comparison with other studies

This section compares the UK human capital results with other publications. As discussed in the earlier section, the Inclusive Wealth Report (2012) and the UK Office for National Statistics (2013) have published monetary estimates for UK human capital in their respective publications. These publications focus on different time periods, therefore, for comparison purposes, various time periods have been selected. Hamilton and Liu (2014) publishes UK human capital per capita for 2005 and therefore table 4.2 also compares UK human capital per capita calculated in this chapter (see section 9 below) with the results obtained by Hamilton and Liu (2014). Table 4.2 provides a comparison of these monetary estimates with the estimates derived in this chapter.

The monetary value of the stock of UK human capital calculated in this paper is close to the value calculated by the ONS, and Hamilton and Liu (2014). This is mainly due to these methodologies being similar to the methodology used in this chapter. On the other hand, the value of UK human capital calculated by the Inclusive Wealth Report is relatively low because of different methodology. It uses Rodriguez-Clare (1997) method that builds on the earlier work of Mincer and average wages to estimate the stock of human capital. Hamilton (2014) argues that Jorgenson - Fraumeni methodology (used in this chapter) employs a much richer set of data to calculate the present value of labour and it is arguably the more accurate estimate of human capital.

Table 4.2: Comparison of employed human capital results with other studies (£ trillion)

Year	IWR (2012)[60]	ONS (2013) [61]	This chapter	Hamilton and Liu (2014)
1990	7.0	-	11.76	-
2000	9.4	-	14.94	-
2008	10.60	18.70	18.96	-
2012	-	17.90	18.31	-
2005[62],[63]	-	-	£290,468	£292,400

10. Empirical analysis

(i) <u>UK human capital</u>

Figure 4.1 show that the value of UK full human capital increased by £6.3 trillion (52%) in 25 years – between 1988 and 2012. Figure 4.2 shows that the UK working age population increased by 4.4 million (12.1%) during this time period. An increase of £6.3 trillion in human capital is not entirely due to an increase in working age population. The value of average human capital per capita of working age population between 1988 and 2012 is

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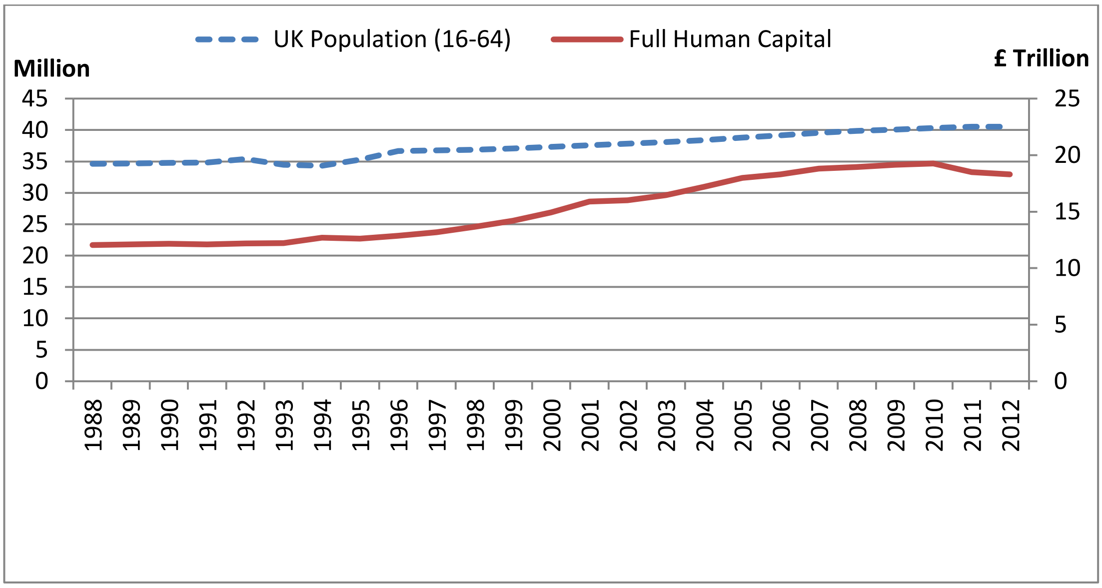
[60] The IWR values were given in USD in 2000 prices. They have been converted into Pound Sterling in 2012 prices.
[61] Source: ONS human capital estimates published in 2013.
[62] Human capital per capita
[63] Figures are in Pound Sterling (not in trillions)

£401,568. By multiplying this number with 4.4 million, it could be concluded that the value of human capital increased by around £1.8 trillion due to an increase in population between 1988 and 2012. The rest of the increase (£4.5 trillion) is due to other factors such as real earnings. This is also evident from figure 4.2, which shows that in 2011 while the population increased, the value of human capital actually fell slightly. Furthermore, the pace of increase in the value of human capital during the 25 years is higher than an increase in the corresponding population.

Figure 4.1 also shows a comparison between full and employed human capital. The figure shows a widening gap between full and employed human capital from 2008 onwards. This is due to an increase in unemployment during the recent financial crisis, which reduced the value of employed human capital. A similar trend can be seen during the early 90's when unemployment increases due to European financial crisis. This shows that during an economic recession, the value of employed human capital reduces due to an increase in unemployment. An increase in unemployment reduces the number of people in the labour market and ultimately reduces the value of human capital. Since employed human capital is sensitive to the market conditions, full human capital is a better indicator of measuring the stock of human capital as it values the stock of human capital embodied in individual regardless of the market economic conditions. Therefore the rest of the analysis in this paper focuses only on full human capital.

Figure 4.2[64]: UK human capital (2012 prices) and working age population (16-64), 1988 to 2012

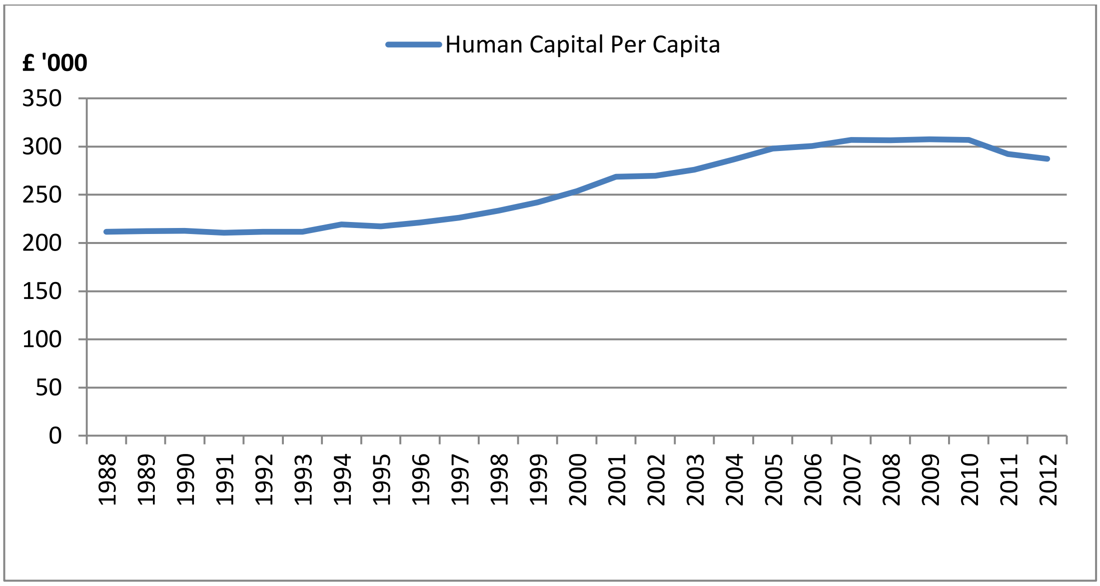


[64] Population is plotted in the left-hand side axis and human capital on the right hand side axis.

(ii) Human capital per capita

As discussed in the earlier section, this paper calculates human capital per capita as human capital of working age population divided by the whole population. Figure 4.3 shows the stock of UK human capital per head from 1988 to 2012. Between 1988 and 2012 the stock of UK human capital increased by 52%; however, human capital per capita increased by 35.8% only. This is because the UK total population increased by 11.9% during this time period. Figure 4.3 shows that the human capital her head as followed a similar trend to stock of human capital in figure 4.1. It has steadily increased since 1994 before started falling from 2011. In 1988, human capital per capita was £211,693, which increased to £307,637 in 2009 before falling to £287,418 in 2012. These changes in human capital can be understood by looking more closely at the distribution of human capital, which is discussed in the next sub section.

Figure 4.3: UK human capital per capita (1988 – 2012) – 2012 prices



(iii) The distribution of UK human capital

This section discusses the distribution of UK human capital from 1988 to 2012 by gender, age and highest qualification. The distribution of human capital across people with different attributes in a country provides useful information for addressing issues related to inequality, poverty and social cohesion.

a) Distribution of human capital by gender

Figures 4.4, 4.5, 4.6 and 4.7 provide information on the distribution of human capital between men and women from 1988 to 2012. The value of UK human capital in men and women has increased by £2.7 trillion and £3.6 trillion respectively between 1988 and 2012. Figure 4.4 shows that although the stock of human capital in men is higher than women, human capital in women is increasing faster than men over the years. Figures 4.5 and 4.6 show that although the population shares for men and women are in general very similar to each other, men dominate women in terms of human capital. Figure 4.7 shows the ratios between the shares of human capital accruing to men and women and their corresponding population share. The figure shows that men are rich[65] in human capital and the higher ratios indicating that they are better off in terms of their holdings of human capital. However, the share of men in terms of holding their human capital is falling gradually over the years. Figure 4.6 shows that in 1988 men accounted for 74 % of the human capital, but it has fallen to 63% in 2102. Figure 4.7 shows though the ratio of share of human capital for women are lower than men; it is gradually improving over the years.

The results of the distribution of human capital by gender can help to throw light on the distributional issues. For equally qualified people, it is interesting to note the disparities in human capital between men and women. These disparities are due to a combination of lower participation of women in the workforce, part-time working and lower wages for women compared to their male counterparts.

Historically women participation in the workforce has been lower than men. However, ONS (2015) report suggests that the difference between the participation rate for men and women has been shrinking considerably – although the rate for men remains higher relative to the rate for women. The participation rate for men has been gradually decreasing from 85.5% to 83% between 1994 and 2014; whereas, for women the rate has been increasing gradually from 71.3% to 74.5% during the same period. This shows that although lower women participation rate is a factor in a lower human capital value for women, it is not the main contributing factor.

Since the value of human capital is estimated by present value of life time earning of equally qualified people, wages plays an important part in determining the life time earnings for men and women. There is a vast literature on the gender pay gaps that concludes that women are paid less compared to their male counterparts. For example,

[65] A ratio larger than 1 implies than men are considered rich in human capital (Liu, 2011)

Scicchitano (2012) has found that women suffer from a significant pay gap along all the wage distribution after controlling for differences in personal, human capital and employment characteristics. Using the Annual Survey of Hours and Earning, the New Earnings Survey panel data set and the Labour Force Survey, ONS (2008) shows that in spite of legislation of minimum wage, a gender pay gap still exists. ONS (2008) results suggest the gender pay gap varies depending on an individual's circumstances. For example, the number of dependent children, company size and type of occupation are major factors in the difference between men's and women's earnings. This shows that the reason for differences between men and women wages can be attributed to a combination of discriminatory and economic reasons. This is supported by a number of other studies. For example, another ONS (2008) study shows that reduction in gender pay gap since 1998 can be attributed mainly to unobservable differences such as discrimination between men and women. A research by Women and Equality Unit (2001) concludes that the main factors influencing the pay gaps are education, work experience, part-time working, travel patterns, and occupational and workplace segregation.

This analysis shows that lower wage rates for women are one of the main reasons for low value of human capital in women. This chapter recognises that the analysis in this chapter is only limited to market activities and if non-market activities are included, the difference between men and women human capital might have been lower. This is because more women take part in non-market activities than their male counterparts.

Figure 4.4: Human capital (full) by gender, 1988 to 2012 - 2012 prices

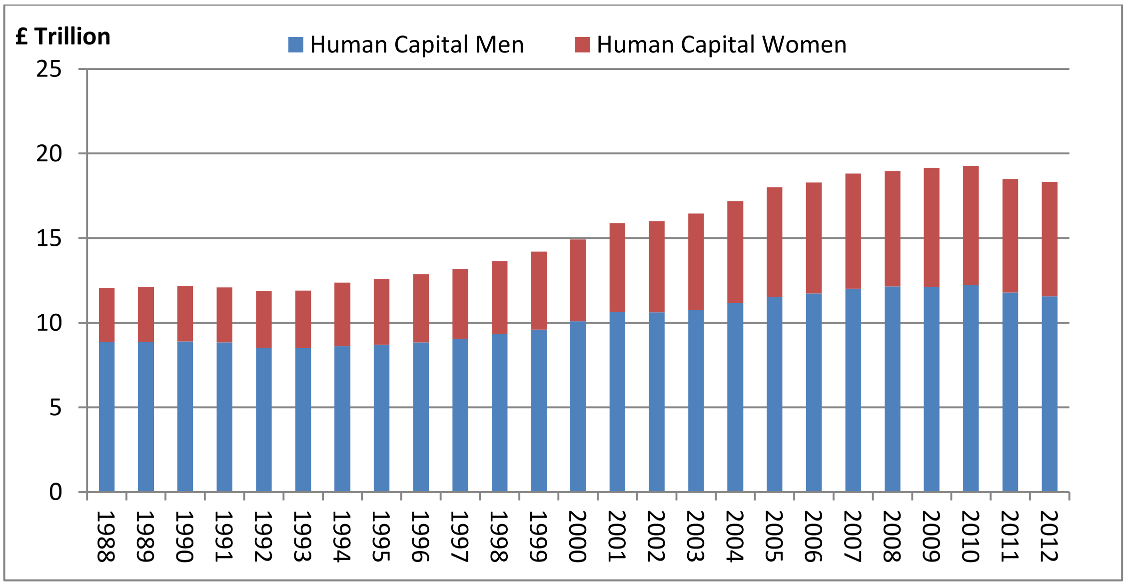


Figure 4.5: UK population by gender (aged 16 - 64), 1988 to 2012

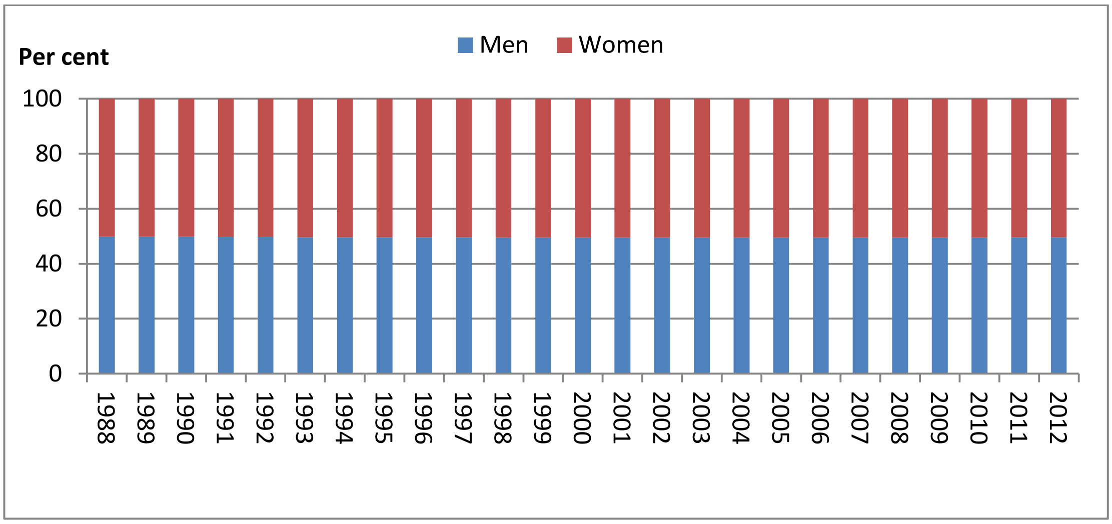


Figure 4.6: Human capital by gender as a percentage of total human capital, 1988 to 2012 - 2012 prices

