LUND UNIVERSITY
School of Economics and Management

Master's Programme in Innovation and Global Sustainable Development

What will be needed in terms of savings and investments to offset the impact of population growth and achieve sustainable development?

A forecast of Swedish genuine savings between 2017-2047

Johanna Pauli

jo1145pa-s@student.lu.se

Abstract

Evidence is indicating that human activity within the Anthropocene, the proposed geological epoch of the current time, are causing extraction of natural resources and land, terraforming, climate change and mass extinction of species (Anthropocene: The Human Epoch, 2018). The identified environmental pressure will continue to grow as the global population is expected to reach 11 billion before the end of the 21st century (UN, 2019, p.1). Hence, estimating and communicating the impact of, and compensation for, human activity is essential. This thesis presents a forecast of the necessary increase in savings and investments for Sweden between 2017-2047 to offset the impact of human activities and achieve sustainable development. From an elaborated time-series of genuine savings (GS), an alternative measure to GDP, extending from 1850 to 2017, this study have quantitatively identified what will be needed for intergenerational equity. In accordance to three constructed scenarios, the results identified that a population growth similar to, or greater than, the current will require GS as % GDP for Sweden to increase with at least 69 % to 2047. In contrast, a population growth close to zero will allow GS as % GDP to decrease with 16.5 % to 2047. The forecast provides a good indication of how non-declining wealth and utility should be achieved. In practice however, substantially more effort will be required for sustainable development.

Keywords: Sustainable development, weak sustainability, strong sustainability, genuine savings, population growth

EKHS34
Master's Thesis (15 ECTS)
May 2020
Supervisor: Cristián Ducoing
Examiner:
Word Count: 13 376

Acknowledgements

First, I want to thank my supervisor Cristián Ducoing for his great enthusiasm for the topic of my thesis, for his patience and insightful comments and ideas. Secondly, I am extremely grateful for the love and support I have received from my friends and family. Not only during this thesis period, but throughout the entire year of this master's programme. Without you, I would not be where I am today.

Table of contents

Abbreviations

ANS	Adjusted Net Savings
CO_2	Carbon Dioxide
GNI	Gross national income
GNNP	Green net national product
GNS	Gross national savings
GS	Genuine Savings
N-leakage	Carbon leakage
NNS	Net national income
NNSEE	Net national income + current operational educational expenditure
NO_x	Nitrogen oxides
PM_{10}	Particulate matter (air pollutant)
$PM_{2.5}$	Fine particulate matter (air pollutant)
SO_2	Sulfur dioxide

List of Figures

List of Tables

List of Equations

1 Introduction

The Canadian documentary film "Anthropocene: The Human Epoch", portrayed a world where humans have taken control over the planet and where the human impact on the environment have increased beyond all natural processes of the earth combined (Anthropocene: The Human Epoch, 2018; Anthropocene Films, 2018). The documentary illustrated how human activity had caused extraction of natural resources and land, terraforming, climate change and mass extinctions of animal species that all together is threatening the existence of human life. A geological shift from one epoch to another occurs when significant changes within the stratigraphic ground has been identified, visualised by changes in among other; the sea level, the global temperature, the level of carbon dioxide (CO_2) in the atmosphere and lastly, the size of the global population (Zalasiewicz et al., 2008). The current geological epoch, the Holocene, have proceeded for almost twelve thousand years (Fairbridge & Agenbroad, 2018). Over the last decades, however, scientists have identified that human activities have left a permanent mark on the environment and the global stratum, the layers of rocks of the earth, and are consequently arguing that we are entering into a new geological epoch, the Anthropocene (Steffen, Crutzen & McNeill, 2007; Steffen, Grinewald, Crutzen & McNeill, 2011; Zalasiewicz et al., 2008; Zalasiewicz, Williams, Haywood & Ellis, 2011).

The term, the Anthropocene, did first receive public attention in 2000 when Crutzen and Stoermer (2000) discussed how human activity within the last three decades has turned into a geological force, referring to the increasing global population and their use and extraction of land and natural resources. Earlier, the same implication was raised by Stoppani in 1873 who defined human activity within the Anthropocene as a "*new telluric force which in power and universality may be compared to the greater forces of earth*" (Crutzen, 2002). At the turn of the century, the global population reached 6,1 billion, and as for today, an additional 2 billion people are walking the earth as the global population was estimated to 7,8 billion in 2020 (Worldometer, 2020). Future estimations presented by the United Nations within the "World Population Prospects 2019" are indicating that before the end of the 21st century, the global population expects to reach 11 billion (UN, 2019, p.1). Further remarked was that human individuals are the main determinant of sustainable development and the report pointed specifically towards four trends of the global population; population growth, population aging, urbanisation and migration. Hence, the impact of human activities cannot, and should not, be ignored. Yet, a gap within the economic literature has been defined on how to properly estimate the increase in savings and investments that will be necessary to offset for the growing pressure placed by humans on the environment, and to achieve sustainable development.

The concept of sustainable development was defined within the Brundtland report in 1987 with the implication of maintaining wealth throughout generations, which accordingly implies achieving intergenerational equity (WCED, 1987). The Brundtland Report, more formally referred to as "Our Common Future", was presented by the World Commission on Environment and Development (WCED) in 1978 and included multiple with long-term strategies for achieving sustainable development. Within economic theory, two opposing approaches on how intergenerational equity should be achieved have been developed, the concepts of *weak- and strong sustainability* (Pearce, Markandya & Barbier, 1989, pp.34-30; Neumayer, 2003, p.21). The strong sustainability approach has been considered as perfectly applicable to the definition of sustainable development since, among others, denoting that all environmental assets are necessary to maintain intact over time (Beckerman, 1994). Any decline in the stock of natural capital is accordingly considered as a signal of unsustainability following the concept of strong sustainability. Based on the work by Hartwick (1977; 1978a; 1987b) and Solow (1974; 1986) on how to achieve intergenerational equity with the existence of finite and exhaustible resources, the concept of weak sustainability was evolved. Weak sustainability is based on the neoclassical assumptions that natural capital could be substituted by other forms of capital within the total capital stock (Neumayer, 2003, pp.22-24). However, the assumption of perfect substitution of natural capital only holds as long as the reduction is appropriately compensated by an increase in other forms of capital, mainly referring to man-made capital, to ensure non-declining wealth and utility across generations. To achieve sustainable development in practice, both weak- and strong sustainability should be emphasised. Additionally, weak sustainability can be considered as a pre-condition for strong sustainability and consequently, the approaches are somehow interlinked. As for today, the economic literature on weak- and strong sustainability has not reached a consensus on which approach ought to be applied within research. Hence, choice of approach will be highly dependent on individual preference and opinions; however, choosing between weak and strong sustainability has been considered as significant for accuracy and consistency (Blum, Ducoing & McLaughlin, 2017).

Sweden is well-known for placing great emphasis on sustainable development and aims to become a global leader in implementing the 17 Sustainable Development Goals following Agenda 2030, the action plan adopted by the UN to achieve sustainable development by 2030 (UN, 2017). In addition, within the latest release of the Environmental Performance Index[1] from 2018, Sweden was ranked 5th on a global scale (Wendling, Emerson, Esty, Levy, de Sherbinin, 2018, pp.1-3; 5-6). The index ranks countries based on 24 indicators of sustainability, both regarding environmental health and ecosystem vitality and includes factors such as air quality, level of pollution and the loss of forest and stock of fish. Sweden performed best within indicators related to the exposure of fine particulate matter ($PM_{2.5}$) and heavy metals such as lead; emissions that may have severe implications on human health (EPI, 2020). By contrast, Sweden received low scores within categories related to tree cover loss and species habitat index, in which the latter indicated a reduction in the proportion of habitat remained for species relative to the baseline year 2001. The impact of human activities have been significant in Sweden over the last decades, demonstrated both through an increasing population and a considerable rise in the extraction of natural resources. First, Sweden has experienced a substantial inflow of immigrants within the 21st century along with relatively high rates of natural population growth (Statistics Sweden, 2020a; Swedish Institute, 2020a). In 2015-2016, a peak within the immigration was identified in which a large number of war refugees migrated to Sweden (Swedish Institute, 2020a). Even though immigration has decreased since then, the increasing population of Sweden is still a standing concern. In 2019, the Swedish population was estimated to 10 327 589 and accordingly, the population growth rate was set to 0.952 % (Statistics Sweden, 2020b). Figure 1 illustrates a clear upward-going trend in the total population of Sweden from 1860 to 2019, in which a further increase can be identified after 2010 when the population growth outpaces the dotted trend line.