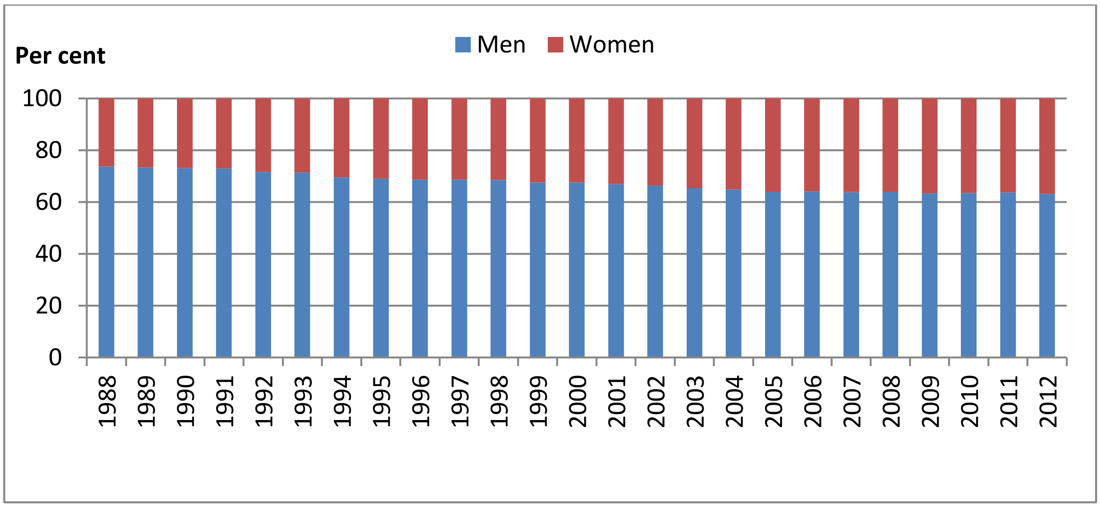
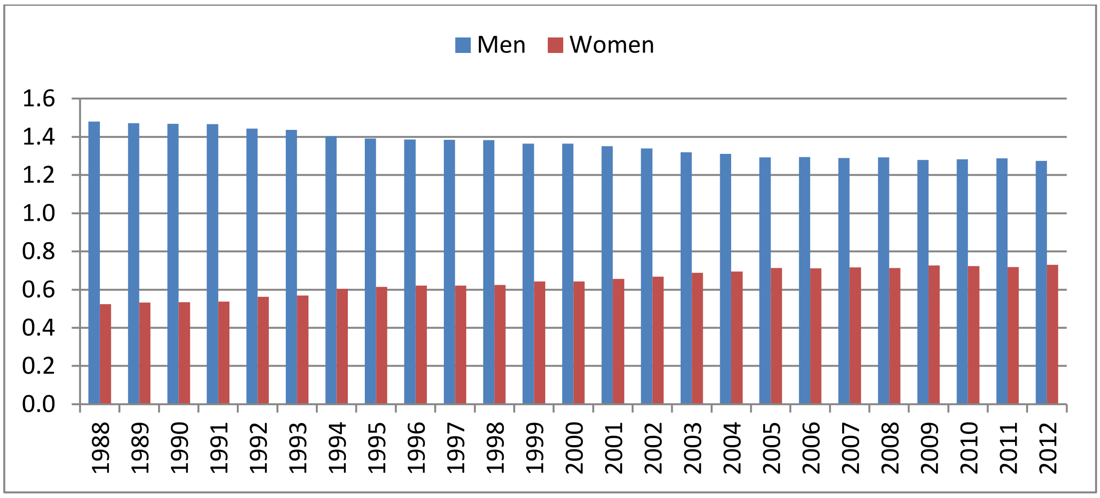


Figure 4.7: Human capital by gender as a ratio of corresponding population (16-64), 1988 to 2012 - 2012 prices



b) Distribution of human capital by age group

Figures 4.8, 4.9, 4.10 and 4.11 provide information on the distribution of human capital between different age groups from 1988 to 2012. Figure 4.8 shows the stock value of UK human capital by age group from 1988 to 2012. The figure shows that the largest increase (£1.9 trillion) in the value of human capital between 1988 and 2012 is due to the age group 25- 34. However, figure 4.9 shows that the size of its population has increased by 3.2% (0.3 million) only. Between 1988 and 2012, the youngest age group (16-24) saw a decrease of 0.7 million in its population, but an increase of £1.1 trillion in the value of its human capital. On the other hand, the age group 55-64 saw the second largest increase [66](2.9 million) in its population, but the lowest increase (£0.3 trillion) in the value of its human capital. This is because a younger person will have longer remaining working years and thus more lifetime incomes than their elder counterparts. This is evident from figures 4.9 and 4.10, which show that the younger the population is, the higher is the value of its human capital. This is supported by figure 4.11 which shows the ratios between the shares of human capital accruing to different age groups and their corresponding population share. The figure shows that age groups 16-24, 25-34 and 34-44 are rich in human capital and the higher ratios of age 16-24 indicates that they are better off in terms of their holdings of human capital. From these figures, it could be analysed that with an ageing population, the UK human capital stock would decline unless it is replaced by younger generation, who have higher value of human capital. It could be a matter of concern that during the period 1988 - 2012 the population of the richest in human capital groups 16-24 declined by 0.7 million and for the other two rich in human capital groups (25-34 and 34-44) increased by 0.3million and 0.8 million only; whereas, the population of other groups 45-54 and 55-64 increased by 2.7 million and 1.3 million respectively. A number of people in the younger age group could be immigrants to the UK, who could be economic migrants with high qualifications and thus earning higher income.

[66] The largest increase was in age group 45-54

Figure 4.8: Human capital (full) by age group, 1988 to 2012 - 2012 prices

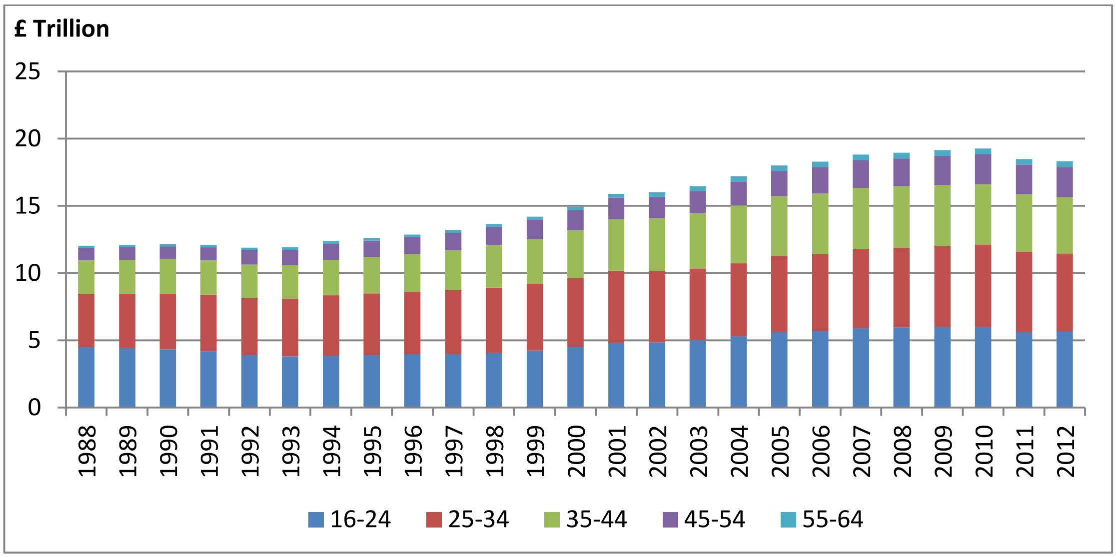


Figure 4.9: UK population (aged 16-64) by age group, 1988 to 2012

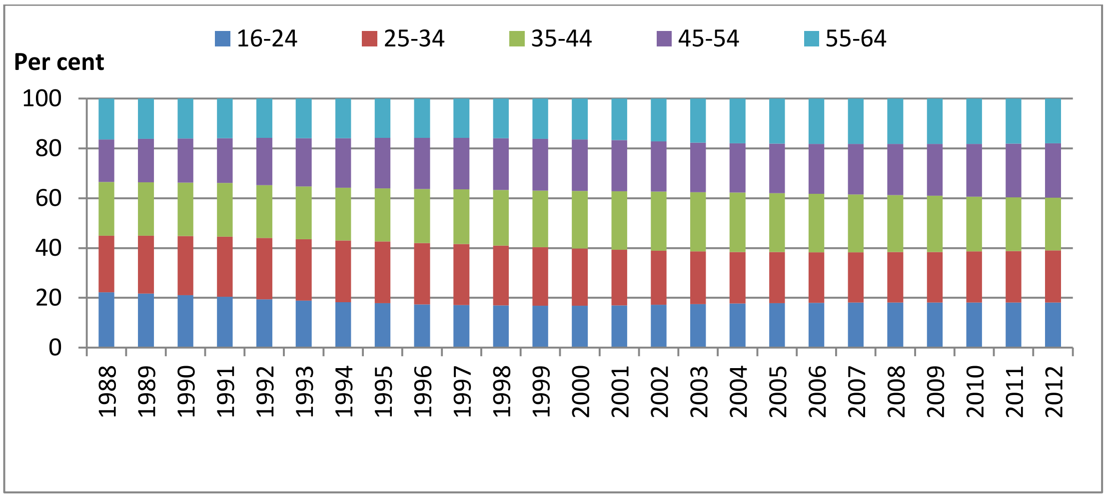


Figure 4.10: Human capital by age group as a percentage of total human capital, 1988 to 2012 – 2012 prices

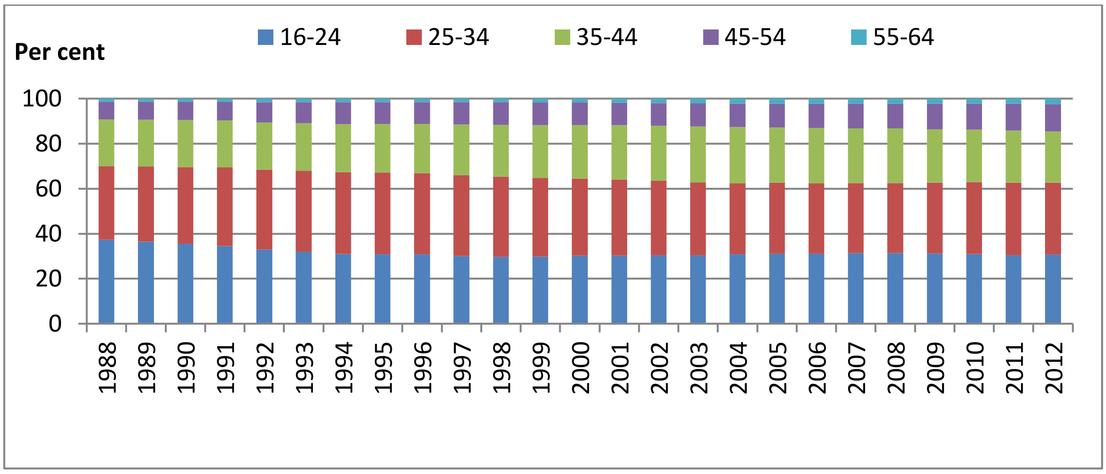
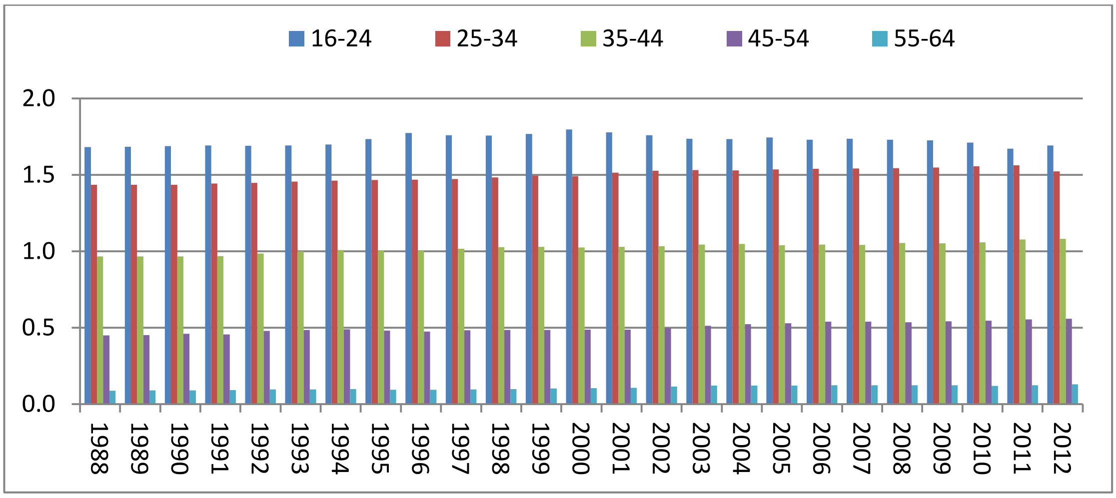


Figure 4.11: Human capital by age group as a ratio of corresponding population (16-64), 1988 to 2012 – 2012 prices



c) <u>Distribution of human capital by educational level</u>

Figures 4.12, 4.13, 4.14 and 4.15 provide information on the distribution of human capital among people with different educational qualifications between 1988 and 2012. Figure 4.12 shows that, between 1988 and 2012, the value of human capital among people with a degree level qualification has seen the largest increase (£4.4 trillion) in their human capital. This is partly due to an increase in number of people who have obtained at least a degree level qualification. Figure 4.13 shows that the number of people with a degree level qualification in the UK is increasing over the years and, between 1988 and 2012, there have been an increase of 7.5 million people who had a degree level qualification. They contributed to an increase of £4.4 trillion in the value of UK human capital during this time period. Figure 4.14 shows that the higher the educational attainment of a person is, the higher is the value of his/her human capital. This is because the higher the qualification of a person is, the higher is the earnings and the probability of having a job, which increases the value of his / her human capital.