[1] The Environmental Performance Index (EPI) is produced by Yale Center for Environmental Law & Policy, Yale University and Center for International Earth Science Information Network, Columbia University in collaboration with the World Economic Forum (Wendling, Emerson, Esty, Levy, de Sherbinin, 2018).

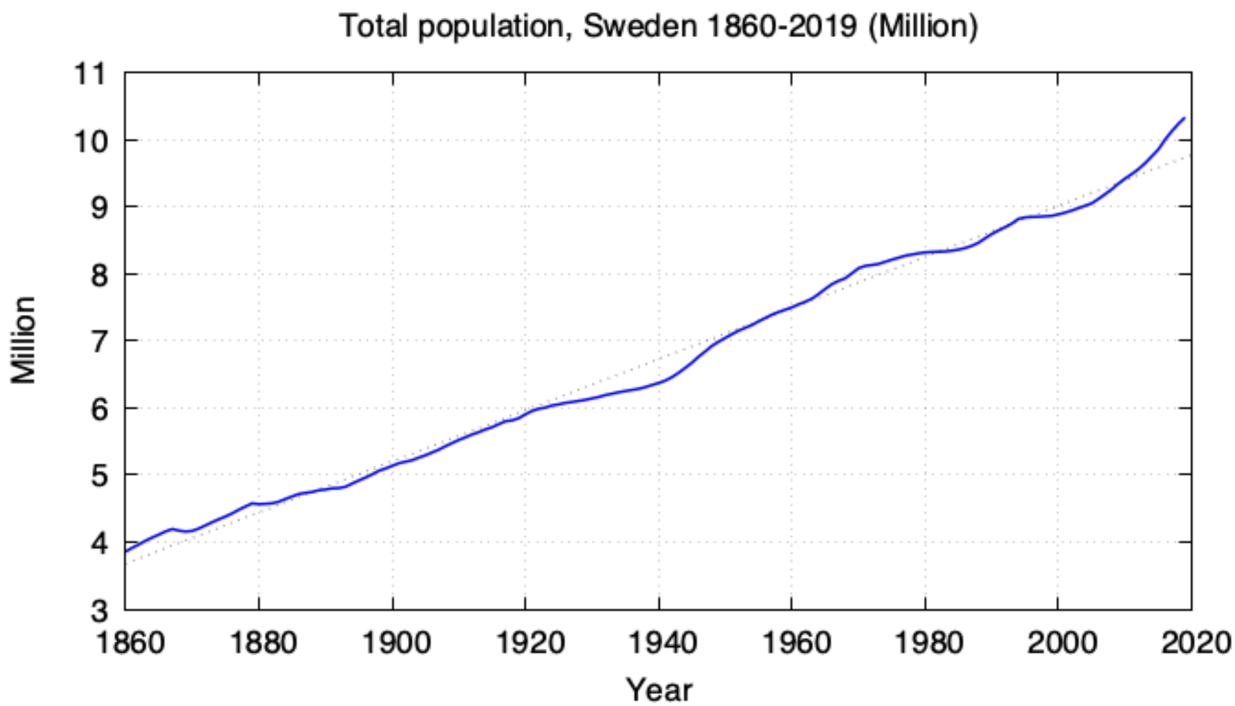

Figure 1. Total population of Sweden, 1860-2019 (Own illustration with data from Statistics Sweden, 2020b).

Secondly, even though Sweden is a country rich in natural resources, the national extraction has increased remarkably since the end of the 20th century (Statistics Sweden, 2018). In 2017, the total extraction of natural resources was estimated at 250 million tonnes, an increase of 13 million tonnes, or 5 %, since the year before (Statistics Sweden, 2018). The main source of extraction was identified as sand and gravel, followed by timber and metal, including iron ore, copper ore and gold and silver ore. Since then, the growth rate has been slower as a consequence of among others, the summer drought and crop failure in 2018 (Statistics Sweden, 2019). Nevertheless, the national level of extraction in Sweden was still identified as above the EU-average within the publication and was estimated at 252 million tonnes in total in 2018. However, sustainable development and environmental awareness pervade the national population and the economic system of Sweden, placing the country on a leading edge in terms of sustainability. The public image of Sweden is acknowledged by their leading position globally within innovation and green technology (cleantech) (Swedish Institute, 2020b) and further by their considerable investments in research and development (R&D) (OECD, 2018). In 2018, the gross domestic spending on R&D accounted for 3.3 % of Swedish GDP, identified as being the highest share among all countries within the

European Union (EU) (OECD, 2018). However, despite prosperity, the evidence just presented are indicating that Sweden is facing several challenges concerning increasing population growth and a rise in the extraction of their natural capital. The contradictory facts of Sweden in terms of sustainability turns the country into an interesting case in terms of analysing their future achievements to offset the pressure placed by human activities.

1.1 Study aim and research problem

Usually, the outcome of human activity and economic performance are studied through changes in GDP or GNP, indicators that are capturing the flow of income and in which the latter only accounts for the economic activity generated by the national residents (Chappelow, 2020a; 2020b). Per definition, neither GDP nor GNP measures sustainable development nor takes into account whether the income is generated with any negative environmental impact. Sustainable development under any definition aims to maintain wealth over generations (Hamilton & Clemens, 1999), and hence, using GDP or GNP as an indicator of sustainable development will become misleading. Consequently, several indicators of sustainable development and measures of national wealth have been presented by various schools within economic theory over time, among other genuine savings (henceforth, GS). Pearce and Atkinson (1993) introduced GS as an indicator of weak sustainability in which a country is considered to be sustainable if and only if national savings are greater than, or equal to, the aggregate value of depreciation of man-made capital and natural capital. The simple model of GS uses GDP as a foundation and includes the value of investments placed on human capital and less the value of natural degradation and pollution (Pearce & Atkinson, 1993). Over time, the indicator has been adopted by the World Bank and further modified by various authors. Among other, Lindmark and Acar (2013) extended the model to be more applicable to the current environmental issues by additionally accounting for the value of multiple pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM_{10}), carbon leakage ($N - leakage$) and biologically infected water. The emissions from CO_2 was accounted for in the original model.

Provably, the impact of human activity on the environment is severe. In accordance with the history of national economic development and future predictions, the global population will continue to increase over the next decades and centuries. From the lack of accuracy with GDP in terms of sustainability, adopting alternative measures of economic activity will be essential to estimate the consequences of economic activity properly. Further, communicating national performance is important to understand and to offset population growth and its growing pressure on the environment, on a national and global level. This leads to the main aim of this thesis, to quantitatively analyse and forecast GS of Sweden based on three different scenarios of population growth. Based on population statistics extending from 1860 to 2019 presented by Statistics Sweden (2020b), three possible future scenarios will be adopted based on previous rates of annual population growth. One scenario will represent the most recent available population growth rate from the population statistics. Additionally, two hypothetical scenarios will be adopted to represent two possible scenarios that may occur in the near future, one with an annual growth rate smaller than the current, and one greater than the current. Accordingly, to enable this, a long time-series of GS have been elaborated by combining data presented by Lindmark and Acar (2013) and the World Bank (2019a; 2019d; 2019e) to extend from 1850 to 2017. GS will be presented as the percentage share of GDP (henceforth, GS as % GDP) and 2017 will be used as a baseline and be representative for the current date. Following the concept of weak sustainability, the wealth of 2017 should be maintained over time to achieve intergenerational equity. Therefore, the forecast of GS will be conducted following the three scenarios of population growth and be presented for three future points in time, 10, 20, and 30 years from 2017. Accordingly, two research questions have been stated. The first research questions have been specified to generate the three scenarios necessary for answering the second research question. Hence, the main research question of this thesis is the second research question.