Figure 4.15 shows the ratios between the shares of human capital accruing to different qualification levels and their corresponding population share. The figure shows that individuals with a degree and GCE, A-level or equivalent in the UK are rich in human capital; however, there is a declining trend among the degree holders. This could be due to an increase in the number of people having a degree level qualification in the UK, which diminishes wage premium. If the wages remain low but the number of people with a degree level qualification increases, the ratio of the share of human capital to degree level qualification will continue to fall and this group (degree level) will not be better-off in terms of its holdings of human capital.

Figure 4.12: Human capital (full) by highest qualification, 1988 to 2012 - 2012 prices

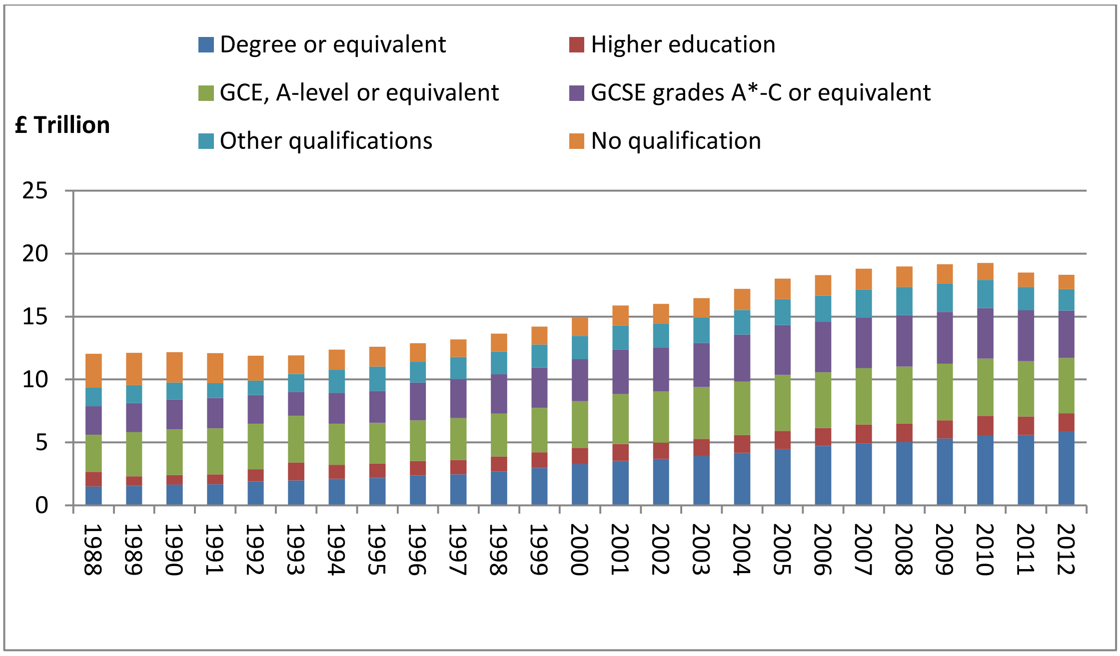


Figure 4.13: UK population (aged 16-64) by highest qualification, 1988 to 2012

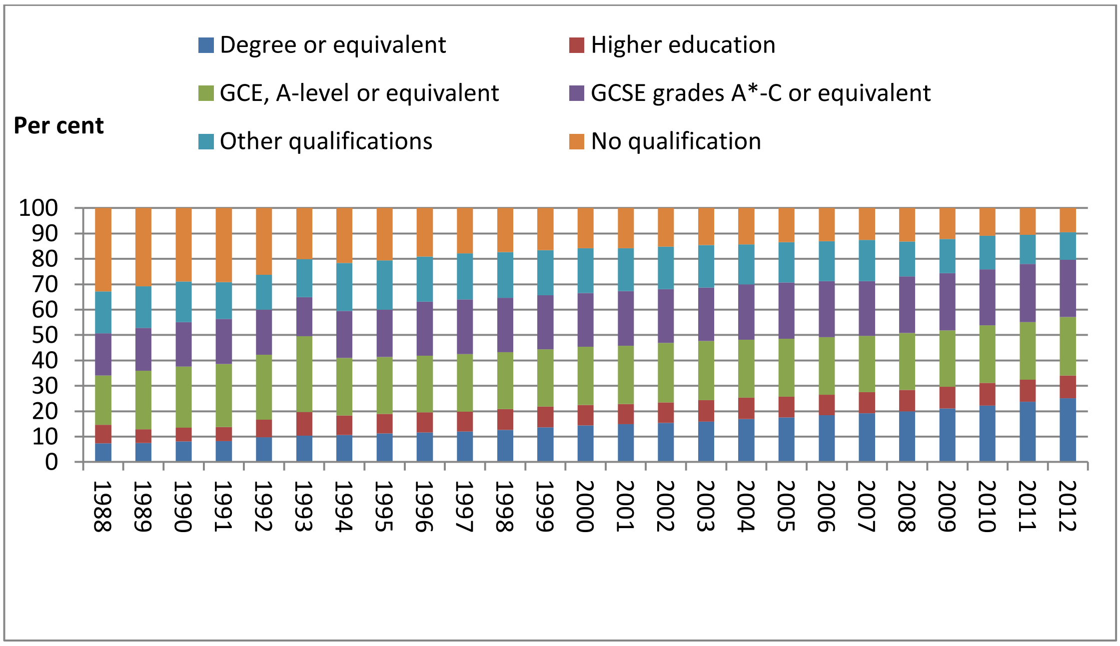


Figure 4.14: Human capital by highest qualification as a percentage of total human capital, 1988 to 2012 – 2012 prices

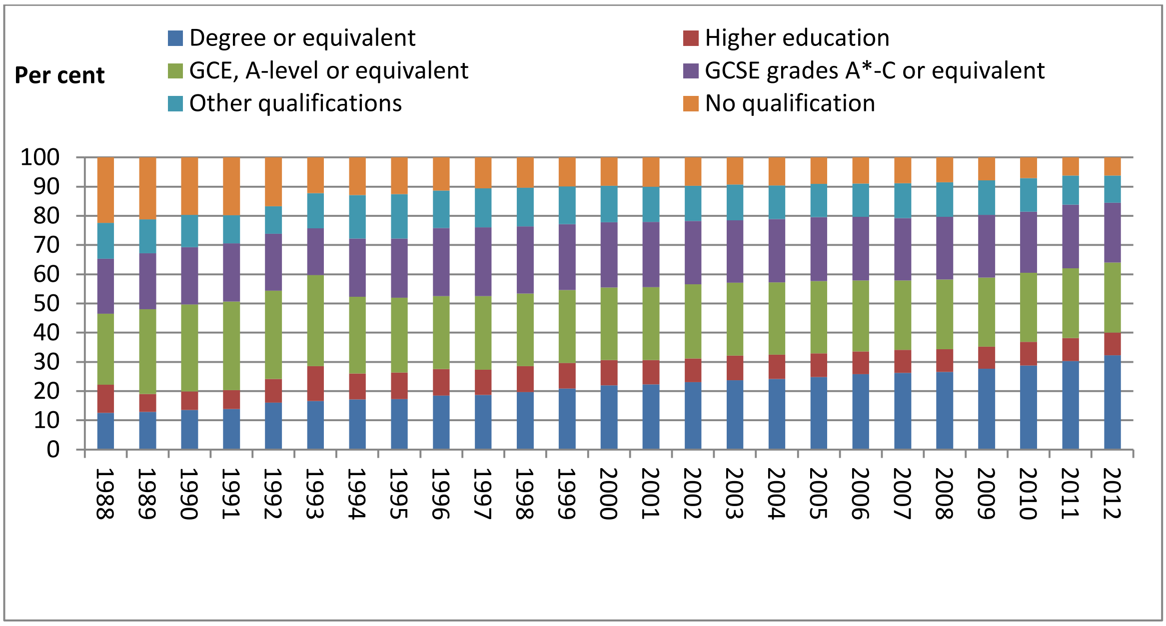
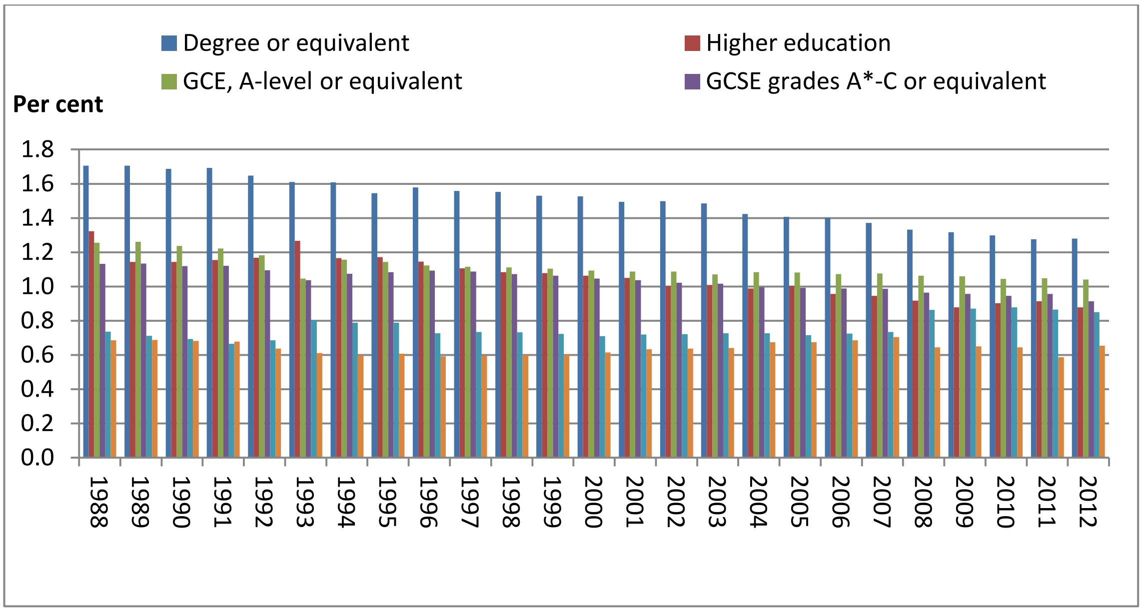


Figure 4.15: Human capital by highest qualification as a ratio of corresponding population (16-64), 1988 - 2012



11. Conclusion

This chapter has calculated the asset value of UK human capital from 1988 to 2012 using lifetime income approach. This chapter has shown that factors such as financial and economic crisis impact the value of the human capital because during economic crisis more people are unemployed, which reduces the value of human capital. Since employed human capital is sensitive to the market conditions, this paper argues that full human capital is a better indicator of measuring the stock of human capital as it values the stock of human capital embodied in individual regardless of the market economic conditions.

Using full human capital as an indicator, this chapter has concluded that between 1988 and 2012 the value of UK human capital has increased by £6.3 trillion (25%), which is due to an increase in UK population and other factors such as real earning. This shows that an increase in population is not always bad for an economy because with an increase in population, more people are in the labour market which attracts higher overall income and thus increases the value of the stock of human capital. However, an increase in population increases the stock of human capital only if the increase in population is due to young and highly qualified work force.

This chapter argues that with an ageing population, the UK human capital stock would decline unless it is replaced by younger generation, who have higher value of human capital. It could be a matter of concern that during the period 1988 - 2012 the population of the richest in human capital groups 16-24 declined by 0.7 million and for the other two rich in human capital groups (25-34 and 34-44) increased by 0.3 million and 0.8 million only; whereas, the population of other groups 45-54 and 55-64 increased by 2.7 million and 1.3 million respectively. A number of people in the younger age group could be immigrants to the UK, who could be economic migrants with high qualifications and thus earning higher income. Future research could look into how much of total UK human capital is contributed by immigration, which could provide important information to the policy makers not only on immigration policies but also on how many immigrants are needed into the UK to sustain UK comprehensive (total) wealth, which is discussed in next chapter.

Chapter 5

UK comprehensive wealth

1. Introduction

As discussed in chapter 1, traditionally wealth has been defined as a stock of produced capital such as buildings, machinery, equipment and infrastructure. However, if wealth is an indicator of sustainability and for the link between changes in wealth and sustainability to hold, the notion of wealth must be truly comprehensive. Wealth, therefore, should not only include reproducible capital goods (roads, buildings, machinery and equipment), but also human capital (education and skills), natural capital (minerals, fossil fuels and ecosystems) and social capital (institutions and governance). Chapter 1 argued that there is still an on-going debate as to what forms of capital should be included in the comprehensive wealth measures because there are arguments that *health* and *time* should also be part of the comprehensive wealth. However, there is a broad agreement on including natural capital, human capital and social capital in addition to the produced capital in the comprehensive measure of wealth.

As discussed in chapter 1, there are two broad approaches to calculate total wealth. It could either be measured by using a theoretical relationship between wealth and the flow of consumption benefits over time (top - down), and then breaking it down into various capitals. This is the World Bank approach adopted in "W*here is the Wealth of Nations" (2006)* and "*The Changing Wealth of Nations" (2011)* and is based on theory developed by Hamilton and Hartwick (2005). The other approach is to add up all the individual capitals to estimate the total wealth (bottom-up), which is adopted in the *"Inclusive Wealth Report" (2012)* and is based on theory developed by Arrow et al. (2012).

Comprehensive wealth combines all forms of wealth into a single measure that assumes a high degree of substitutability among different forms of capital. There are two opposing weak and strong paradigms of sustainability. Weak sustainability is based on the work by Solow (1974, 1986, and 1993) and Hartwick (1977, 1978). It is based on the belief that what matters for future generations is only the total aggregate stock of physical, human, natural and possibly other forms of capital such as social capital. Therefore, it does not matter whether the current generation uses up non-renewable resources or pollutes the environment as long as depleting natural capital can be compensated by increases in a country's other assets such as investing in human capital or in factories - for example, Hamilton and Atkinson (2006). The concept of weak sustainability attracts some criticism and there are arguments for strong sustainability which assumes that human and manufactured capitals are complementary to natural capital. They are not interchangeable. This is because natural capital absorbs pollution and is a direct provider of utility in the form of environmental amenities. Neumeyar (2013) refers weak sustainability as the substitutability paradigm; whereas, strong sustainability as a non-substitutability paradigm and concludes that both paradigms are non- falsifiable and cannot be conclusively decided. The support of one or the other depends on basic beliefs or policy needs.

To measure weak sustainability, as discussed in chapter 1, Pearce and Atkinson (1993) introduced the concept of genuine savings which provides a much broader indicator of sustainability by valuing changes in natural resources, environmental quality, and human capital in addition to the traditional measure of changes in produced assets provided by net saving. On the other hand, Naumeyar (2013) suggests that strong sustainability could by measured by two ways: either by maintaining natural capital in value terms or preserving physical stock of critical natural capital, with the latter a more favourable approach.

This chapter starts with a brief discussion on the approaches used by the World Bank and the Inclusive Wealth report to calculate total wealth. Section 3 discusses the approach used in this paper to calculate UK total wealth for 25 years – from 1988 to 2012. Section 4 estimates UK total wealth by adding up (bottom-up) the individual components - produced, financial, natural (including non-marketed ecosystem services) and human capital. Section 5 calculates UK total wealth directly (top-down) by using World Bank approach as a present value of future consumption. Section 6 compares the total wealth calculated by both approaches and discusses the results. Section 7 measures UK sustainability by calculating a change in per capita wealth and genuine saving and provides the results. Section 8 compares genuine savings results derived in this chapter with World Bank's genuine saving estimates and the final section concludes the chapter.

2. Approaches to calculate total wealth

As discussed in the previous section, there are two broad ways to measure the total wealth of a country. A brief overview of these two approaches is given below:

1) <u>World Bank comprehensive wealth</u>

World Bank (2006, 2011) measures total wealth based on economic theory developed by Hamilton and Hartwick (2005), which is consistent with the System of National Accounts. This theory states that wealth is the expected present (discounted) value of future stream of consumption that includes not only produced goods and services but also the enjoyment of environmental amenities. The rationale behind measuring total wealth as present value of future consumption is that, for example, if a household suddenly and permanently lost all capacity to earn income, then its future consumption would be constraint by the current total value of its assets (Hamilton and Liu, 2014). World Bank (2006, 2011) calculates total wealth as:

Equation 5.1

$$W_t = \int_t^{\infty} C(t).e^{-\rho(s-t)}.ds \;,$$

where:

W_t = total value of wealth in year t

C (t) = consumption in year t

ρ = pure rate of time preference

Equation 5.1 states that the current value of total wealth at time *t* is a function of the consumption flows from time *t* and the pure rate of time preference. Equation 5.1 implicitly assumes that consumption is on a sustainable path - the level of saving is enough to offset the depletion of natural resources. To consider the volatility of consumption and negative adjusted net saving (when countries are consuming natural resources), the World Bank modifies the results in three ways: (1) to adjust the volatility of consumption, the initial level of consumption from which the path of future consumption is generated is calculated as a rolling average of recent years; (2) if there are negative genuine savings, the consumption is re-estimated as the lower level at which genuine savings would have been zero; and (3) discounting is carried out only for 25 years instead of infinite number of years, roughly the life of one generation.

Using equation 5.1, the World Bank calculates total wealth by deriving the path of future consumption as a rolling average of consumption of recent years (for example, for wealth calculation for 2005, average consumption of 2003 – 2007 is calculated) and then keeping it constant for the next 25 years. Equation 5.1 also requires assumptions about the choice of discount rate. The World Bank (2006, 2011) uses a pure rate of time preference of 1.5%[67] – it is assumed that discount rate equals the pure rate of time preference[68].

The World Bank then estimates the values of produced and natural capital directly. The perpetual inventory method[69] is employed to estimate the value of produced capital. Natural capital is valued by taking the Net Present Value of future resource rents over a maximum of 25 year period[70]. Intangible wealth is determined as the residual – the difference between the estimates of the total wealth and the sum of the values of produced and natural capital. Since it includes all assets that are neither natural nor produced, the residual includes human capital, social capital, the quality of institutions and the effects of technological progress.

In summary, the intangible capital is:

Intangible capital = estimated total Wealth (present value of future consumption) - Produced Capital - Natural Capital

Recently, McLaughlin et al. (2014) calculates historical wealth accounts for Britain from 1760 – 2000 following the World Bank methodology. However, the authors calculate the human capital directly and deduct produced, human and natural capital from the total wealth to estimate the intangible capital.

[67] Based on Pearce and Ulph (1999)
[68] See chapter 2 for a detailed discussion on discount rates.
[69] It is the sum of additions, minus the subtractions, made over time to an initial stock.
[70] See chapter 2 on how World Bank has calculated natural capital.

2) Inclusive Wealth Report

Unlike World Bank (2006, 2011), the Inclusive Wealth Report (IWR), which is based on Arrow et al. (2012) methodology, measures the individual components – produced capital, natural capital, human capital and health capital - and then adds them up to calculate the total wealth of a country. The report presents a new metric known as the Inclusive Wealth Index (IWI) for evaluating progress in human well-being. Unlike the World Bank comprehensive wealth, where a major part of wealth is embedded in intangible capital, IWI computed the individual elements of wealth to estimate the total wealth and defines the IWI as:

Wealth (IWI) = Produced capital + Natural capital + Human capital

The total wealth is calculated by adding up the social values of produced, natural and human capital. The capitals are then adjusted for specific factors that further affect the size of the productive base of a nation. The following three adjustments are made:

1) Carbon damages – adjustments are made to capture environmental externalities by deducting annual carbon emissions from the wealth estimates

2) Oil capital gains – capital gains from increases in oil prices are separately accounted for in the wealth accounts by computing oil capital gains, which are redistributed to those nations that consume this commodity. Additionally, net oil capital gains - the difference between oil capital gains and losses - are also computed and adjusted to the wealth of those countries that not only export oil but also consume it.

3) Total factor productivity (TFP) – wealth is adjusted for TFP changes because technical changes can lead to an increase in aggregate output.

Health is treated separately from other capital forms as modest changes in health capital would overweigh any changes in the other three assets. Social capital is not calculated due to lack of empirical measures.

3. Calculating UK comprehensive wealth, 1988 – 2012

The two approaches to developing comprehensive wealth accounts, as discussed in the above section, have shortcomings. For example, by calculating total wealth as a present value of future consumption, the World Bank does not include benefits from ecosystem services which are not marketed and are not part of measured consumption[71]. If this approach is adopted to calculate total wealth, and ecosystem services are included in the natural capital calculation, the total estimated wealth will not be consistent with the natural capital estimates within the same framework. This is because the benefits of some of the non-market ecosystem services would not be part of the total estimated wealth in this approach.

This thesis has estimated the monetary value of natural capital in chapter 3 by including two ecosystem services – outdoor recreation and GHG sequestration. Much of the value of these services does not end up in measured consumption because of their non-marketed nature. Therefore, if the World Bank approach is used to measure total wealth, it could be underestimated. Furthermore, as mentioned above, if this calculated wealth is broken-down into individual components, non-marketed ecosystem service benefits need to be deducted from natural capital because these are not part of the total wealth calculated as present value of future consumption.

On the other hand, if the IWR approach is adopted, there is still an on-going debate on what forms of capital should be included in calculating total wealth (see chapter 1). Therefore, firstly it is not clear that by aggregating individual capital assets, such as produced, human, natural, health, social and so on – the total wealth will be over or under estimated. This is true when empirical measures for some of the capitals, such as social capital, are not available. Secondly, it would be difficult to estimate a change in wealth on consistent basis if the capitals that make up total wealth changes over time. This is because for measuring sustainability in accounting terms, it is important to have a consistent set of capitals which could be estimated over time to monitor a change in total wealth.

Although there are shortcomings in both approaches, they provide a framework for developing comprehensive wealth accounts. The World Bank provides an approach which is consistent with the System of National Accounts (SNA) but the resulting total wealth could be underestimated due to non-inclusion of ecosystem services that are not part of

[71] As measured in System of National Accounts

measured consumption. These non-marketed ecosystem services could be valued using the System of Environmental Economic Accounts principles which are based on the SNA (chapter 3 discusses this in detail). To include these services in the total wealth using the World Bank approach, the consumption model needs to be extended to incorporate those services that are not part of human consumption but are part of natural capital. On the other hand, The IWR provides a sound approach to add up all the capitals to calculate total wealth, but only and only if it could be agreed what capitals should be included in the calculations. There is a broad agreement on including natural capital, human capital and social capital in addition to produced capital; however, due to lack of empirical measures on social capital, total wealth could also be underestimated by using this approach.

This chapter calculates UK total wealth from 1988 to 2012 using both World Bank and IWR approaches[72]. These approaches are discussed in the next two sections (4 and 5). Section 6 compares the total wealth calculated by both approaches and discusses the results.

4. UK Total wealth (1988 – 2012) by "bottom-up" approach

The UK total wealth by using the "bottom-up" approach is calculated as:

Equation 5.2

$$W = PC + NFC + HC + NC,$$

where:

W = Total Wealth

PC = Produced (non-financial) capital

NFC = Net financial capital

HC = Human capital

NC = Natural capital

In the UK balance sheet, non-produced non-financial capital such as radio spectra and cherished or personalized license plates, are also included. However, these figures are very

[72] Only IWR approach has been used, not the IWR methodology of calculating natural and human capitals, which is not consistent with the SNA as it uses shadow prices. Natural and human capitals are calculated in chapters 3 and 4 respectively and are consistent with the SNA and World Bank methodology.

small – around 0.4% of total non-financial capital - and are not included in the overall wealth calculations.

In addition, similar to Inclusive Wealth Report (2012), total wealth has been adjusted to capture environmental externalities by deducting the costs of annual carbon emission from the wealth estimates.

Natural capital

The value of UK natural capital from 1988 to 2012 is calculated in chapter 3 of this thesis.

Human capital

The value of UK human capital stock from 1988 to 2012 is calculated in chapter 4 of this thesis.

Net financial capital

Net financial capital is calculated as total assets minus total liabilities. It includes means of payment, such as currency; financial claims, such as loans; and economic assets, which are close to financial claims in nature, such as shares. The data for net financial capital from 1988 to 2012 are from the UK balance sheet published by the ONS.

Produced (non-financial) capital

Produced capital comprises material goods or fixed assets which contribute to the production process rather than being the output itself. It includes (source: ONS):

- dwellings
- other buildings and structures
- machinery and equipment
- weapons systems
- cultivated biological resources such as livestock for breeding, dairy etc
- transport equipment
- intellectual property products
- inventories

The data for UK produced capital for 1988 to 2012 are from the Office for National Statistics. The data are published in the UK Balance Sheet on an annual basis.

While adding up all the capitals to calculate total wealth, one of the potential issues is double counting. One possible double counting that could arise in this paper is the value of timber. This thesis values timber as part of natural capital; whereas, the values of UK trees are also included in the UK balance sheet, which is already accounted for in the produced capital as cultivated biological resources. Therefore, to avoid double counting, the value of trees has been deducted from the produced capital.

CO_2 Emissions

One of the issues that arise is how climate change can affect a country's comprehensive wealth. The Stern Review (2006) has given a significant boost to the profile of climate change as a development issue. Emissions from greenhouse gases (GHG) are considered to be responsible for climate change. Carbon dioxide (CO_2) is the most common GHG emitted by human activities, in terms of the quantity released and the total impact on global warming. Damages produced by CO_2 will have an impact on wealth and sustainability of a country. Therefore, total wealth needs to be adjusted for these CO_2 damages.

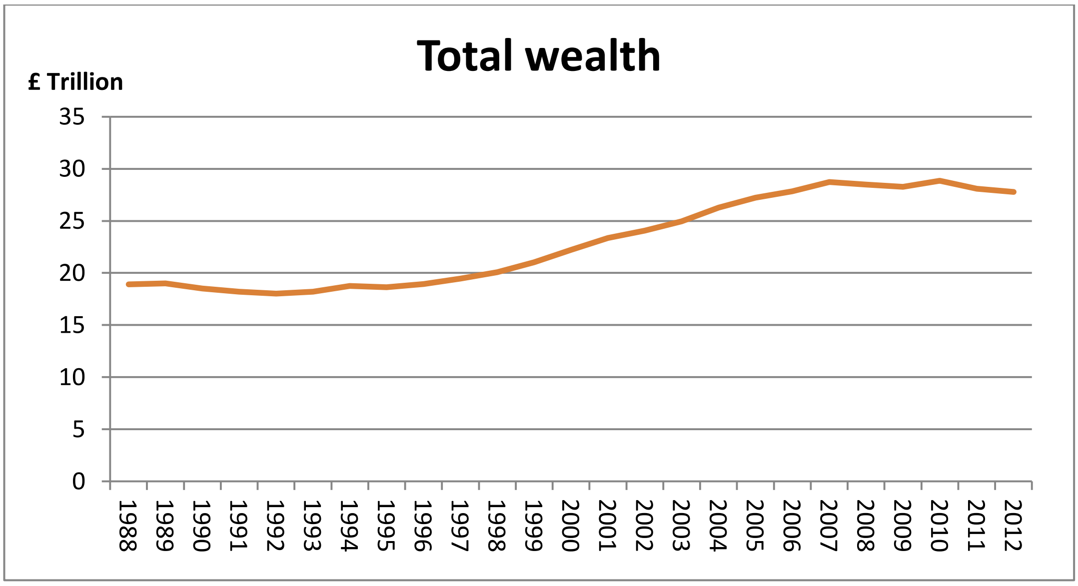
This chapter deducts the cost of annual CO_2 emissions from the total wealth. The data for annual CO_2 emission are from the Department for Energy and Climate Change. As discussed in chapter 3, there are large variations in the estimates of the unit costs of climate change from carbon emissions (McLaughlin et al, 2014). For example, Tol (2008) has used \$23 / tonnes and Stern (2006) has used a range from £68.2 per tonne to £201.2 per tonne. To estimate the value of CO_2 emissions, this chapter allocates the emissions to traded and non-traded sector. This is because both traded and non-traded carbon attracts different prices. The EU Climate and Energy Package (December 2008) introduced separate emissions reduction targets for the traded sector (those emissions which are covered by the EU Emission Trading System - EU ETS), and for the non-traded sector (those emissions not covered by the EU ETS). The presence of separate targets in the traded and non-traded sectors implies that emissions in the two sectors are essentially different commodities. Changes in emissions which occur in the traded sector are valued at the traded price of carbon, whereas changes in emissions in the non-traded sector are valued at the non-traded price of carbon. These traded and non-traded carbon prices are different in the short-term, but are projected to converge, becoming equal in 2030 and remaining so in further years. This is based on the assumption that there will be a fully functioning global carbon market by 2030[73].