1. ***Based on three scenarios of population growth, what will the size of the total Swedish population be in 10, 20 and 30 years from the current time?***

and

2. ***Based on three scenarios of population growth, what will the necessary increase in GS be in 10, 20 and 30 years from the current time to ensure intergenerational equity?***

From the lack of historical estimates of GS extending to the current date and forecasts to ensure sustainability over time, this thesis may contribute with useful information and insight for both policymakers and researchers. Estimating and communicating the consequences of human activity on the environment and the stock of natural capital is essential for sustainable development. Forecasting the necessary increase in savings, investment and sustainable development to offset for the growing population may raise awareness of the consequences of the increasing use of land and natural resources it implies and contribute with some behavioural change. Also, no other studies have been found that forecast GS, with or without population growth.

1.2 Outline of the Thesis

The outline of this thesis will be presented as follows; section 2 will give the theoretical implication of sustainable development and its opposing approaches of weak and strong sustainability. Further, the theoretical background on GS will be presented, followed by the previous research on using GS as a replacement for GDP. Section 3 will introduce the data that has been collected for the quantitative analysis and the process of elaborating already existing data on GS into one long consistent time-series. Section 4 will outline the methodology behind genuine savings and the approach applied to forecast wealth based on three scenarios of population growth. Section 5 will present an empirical analysis of the results, while the concluding discussion will be given in Section 6. Lastly, references and Appendix will be presented at the end of the thesis.

2 Theory

This section aims to explain the concept of sustainable development and its two opposing approaches on how to achieve intergenerational equity, *weak and strong sustainability*. Further, the theoretical background and previous research on GS will be presented. This section will highlight the importance of replacing and/or complementing GDP as a measure of sustainable development.

2.1 Sustainable development

In recent decades, a widening within the economic literature has been identified in which the appearance of environmental issues from human activities have received increasing attention. Sustainable development was defined within the Brundtland report as, "... *the development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*" (WCED, 1987). The main audience for the "needs" was raised to be the poor population. Since then, the definition has become universally accepted to explain sustainable development. However, despite being frequently used, the definition has not managed to avoid criticism and scepticism over time. Beckerman (1994) analysed the use of sustainable development per definition and raised the inadequate definition of the "needs", both regarding the present and future generations. Explained by the author was that the "needs" of an individual is highly dependent on time and space and additional individual factors such as income and background. Hence, to use sustainable development per definition as something desirable, the authors argued that the concept needs to be technically defined, or complemented, to allow for valuation and utilised within analyses for economic performance. To solely use the "needs" on how to achieve sustainable development was argued by the author as indefinite.

By way of introduction, to properly understand the implication of sustainable development within economic theory, the distinction between economic growth and *sustainable* economic growth needs to be highlighted. While economic growth implies increased real GDP or GNP over time, sustainable economic growth requires the growth to be achieved without any biophysical- or social impact (Pearce, Markandya & Barbier, 1989, p.33). By definition, sustainable economic growth takes into account whether the economic activity is generated with any negative environmental impact such as pollution or degradation of natural resources and land. Sustainable development within economic theory is commonly studied through the level of utility or well-being, two terms with the same purpose, received by the population from the total capital stock (Pearce, Markandya & Barbier, 1989, p.32). Hence, sustainable development is achieved by presenting constant or improved levels of utility or well-being per capita over time (Pearce, Markandya & Barbier, 1989, p.32).