In order to be consistent with the national Accounts, market prices should be used to value carbon emissions. Traded carbon prices can be considered as market prices but since non-traded carbon prices are not derived from the market, they are not market prices. However, they are a close proxy to market prices and in the absence of any market prices; this chapter uses non-traded market prices to value emissions in non-traded sector. For both traded and non-traded carbon, central price estimates are used. For example, for 2012, £22 per tonne and £53 per tonnes are used for traded and non-traded carbon respectively.

Total wealth

Using equation 5.2 and after deducting carbon emissions, UK total wealth by "bottom- up" approach from 1988 to 2012 is given in figure 5.1 below. Section 7 discusses changes in wealth along with changes in wealth per capita.

Figure 5.1: UK total wealth by "bottom-up" approach, 1988 to 2012 – 2012 prices



[73] Source: Department for Energy and Climate Change https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483278/Valuation_of_energy_use_and_greenhouse_gas_emissions_for_appraisal.pdf

5. UK Total wealth (1988 – 2012) by "top-down" approach

UK total wealth as a present value of future consumption is calculated as:

Equation 5.3

$$\boldsymbol{W_t} = \sum_{t=0}^{n} \frac{\boldsymbol{C_t}}{(\boldsymbol{1}+\boldsymbol{r})^{t}} ,$$

Where:

W_t *= Total wealth in year t*

C_t *= Consumption in year t*

n= Total number of years (50)

t = year

r = declining discount rate

I. <u>The choice of time period</u>

The World Bank (2006, 2011) assumes 25 year time horizon for total wealth and for most of natural capital. The resulting estimates of asset values are conceived as a 'generational account' - the wealth enjoyed by the current generation (Hamilton and Liu, 2014). However, it could be argued that this is a short time period because human consumption could be infinite (until all humans die) and the asset life of renewable assets could also be infinite if they are managed sustainably. However, infinite time horizon is not appropriate because of the uncertainty of a human life and lack of information on the sustainable management of renewable resources. Furthermore, if an infinite asset life is assumed, non-negligible discounting would render future values relatively immaterial.

In chapter 3, most components of the natural capital are valued using an asset life of 50 years[74]. In chapter 4, human capital is calculated until the age of 65. This amounts to 49 years of time horizon for a 16 year old individual (the minimum age group included in human capital calculation). Therefore, for consistency a purpose, this paper assumes 50 year time horizon for consumption in order to calculate total wealth using equation (5.3).

[74] See chapter 2 and 3 for a detailed discussion.

II. Consumption and discount rate

Wealth calculated as present value of future consumption requires assumptions about the path of future consumption and discount rate. Since the path of future consumption is not observable, it could be derived by estimating future consumption by taking an average of previous year consumption and keeping it constant for the rest of the time period. This paper prefers this approach because it not only assumes sustainable consumption but also is consistent with the estimation of future resource rent for natural capital in chapter 2. Future consumption is derived by taking an average of latest 5 years consumption and keeping it constant for the next 50 years. In short, the path of future consumption (C) is calculated as:

Equation 5.4

$$\bar{C}_t = \frac{C_{t-4} + C_{t-3} + C_{t-2} + C_{t-1} + C_t}{5} ,$$

Where:

t = year

It could be argued that future consumption would increase as population increases; however, it is also argued that if future consumption continues to increase, it will not be on sustainable path. If the purpose is to measure sustainability, future consumption needs to be on sustainable path. This poses two issues:

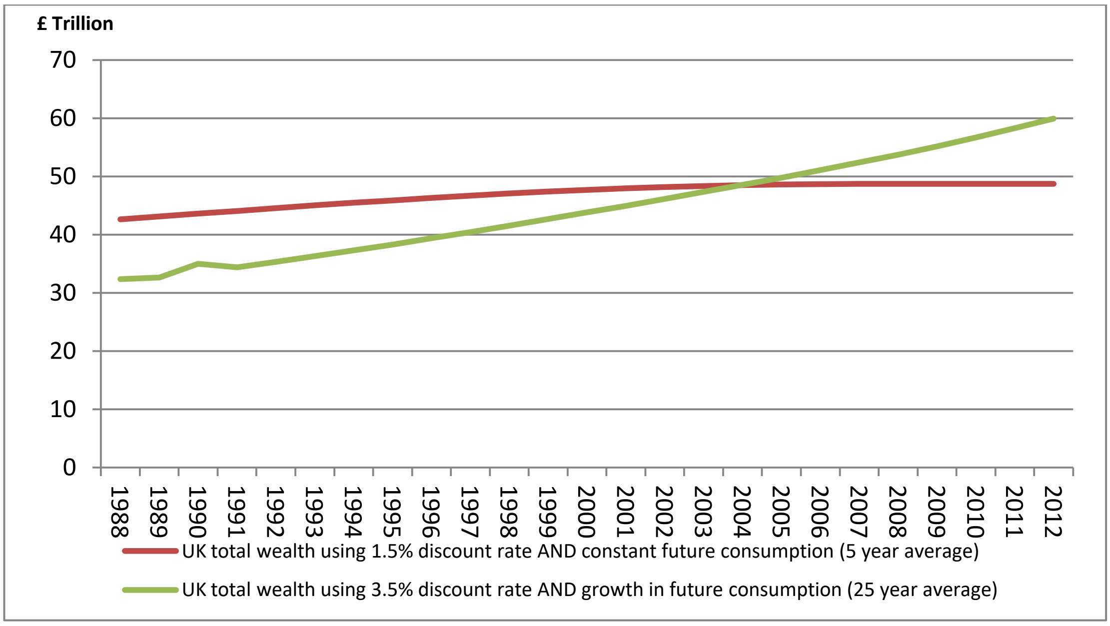
i. How should future *sustainable* consumption be predicted? The path of future consumption could be derived based on historical consumption; however, any approach adopted could be disputable. For example, HM Treasury Green Book sets the annual growth in per capita consumption at 2% based on Maddison (2001), which shows that growth per capita in the UK to be 2.1% over the period 1950 to 1998. However, data from the UK National Accounts suggest that, in the UK, consumption has increased by an average of 5% between 1988 and 2012.

ii. If consumption continues to increase, total wealth would also continue to increase if wealth is calculated as present value of future consumption.

This chapter uses the first method (constant consumption) to estimate UK total wealth by "top-down" approach. The data for final consumption expenditures (household and government) from 1988 to 2012 are taken from the Office for National Statistics. In the UK, HM Treasury Green Book recommends using the social rate of time preference as the standard real discount rate. Using the Ramsay formula[75], the Green Book calculates the social rate of time preference at 3.5%. This discount rate includes a 2% annual growth rate in per capita consumption, if per capita consumption is expected to grow over time. Since the above approach assumes future consumption to be constant, 1.5% discount rate is used to estimate the wealth. Taking present value of future consumption (equation 5.4), applying 1.5% discount rate and taking a 50 year time horizon, UK total wealth from 1988 to 2012 is given in figure 5.2 below. Similar to chapter 3, GDP deflators are used to convert the consumption into 2012 prices.

For comparison purposes, total wealth has also been calculated using the second approach (increasing consumption). Taking present value of future consumption, using 5% growth in consumption, applying 3.5% discount rate (3.5% because consumption is increasing) and taking a 50 year time horizon, UK total wealth from 1988 to 2012 is also given in figure 5.2 below. The figure shows that total wealth increases with an increase in future consumption.

Figure 5.2: UK total wealth "top-down" approach, 1988 to 2012 – 2012 prices

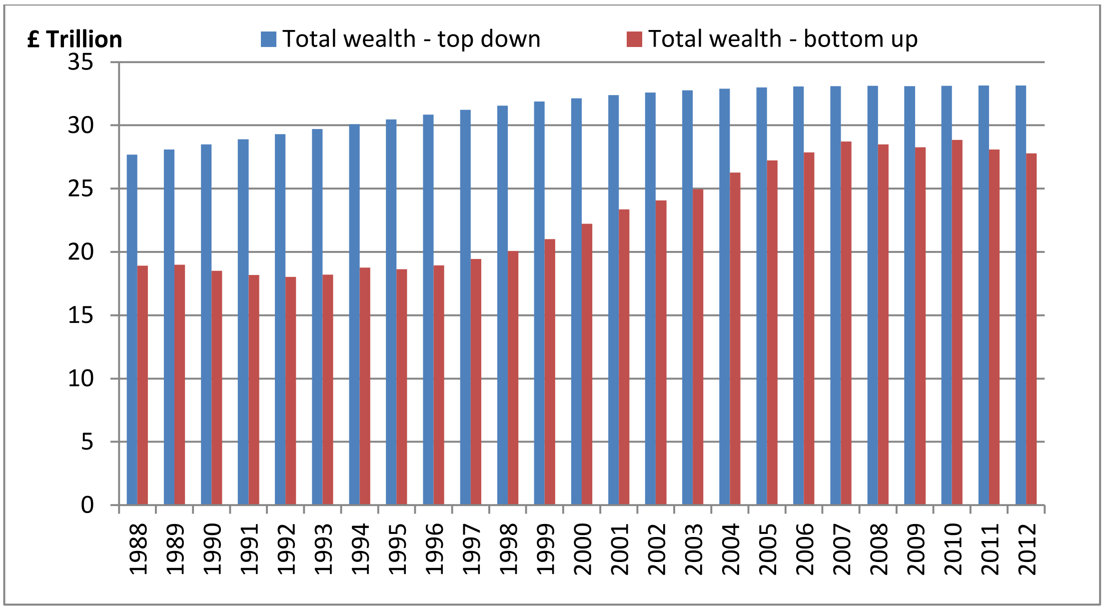


[75] See detailed discussion in chapter 2

6. Comparison of total wealth calculated by "top-down" and "bottom-up" approaches

Figure 5.3 shows UK total wealth calculated by both "top-down" and "bottom-up" approaches. The figure shows that the total wealth calculated by these two approaches is not the same.

Figure 5.3: Total wealth by top-down and bottom-up approaches, 1988 to 2012, 2012 prices



Both "top-down" and "bottom-up" approaches are conceptually similar to each other as they both are based on an economic welfare model developed by the World Bank (2006, 2011) and Arrow et al. (2012) respectively and measure sustainability by measuring wealth instead of economic growth and income. Total wealth calculated by the "top-down" approach is a comprehensive measure of the wealth which measures the consumption of produced goods and services. Whereas, total wealth calculated by "bottom-up" approach is a comprehensive measure of wealth which measures the productive base of an economy that comprises the entire range of capital assets to which people have access. One of the main differences in these two approaches is the methodology used to calculate the total wealth. The World Bank (2006, 2011) methodology is consistent with the System of National Accounts as it uses market prices to estimate natural capital; whereas, the Inclusive Wealth Report (2012) uses a different approach to estimate the prices to value natural capital because it has a wider scope in terms of well-being and does not restrict itself to consumption based prices as defined by the System of National Accounts. The World Bank calculates human capital indirectly as an intangible capital; whereas, the Inclusive Wealth Report values human capital directly using average wage rate.

This chapter uses the both approaches while eliminating the differences between them. It uses market prices to value natural capital in both approaches and values human capital directly using lifetime income approach in order to stay closer to the System of National Accounts. Despite using the same methodology, the total wealth calculated is not the same. If wealth by “top-down” approach is considered as the total wealth of the UK then the difference between these two approaches could be due to intangible capital such as social capital. However, it is not straightforward to draw this conclusion. As discussed above, total wealth calculated by the “top-down” approach is a comprehensive measure of the wealth which measures the consumption of produced goods and services. Whereas, total wealth calculated by “bottom-up” approach is a comprehensive measure of wealth which measures the productive base of an economy that comprises the entire range of capital assets to which people have access. The main difference is that not all productive base of an economy ends up in the measured consumption function, for example non-produced goods and services such as ecosystem services. If the consumption function is extended to include ecosystem services that are not part of measured consumption function, or if these ecosystem services are excluded from the top-down approach, the difference in the total wealth calculated by these two approaches would be the social capital and the stock value of technological change (together known as intangible capital). However, as discussed in chapter 2, ecosystem services are natural capital and should be included in the comprehensive wealth. Thus to obtain the value of intangible capital, ecosystem services need to be added to the measured consumption function. This is an area of future research.

This thesis has included two ecosystem services in the “top-down” approach. Some values of these ecosystem services, for example the time spent at the recreation site, would not end up in the measured consumption function. Though this chapter has included two ecosystem services in the “bottom-up” approach, the total wealth calculated by this approach is still lower than the wealth calculated by “top-down” approach. This could be because some of the missing ecosystem services that are not calculated in this thesis (chapter 2 discusses the missing ecosystem services) and are not included in the “bottom-up” approach. Since the focus of this research is to calculate individual component of total wealth, rest of the analysis in this chapter is carried out on total wealth calculated by “bottom-up” approach.

7. Measuring sustainability

This section measures the sustainability of UK economy (sustainable development) from 1988 to 2012. A change in wealth over time suggests whether or not a country is on a sustainable path. An increase in wealth requires investment and national savings to finance this investment. In other words, saving or investment is the dynamic behaviour that drives wealth changes from one point to another. This shows that sustainability can be measured in two ways:

i. Calculating a change in comprehensive wealth
ii. Calculating savings

In theory, these measures are very similar. The main difference between them is that gross saving is income based measure; whereas, comprehensive wealth includes all the capitals – produced, financial, human and natural. However, "genuine" savings, an indicator based on the theory of sustainable development, attempts to adjust for changes in all forms of capital. This chapter measures UK economy’s sustainability by these both measures. These measures are discussed below.

i. Changes in wealth

The first indicator to measure sustainability is change in comprehensive wealth. A change in comprehensive wealth can be measured by calculating a change in total wealth, per capita wealth or in annual growth rate. These three measures are discussed below.

a) Total wealth

Figure 5.4 shows that UK total wealth has increased by £8.9 trillion (47%) between 1988 and 2012. This is mainly due to an increase in the values of UK produced and natural capital, which have increased by £2.8 trillion (59%) and £6.3 trillion (52%) respectively. The figure shows that the UK wealth was at its peak in 2007 and then it declined every year, bar 2010, until 2012. Between 2007 and 2012, UK total wealth declined by almost £1 trillion.

Figure 5.4: Components of UK total wealth, 1988 to 2012 – 2012 prices

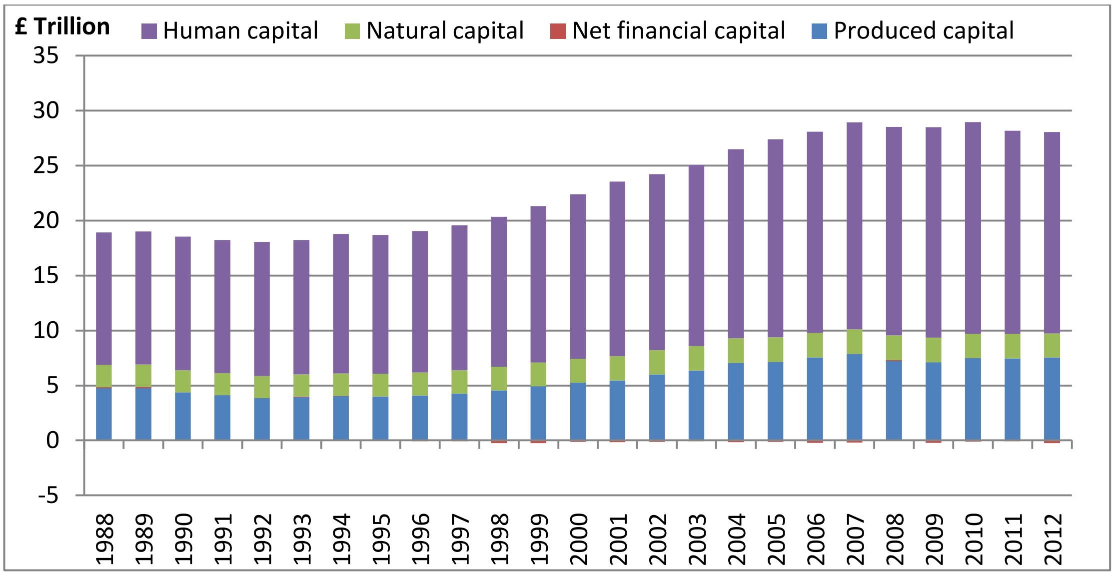


Figure 5.5 shows UK financial, produced, human and natural capital as a percentage of total wealth from 1988 to 2012. The figure shows that human capital has dominated UK total wealth during the 25 year period (1988 -2012). The average share of human capital is 66.6%; whereas, the average shares of produced and natural capital are 24.3% and 9.6% respectively.

Figure 5.5: Composition of UK total wealth, 1988 to 2012 – 2012 prices

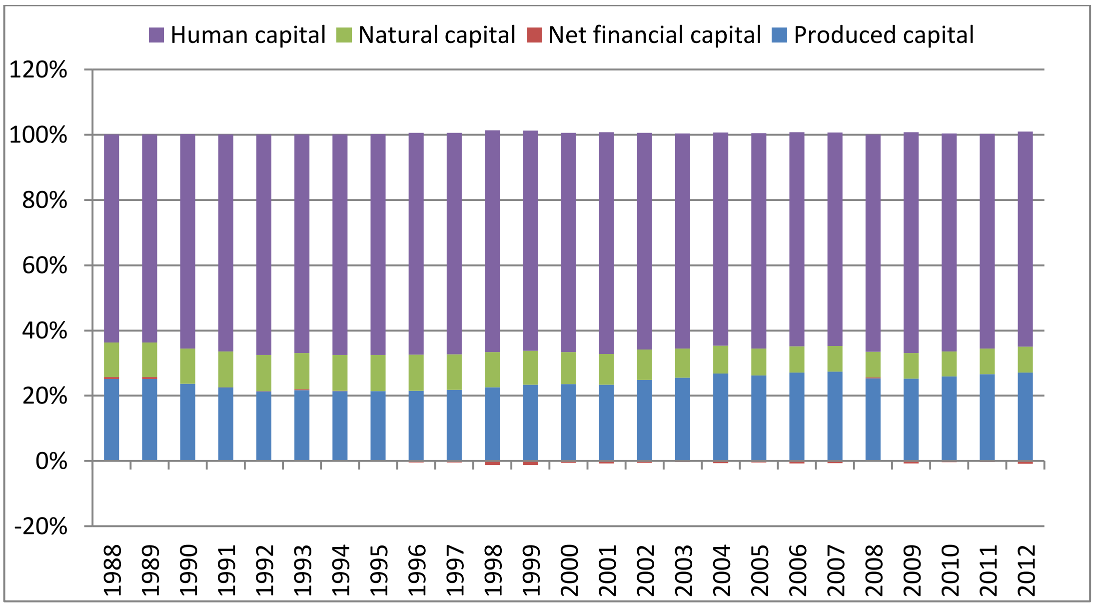
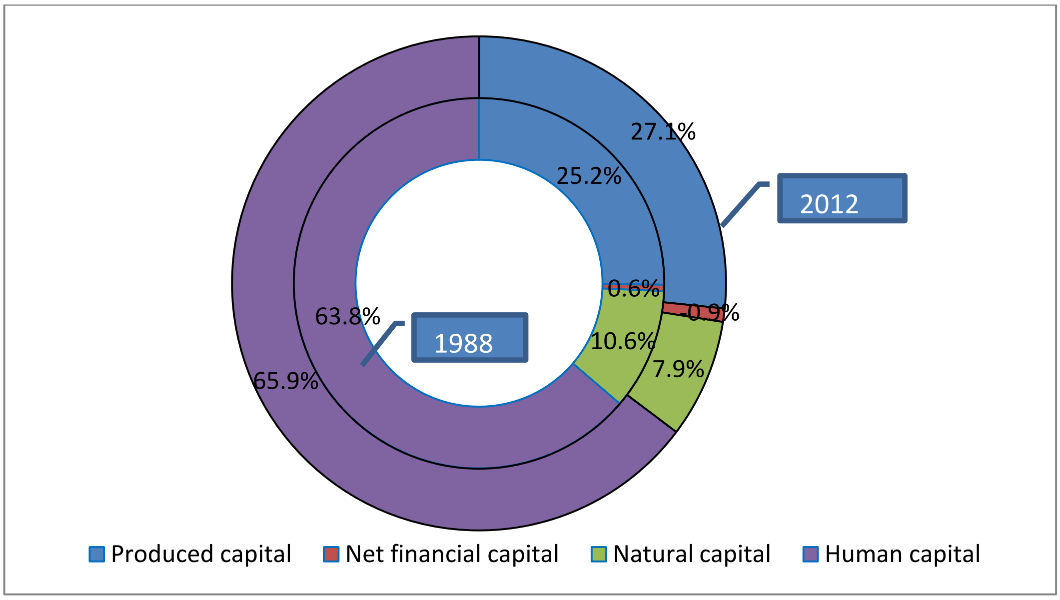


Figure 5.6 shows the changes in total wealth between 1988 and 2012. The figure shows that during the 25 year period (1988 to 2012), the shares of human capital and produced capital have increased by 2.1% and 1.9% respectively; whereas, the shares of natural capital has fallen by 2.7%. Although the value of UK natural capital has increased by £0.2 trillion (9%) between 1988 and 2012, its share to total wealth has fallen because total wealth has increased by £8.9 trillion (47%), which is mainly due to an increase in produced and human capital. The values of UK produced and human capital have increased by £2.8 trillion (59%) and £6.3 trillion (52%) respectively.

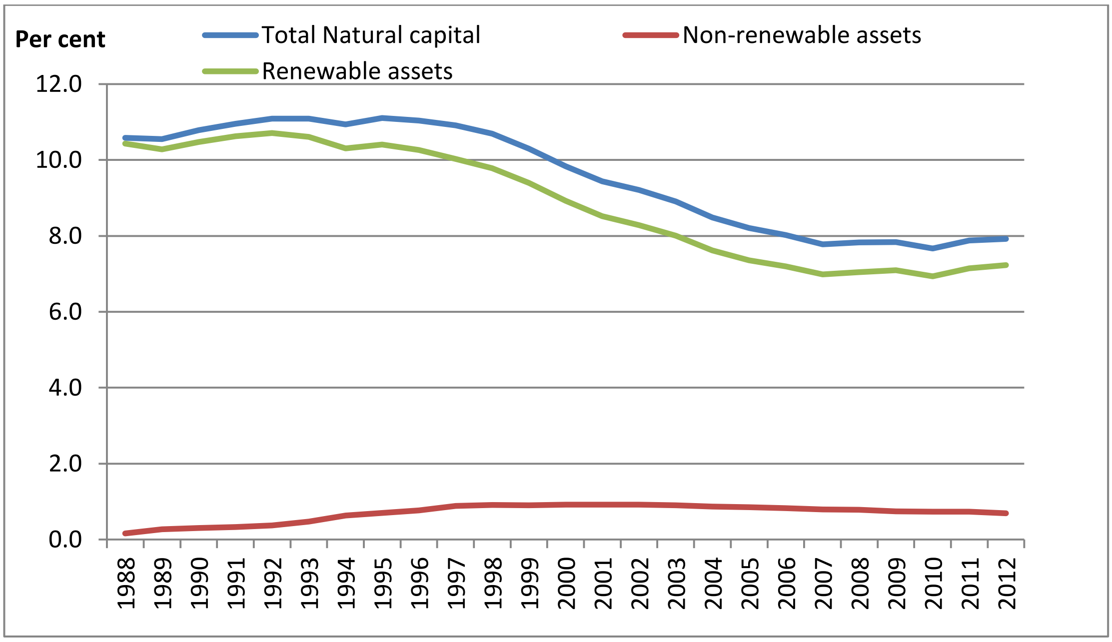
Figure 5.6: Changes in UK wealth between 1988 and 2012 – 2012 prices



Within the natural capital, the share of non-renewable assets (oil & gas, minerals and agricultural land) is less than 1% of total UK wealth. Figure 5.7 shows UK natural capital along with non-renewable and renewable assets as a percentage of total wealth. The share of non-renewable assets has increased from 0.2% to 0.9% between 1988 and 1997, remained at 0.9% until 2005 and then has started to decline. In 2012 this share has fallen to 0.7%. An increase in the share of non-renewable assets is due to an increase in oil and gas reserves and an increase in their unit cost, which increased sharply during the 90s and early twenties because of an increase in demand. This thesis only values commercially recoverable reserves (class A) which are consistent with the System of National Accounts (see chapter 3). Between 1988 and 1994 UK Continental Shelf oil and gas reserves have increased by 26%; whereas, between 1994 and 2012, the reserves have fallen by 57%. On the other hand, oil unit prices were lower in the 90s and then increased until 2009 before started to fall due to the financial and economic crises. This shows that both reserves and prices have played a part in determining the share of non-renewable assets to total wealth - when reserves were declining, higher oil & gas prices were increasing the value of lower reserves and thus their share to total wealth.

In contrast, the share of renewable assets to total wealth has been generally declining since 1988. It has declined from 10.4% to 7.2% between 1988 and 2012. This is because although the value of UK measured renewable assets remains the same during the 25 years, its share to total wealth has fallen because total wealth has increased due to an increase in human and produced capital. This means that the income received from non-renewable assets might have not been invested in renewable assets, but in human or produced capital, which have increased during this time period.

Figure 5.7: Natural capital as a percentage of total wealth, 1988 to 2012, 2012 prices



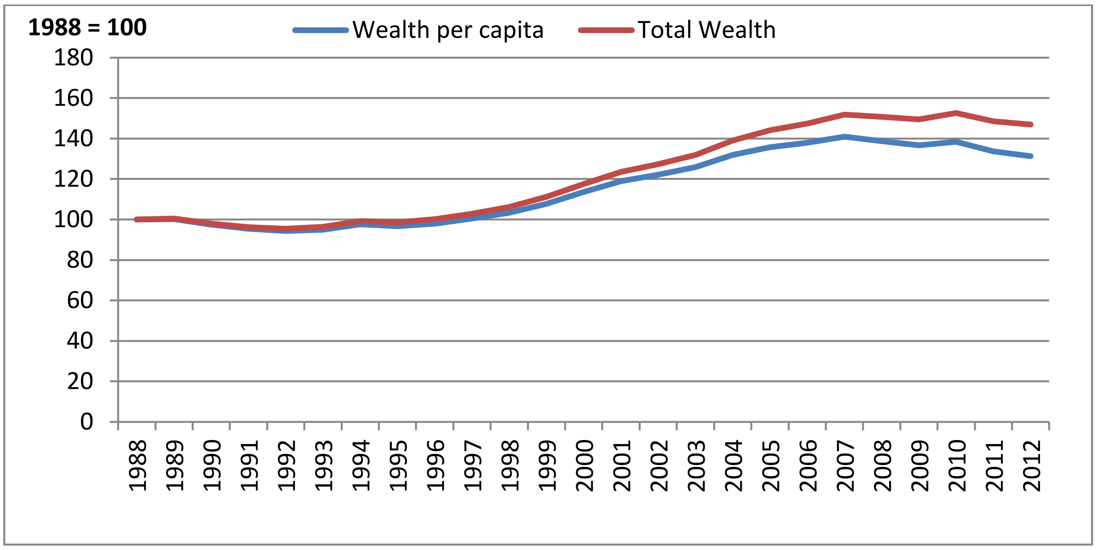
b) <u>Changes in UK per capita wealth</u>

Figure 5.8 shows UK total wealth per capita from 1988 to 2012. Between 1988 and 2012, UK total wealth has increased by 47%; however, total wealth per capita has increased by 31.3% only. This is because UK population has increased by 11.9% during this time period. The figure shows that UK total wealth and wealth per capita have followed a similar pattern until 1997, but from 1998 they both started to diverge. Since 2007, although both wealth and wealth per capita have started to fall, wealth per capita has fallen more than total wealth. In 1988, UK total wealth per head was £332,148, which increased to its highest level in 2007 at £468,297. It then started to decline and was £436,092 in 2012.

Between 1988 and 2007, wealth per capita has increased by 41% despite a 7.7% increase in UK population. This increase in per capita wealth is due to an increase in overall wealth, which has increased by 52% during this period. Both produced and human capital are the main components of wealth that increased sharply during this time period - they increased by 66% and 56% respectively. This shows that an increase in population does not always decrease per capita wealth. This is because an increase in population driven by a skilled worked force, for example, highly skilled immigrants, increases the value of human capital and thus total wealth. This increase in wealth could offset an increase in population keeping per capita wealth intact. Therefore, policies attracting highly skilled workforce into a country are positive for increasing wealth. Chapter 4 on human capital support this conclusion.

However, between 2007 and 2012, wealth per capita has declined by 6.9%. This is due to a fall in overall wealth combined with an increase in UK population - UK total wealth has decreased by 6.9%; whereas, the population has increased by 3.9%. UK total wealth has decreased due to a fall in both produced and human capital, which has fallen by 4.3% and 2.7% respectively. A larger fall in the value of produced capital during 2007 and 2012 is due to the financial crises (2007-2009) that cut back investment in fixed assets; whereas, a fall is the value of human capital is due to an increase in unemployment during the recent financial crisis (chapter 4 discusses this in detail).

Figure 5.8: UK total wealth and wealth per capita (1988 = 100)



c) <u>Average annual growth rate</u>

Table 5.1 shows average annual growth rate for UK wealth and UK wealth per capita along with components of wealth. The table shows that UK has positive average annual growth rates for total wealth (1.65). An increase in total wealth does not necessarily indicate that future generations may consume at the same level as the present one because as population grows, each form of capital is more thinly spread over the society. Therefore, average annual growth rate per capita is of more interest. The table shows that though UK also has positive annual average growth rate for wealth per capita between 1988 and 2012, average annual growth rate for natural capital has moved into non-sustainable position.

Table 5.1: Growth rate of UK wealth between 1988 and 2012 – 2012 prices

	Total wealth	**Population**	**Produced capital**	**Human capital**	**Natural capital**
Average annual growth rate	1.65	0.47	2.08	1.79	0.36
Average annual growth rate per capita	1.17	-	1.60	1.31	-0.11

However, we see a different picture, if we look at the annual growth rate in UK wealth and wealth per capita from 2007 on-wards. From 2007 to 2012, average annual growth rate of UK wealth has moved to un-sustainable position. Average annual growth rate in produced and human capital has been very low and for natural capital it has tuned into negative. The picture is worse in the case of average annual growth rate in per capita wealth. Average annual growth rate per capita for human and produced capital has turned to negative; whereas, for natural capital it has been worse.

Table 5.2: Growth rate of UK wealth between 2007 and 2012 – 2012 prices

	Total wealth	**Population**	**Produced capital**	**Human capital**	**Natural capital**
Average annual growth rate	-0.02	0.77	0.05	0.04	-0.26
Average annual growth rate per capita	-0.79	-	-0.71	-0.73	-1.03

This analysis shows that since 2007 UK is not on sustainable path due to negative growth rates. In order to reverse the trend, either UK has to reduce its population growth or it needs to reinvest in all capital asset bases to increase the rate of wealth growth. However, above discussion also shows that decreasing the population does not necessarily increase the total wealth or wealth per capita because of the human capital embedded in the work force. For UK, which is not a resource rich country, investment in human capital is needed to increase the rate of wealth growth.

ii. Savings

The second indicator to measure sustainability is national savings, which is derived from standard National Accounts. National savings (gross) is derived by deducting final consumption expenditure from Gross national disposable income, and consists of personal saving, business saving, government saving, but excludes foreign saving.

Gross national savings can say little about sustainable development as assets depreciate over time; therefore, the first step is to adjust gross saving for capital depreciation to derive traditional measure of net national saving. Net national saving is a standard variable in the UK national accounts that provides information on the investment that is available to UK to build its national wealth. A negative number indicates that the economy as a whole is spending more income than it produces, thus drawing down national wealth.

However, net national saving does not take into account the depletion of natural resources and degradation of natural environment. Therefore, the next step in measuring sustainability is to adjust net saving for the accumulation of other assets – human and natural capital – that underpin development[76]. In order to capture the depletion of natural resources, this paper proposes a new indicator[77] – depletion adjusted net saving – to measure UK sustainability based on the concept of extended national accounts. This indicator takes into account depletion of natural resources in addition to standard depreciation. Depletion adjusted net saving is calculated as:

Equation 5.5

Depletion adjusted net saving = Gross national saving – depreciation of fixed capital – depletion of natural resources

Depletion adjusted net saving should be the minimum that UK should be aiming for in order to measure the sustainability of its wealth. However, depletion adjusted net saving is at best a necessary, but not sufficient condition of sustainability because it does not take into account environmental degradation. Damages from greenhouse gas emissions, such as CO_2, also have an impact on the sustainability of a country. Therefore, the estimates of the shares of the stock of atmospheric CO_2 should also be formally incorporated into the above framework. This chapter subtracts the values of CO_2 emissions and PM10 emissions from depletion adjusted net saving to derive a more relevant sustainability indicator known as depletion and degradation adjusted net saving (equation 5.6).

Equation 5.6

Depletion and degradation adjusted net saving = Gross national saving – depreciation of fixed capital – depletion of natural resources - value of environmental degradation

[76] World Bank (2006, 2011)

[77] This indicator has also been suggested by the author in a paper published by the ONS. See (Khan, J; 2013)

However, for comprehensive wealth, the expenditures on education need to be added into equation 5.6 because they are investment into a country's human capital. The resulting indictor is known as *adjusted net saving* or *genuine savings*, which is developed by the World Bank (2006, 2011) to assess an economy's sustainability. Genuine saving is based on the theory of sustainable development and is measured as:

Equation 5.7

Genuine saving = Depletion adjusted net saving - value of environmental degradation + expenditure on education expenditures

To achieve Sustainable Development, genuine savings rates must not be persistently negative. Positive genuine savings allows wealth to grow over time, thus ensuring that a country's living standard is sustained and negative genuine savings implies that total wealth is in decline and a country is running down its capital stocks and policies leading to persistently negative genuine savings are unsustainable.

Figures 5.9 and 5.10 show gross and net savings, depletion adjusted net savings (DANS), depletion and degradation adjusted net savings (DDANS) and genuine savings (GS) for the UK economy from 1988 – 2012. The data for gross and net savings are from the UK National Account[78]. Depletion of those non-renewable resources (oil & gas, coal, silver, limestone, chalk, lead, salt, and sand and gravel) is calculated which are part of natural capital calculation in chapter 3. The data sources for these assets are discussed in chapter 3. The data on carbon emissions and carbon prices are from the Departments for Energy and Climate Change. Similar to chapter 3 and in section 4 of this chapter, non-traded carbon prices (central estimate) are used to estimate the value of CO_2 emissions. The data on PM10 damages are from the World Bank. To calculate GS, the data on education expenditures are taken from the Office for National Statistics. This chapter includes both public and private education expenditures; whereas, both the World Bank (2006, 2011) and McLaughlin et al. (2014) include only public expenditures in their genuine savings calculations.

The figures show that although UK gross saving has been increasing for most of the years, once depreciation of fixed assets, depletion of natural resources and environmental

[78] Bluebook 2014

degradation are taken into account, UK DDANS has been actually falling. Between 1999 and 2009 – a period of high economic growth, UK DDASN has fallen sharply. This would have been due to an increase in economic activity that has led to depreciate and deplete more resources and released more emissions into the atmosphere. Since 2006, UK DDASN has fallen into negative territory (bar 2007 when it is close to zero), which shows that UK total wealth has been in decline and not on sustainable path. Figure 5.9 and 5.10 provide an early warning signal to policy makers that UK is on a downward path. In order to reverse this trend, the government needs to either reinvest in produced capital or in natural capital to sustain it. However, more investment in produced capital could put additional pressure on natural capital which will not be sustainable and therefore the government needs to either reinvest in natural capital to keep it intact or invest in human capital to offset the loss in total wealth. As discussed in the earlier section, the proponents of weak sustainability argues that capital are substitutable as long as depleting natural capital can be compensated by increasing investment in country's other assets, such as, human capital. It does not mean this chapter is suggesting that natural capital should not be sustained. Instead physical indicators should be developed to monitor those natural capital which are critical for human being, such as environment degradation and biodiversity, and income from non-renewable natural capital should be reinvested either in these natural capital (strong sustainability) or in human capital (weak sustainability). For UK, which is not a resource rich country, investment in human capital is needed to increase the rate of weal growth.

Figure 5.10 shows that by adding educational expenditures (a proxy for investment in human capital) to DDANS, UK genuine savings has landed into positive territory for all years from 1988 to 2012. This means that depreciation and depletion of UK produced and natural capital is being offset by an investment in human capital. However, it is not straightforward to say that a positive genuine savings implies that UK is on a sustainable path. If genuine savings is high enough to maintain per capita wealth, then it could be concluded that UK is on a sustainable path. From 2007, although UK genuine savings per capita is positive (figure 5.11), wealth per capita is in decline (figure 5.8 and table 5.2). As discussed above, wealth per capita has declined due to a fall in overall wealth combined with an increase in population. A positive genuine savings with a fall in wealth per capita shows that UK savings has not been sufficient to compensate for a fall in wealth and population growth.

Therefore, it can be concluded that from 2007, despite positive genuine savings, UK is not on a sustainable path.

Figure 5.10 provides interesting findings for the UK policy makers. However, these findings need to be interpreted carefully. Due to data and methodology limitations, some elements of natural capital and human capital are not estimated and are not part of total wealth. For example, a number of ecosystem services, such as aesthetic enjoyment of the countryside, flood risk management, noise protection and air quality are currently missing from natural capital estimates. On the other hand, the value of human capital excludes people over the aged of 65 and non-market activities. Furthermore, this thesis does not account for employer contribution to pension schemes and employer national insurance contributions. Future research could explore how these elements could be included into the wealth accounting in order to improve UK sustainability results derived in this chapter.

Figure 5.9: UK savings, 1988 to 2012 – 2012 prices

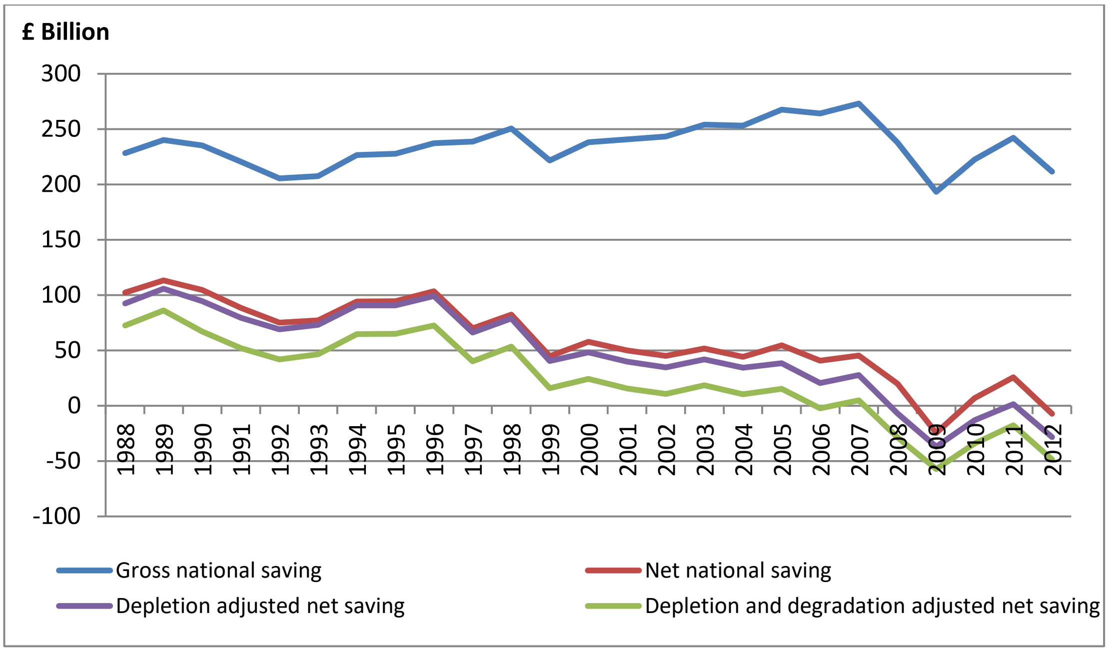


Figure 5.10: UK genuine savings, 1988 to 2012 – 2012 prices

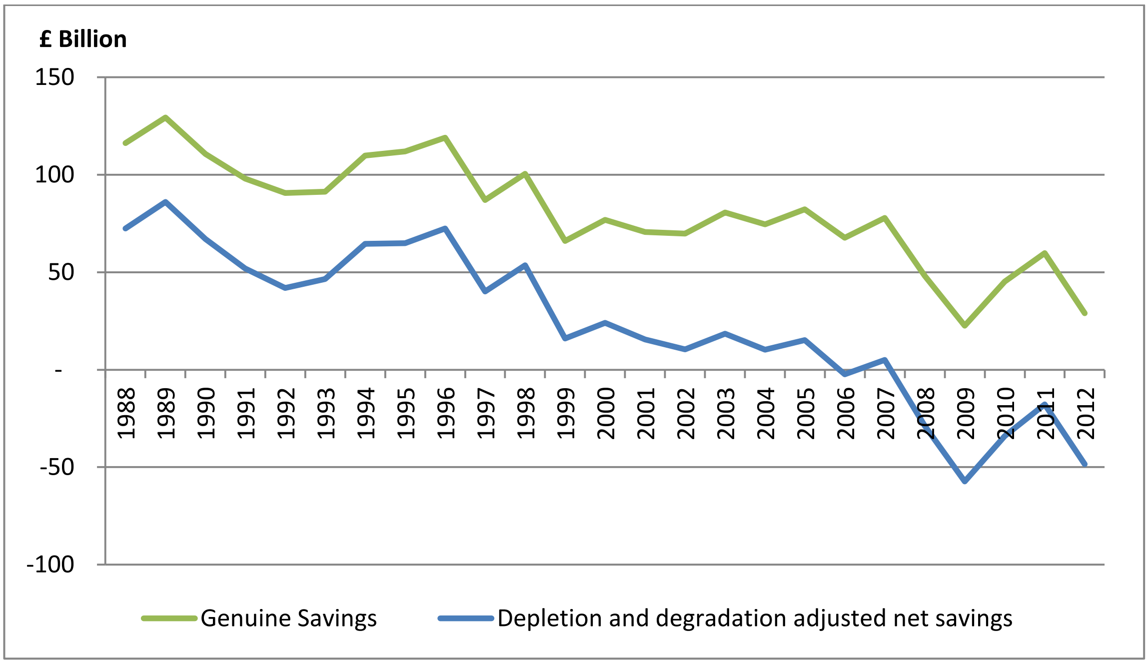


Figure 5.11: UK genuine savings per capita, 1988 to 2012 – 2012 prices

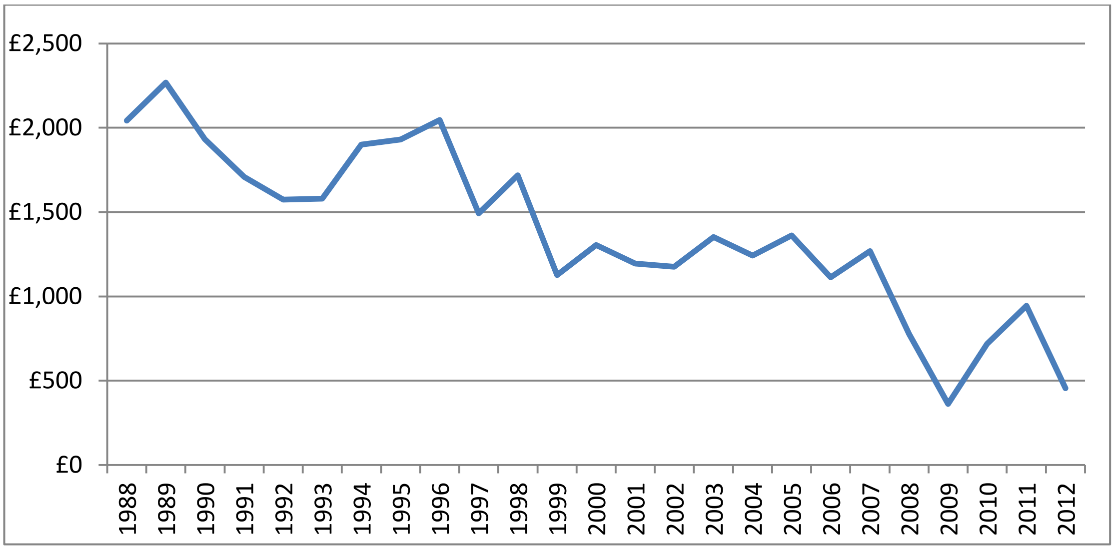
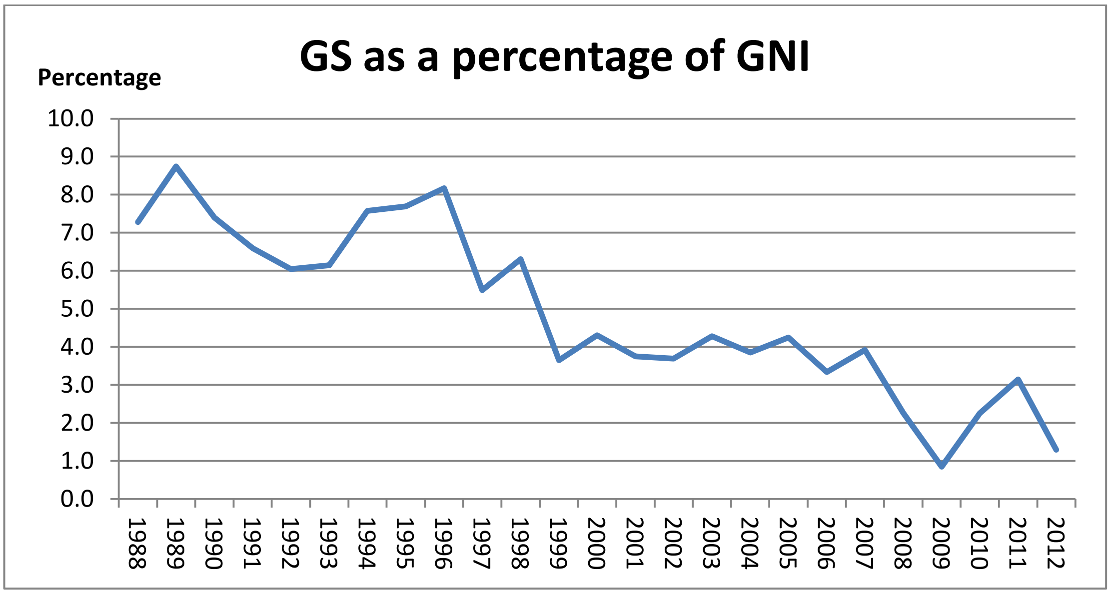


Figure 5.12 shows UK genuine savings as a percentage of Gross National Income (GNI). The figure shows that UK genuine savings, as a percentage of GNI, is declining almost every year and fell from 9% in 1988 to 1.6 % in 2012. This means that although UK is accumulating wealth by adding to savings, genuine savings is in continuous decline. If this decline continues, the UK will not be on a sustainable path as it will be running down its capital stock and thus reducing future well-being of its citizens.

Figure 5.12: UK genuine savings as a percentage of GNI, 1988 to 2012 – 2012 prices



The results from genuine savings are almost similar to the results obtained by calculating a change in wealth. Both of these indicators suggest that UK is running down its capital stock and not on sustainable path. These both indicators provide very important information to policy makers. Comprehensive wealth provides a medium to long term indicator that is more comprehensive than depletion and degradation adjusted net saving and genuine savings, but depleted and degradation adjusted net saving and genuine savings provide policy makers immediate feedback on annual basis about the direction of the economy is heading and possible changes they need to make.

8. Comparison of genuine savings with other studies

Table 5.3 provides a comparison of UK genuine savings calculated by the World Bank (2011) with the results derived in this chapter. Due to different monetary units and different base price years, a comparison of genuine savings as a percentage of Gross National Income is presented in table 5.3.

Table 5.3: Comparison of genuine savings results with World Bank (% of GNI)

Year	World Bank (2011)	This chapter
2000	8.1	5.6
2005	7.9	5.1
2008	3.9	2.9

Table 5.3 shows that UK genuine savings calculated in this chapter is lower than the World Bank's calculations. This could be due to three reasons. Firstly, it could be due to different data sources. This chapter uses National Accounts data from Office for National Statistics for most components of genuine savings; whereas, the World Bank figures for genuine savings have weakness which are inherent in the need to calculate genuine savings for 120 countries, which necessitates the use of international data sets, or the use of modelling in the case of particulate damage (Hamilton, Hartwick; 2014). Secondly, the World Bank uses a very low price ($20 per tome) to value carbon emissions. Thirdly, one of the main reasons for World Bank's higher genuine savings is the way carbon damages are estimated. The World Bank (2011) estimates the value of carbon in CO_2 emissions instead of estimating the value of total emissions emitted by CO_2. In their calculations, the World Bank (2011) multiplies the values of CO_2 by (12/44) to estimate the value of carbon in the emissions. This is because the atomic weight of carbon is 12 and of carbon dioxide is 44 and carbon is only (12/44) of the emissions. However, carbon on its own is not a greenhouse gas and does not emit emissions. It is CO_2 that emits emissions and therefore this chapter deducts the overall CO_2 emissions value from genuine savings. This approach is consistent with the comprehensive wealth calculated by "bottom-up" approach in section 4, where wealth has been adjusted for CO_2 damages.

9. Conclusion

This chapter has presented UK's first wealth accounts that are consistent with the System of National Accounts. This chapter has shown how both "bottom-up" and "top-down" approaches can be combined together to calculate not only the intangible capital but also indicators that measures a country's sustainability. By using both wealth and genuine savings indicators, this chapter concludes that though UK wealth has increased between 1988 and 2012, since 2007 it is in decline. Despite a positive genuine savings, since 2007 UK wealth has a negative growth rate and wealth per capita is in decline. A positive genuine savings with a fall in wealth per capita shows that UK savings has not been sufficient to compensate for a fall in wealth and population growth. Therefore, this chapter concludes that since 2007 UK is not on a sustainable path. In order to reverse the trend, either UK has to reduce its population growth or it needs to reinvest in all capital asset bases to increase the rate of wealth growth. However, this chapter and chapter 4 shows that decreasing the population does not necessarily increase the total wealth or wealth per capita because of the human capital embedded in the work force. For UK, which is not a resource rich country, investment in human capital is needed to increase the rate of wealth growth.

Chapter 6

Concluding remarks and future work

This chapter summaries the thesis and review the strengths and limitation of this research. It also suggests some ways forward for improving the estimates of UK total wealth over time.

1. Concluding remarks

This thesis has developed an original set of UK wealth accounts for 25 years – from 1988 to 2012 – to measure UK sustainability. While doing so, this thesis has calculated the monetary value of UK natural capital and human capital from 1988 to 2012. The monetary values of natural capital and human capital were then added into produced capital to develop a first comprehensive wealth account for the UK over 25 years (1988 - 2012). This thesis has argued that both wealth accounting approaches - "top-down" and "bottom-up" - are conceptually the same. They only differ empirically because of the methodologies employed to calculate natural capital, human capital and total wealth. This thesis has shown how both these approaches can be combined together to estimate not only the value of UK intangible capital (social capital and the stock value of technological changes), but also to measure UK sustainability.

Using comprehensive wealth per capita and genuine savings indicators, this thesis has measured UK's sustainability and has concluded that since 2007 UK is not on a sustainable path. Chapter 5 has shown that though UK wealth has increased between 1988 and 2012, since 2007 it has been in decline. Despite a positive genuine savings, since 2007 UK wealth has a negative growth rate and wealth per capita is in decline. A positive genuine savings with a fall in wealth per capita shows that UK savings has not been sufficient to compensate for a fall in wealth and population growth. Therefore, this thesis has concluded that since 2007 UK is not on a sustainable path. In order to reverse the trend, either UK has to reduce its population growth or it needs to reinvest in its capital asset bases to increase the rate of wealth growth.

The analysis in this thesis has shown that the UK has not invested enough in its natural capital but in produced and human capital to increase the rate of wealth growth. Chapter 3 has shown that although the value of UK natural capital has increased between 1988 and 2012 mainly due to an increase in the value of non-renewable assets, chapter 5 has shown that its share of total wealth has actually fallen. Chapter 5 has also shown that the share of non-renewable assets to total wealth started to decline from 2005; whereas, the share of renewable assets to wealth has been declining since 1988. This could mean that the income received from non-renewable assets is not invested in renewable assets, but might have been invested in human or produced capitals, which have increased between 1988 and 2012. However, the increase in produced and human capital has not been sufficient to compensate for a fall in wealth per capita.

As mentioned above, one way to increase UK wealth per capita is to reduce the UK population. However, chapter 5 has shown that an increase in population does not always decrease per capita wealth. This is because an increase in population driven by a skilled work force, for example, highly skilled immigrants, increases the value of human capital and thus total wealth. This increase in wealth could offset an increase in population keeping per capita wealth intact. Furthermore, chapter 4 has shown that with an ageing population, the UK human capital stock would decline unless it is replaced by younger generation, who have higher value of human capital. It could be a matter of concern that during the period 1988 - 2012 the population of the richest in human capital group (aged 16-24) has declined; whereas, the population of other groups aged 45-54 and 55-64 has increased substantially. A number of people in the younger age group could be immigrants to the UK, who could be economic migrants with high qualifications and thus earning higher income. Therefore, policies attracting young highly skilled work force into a country are on the whole positive for increasing wealth. Furthermore, for UK, which is not a resource rich country, investment in human capital is needed to increase the rate of wealth growth.

The results derived in this thesis are consistent with the System of National Accounts (SNA) and could be incorporated into UK National Accounts. To obtain SNA consistent results, this thesis has constructed a very large database which is very extensive and had been obtained from various sources. Some of the data are held by public bodies which are exclusively made available to the author for this research. Since the objective of this research is to develop comprehensive wealth estimates which are consistent with the national accounts, a large amount of data are also obtained from the UK National Accounts and where National Accounts data are not available, the author has worked with the UK Office for National Statistics (ONS) to estimate National Accounts consistent data. Where external data are used, the author has worked with the ONS to make it consistent with the National Accounts. Thus, this thesis has an advantage to all other existing studies that has measured UK comprehensive wealth and sustainability because its uses more accurate and timely data. This is an advantage relative to all other existing studies that have measured UK comprehensive wealth and sustainability, such as World Bank (2006, 2011), Inclusive Wealth Report (2012), McLaughlin et al. (2014) and Hamilton and Liu (2014).

2. Limitations

Although this thesis has constructed an extensive database and developed new methodologies to measure UK comprehensive wealth and sustainability, there are some limitations as well. The main limitations are given below:

1. The calculation of total wealth by the "top-down" approach requires assumptions about the path of future consumption. Similarly, the calculations of natural capital to calculate total wealth by a "bottom-up" approach requires assumptions about the future state of assets (including extraction pathways of non-renewable resources, management regimes for renewable resources and the extent and condition of natural habitats) and of future scarcities. Due to these assumptions there is the likelihood that consumption or certain components of natural capital are over or under-estimated. For example, due to data limitations, the value of outdoor recreation from the UK natural environment might be over-estimated because they are based on gross benefits without deducting the use of inputs; such as cost of maintaining recreational sites; whereas, the value of water resources might be underestimated because only a proportion of the water abstracted has been valued in the estimates presented in this thesis.

2. Natural capital and ecosystem services are valued in a wealth accounting context while being consistent with international accounting standards and guidelines. This approach uses the general balance sheet framework of the System of National Accounts (SNA) and extends the coverage to incorporate the value of those assets that are not

considered economic assets in the SNA. Monetary valuation of natural capital in an accounting context focuses on economic value as expressed in real or hypothetical transactions. It can reflect the value of non-market goods or services provided that it is possible to construct a hypothetical transaction leading to a price for the goods and services in question. It does not include the contribution natural capital makes to wider human welfare, such as to people's livelihood or security, nor it is seeking to capture the broader range of non-use values that people may legitimately attach to the environment, such as existence values. Natural capital and ecosystem services are valued using exchange values or market prices, which are described in the United Nations System of Economic and Environmental Accounts (SEEA)[79]. Therefore, the elements of natural capital that cannot be valued by using market prices, or for which the market prices could not be observed or estimated, are excluded from this framework.

3. Future work

Due to data and methodology limitations, some elements of natural and human capital are not estimated and therefore are not part of total wealth. Future research could explore how these elements could be included into the wealth accounting in order to improve UK sustainability results derived in the thesis. This thesis identifies the following areas for future research.

- How could ecosystem services that are excluded from this thesis (see chapter 2) be added to complete the natural capital accounts?

- How could the measured consumption function be expanded to include ecosystem services in order to value intangible capital (social capital and the stock value of technological change)? This thesis shows that the difference between the total wealth calculated by "top-down" and "bottom-up" approaches is the intangible capital. However, for this relationship to hold, ecosystem services need to be included in the measured consumption function because they are included in the valuation of natural capital as part of "top-down" approach (see chapter 5).

[79] Source: SEEA Central Framework chapter 5

- The UK natural environment is used by society for recreation, and this aspect of the value of natural capital is included in the estimates derived in this thesis. However, there will be other significant benefits from the aesthetic enjoyment of the countryside which are not included in these values. People are willing to pay higher prices for homes and, to some extent, for commercial properties in areas of great aesthetic beauty, such as coastal or woodland settings, or for the amenity benefits of urban green space and of the climate.[80] If the value of these ecosystem services were estimated and included in the monetary estimates of UK natural capital developed in this paper, the total calculated value would have been much higher.

- One regulating service, net greenhouse gases sequestration, is included in these monetary estimates. Pollination and water filtration services are important regulating services and are already partially incorporated in the value of agricultural land. However, pollination services which impact on non-crop plant, for example wild flower, are excluded. Furthermore, disentangling these values and isolating the value would make it clearer how the different components of natural capital contribute to the economy. Other important ecosystem services, such as flood risk management (or hazard protection), air quality and noise protection, are also currently missing from these estimates due to data limitations.

- Investigate the inclusion of pensions and national insurance contributions. This research does not account for employer contribution to pension schemes and employer national insurance contributions. These are part of an individual's earnings and should be accounted for especially for cross-country analyses.

- Extend the scope of the population to include people above 65 years old because, in the UK, there is no compulsory retirement age. It is very likely that some people above 65 years old are still in the labour market and therefore it makes sense to extend the upper age limit of the population.

- Explore to include non-market activities because women, in general, tend to do more non-market activities and including these activities would provide a better analysis of human capital distribution by gender.

[80] National Ecosystem Assessment, chapter 22

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