Moreover, Pezzey (1992) defined sustainable development and sustainable growth as non-declining consumption per capita and non-declining utility per capita over time. Within the economic theory, the author argued how both non-declining-conditions have to hold to achieve sustainable development. The condition of non-declining consumption was based on the work presented by Hartwick and Solow. Hartwick (1977; 1978a, 1978b) explained how intergenerational equity should be achieved by reinvesting all the rents received from the depreciation of exhaustible natural capital into reproducible capital. Accordingly, to ensure that the production capacity will be transmitted over time and that no generation would be better off, Hartwick (1977) advocated efficient use of natural resources and substitution between various forms of capital. Solow (1974; 1986) argued that the elasticity of substitution between natural capital and man-made capital should be no less than unity to ensure constant consumption and intergenerational equity. The author argued that the present generation should be allowed to reduce the stock of natural capital as long as the reduction is appropriately compensated by an increase in reproducible-; man-made, capital to ensure that the total capital stock is preserved intact. This discussion have later turned into a commonly used rule for intergenerational equity and sustainable development; the "Hartwick rule", or the "Hartwick-Solow rule".

2.2 Weak and strong sustainability

Sustainable development as intergenerational equity was defined by Pearce, Markandya and Barbier (1989, pp.34-40) as implying that each generation should receive the same amount of wealth, relating to the utility or well-being obtained from both man-made capital and natural capital (environmental assets). The authors presented two interpretations of how constant wealth could be achieved, by preserving the *total* stock of capital over time or solely the environmental assets within the *natural* capital stock due to their essential function for humanity. As for today, this discussion has resulted in two approaches commonly used within debates and economic theory related to sustainable development today, the concepts of *weak- and strong sustainability* (Neumayer, 2003, p.7).

Multiple contributions to the concept of strong sustainability have been presented over time, and hence, the approach has not become mainstream within economic theory. However, Neumayer (2003, pp.24-25) enlightened that the essential within strong sustainability is that other forms of capital cannot substitute natural capital. The author presented two interpretations on the condition adopted within the literature. One interpretation argues that substitution between renewable and non-renewable resources should be allowed as long as the aggregate value received from the stock of natural capital remains constant over time. Contrary, the other interpretation argues that the condition should only apply to the physical stock of critical natural capital, the natural capital that provides essential functions for the existence of life, to ensure their function remains intact over time. Costanza and Daly (1992) advocated strong sustainability and argued that man-made capital should be considered as a complement to natural capital rather than a substitute. For the condition of perfect substitution of natural capital for man-made capital to be applicable, the authors argued that the opposite must hold, which is practically not the case. Additionally, strong sustainability is considered as emphasised within the definition of sustainable development since it among others entails perfect conservation of species, both animals and plants and allows for no substitution between different forms of capital (Beckerman, 1994; WCED, 1987). Consequently, Beckerman (1994) considered strong sustainability to be "morally repugnant" since indicating that the present generation should look beyond the current global problems such as poverty to among others, instead of preserving species even though the outcome and utility received by future generation are uncertain. The author further explained that, rather than holding the natural capital stock intact, substitution between forms of capital should be allowed to maximise welfare throughout generations. Later on, the concept of weak sustainability emerged to address the flaws of strong sustainability (Beckerman, 1994).

The first to present weak sustainability as an indicator of sustainable development was Pearce and Atkinson (1993) who generated an equation based on the neoclassical framework and with the crucial assumption that natural capital could be substituted by man-made capital. The authors first presented weak sustainability as a savings rule, as illustrated in Equation 1.

$$Z_0 > 0 \ iff \ \left(\frac{S}{Y}\right) > \left[\left(\frac{\delta_M}{Y}\right) + \left(\frac{\delta_N}{Y}\right)\right]. \tag{1}$$

In Equation 1, Z_0 represents the sustainability index, S savings, Y income, and δ_M and δ_N, the value of depreciation of man-made capital and natural capital, respectively. By dividing by income, each component will be presented as a ratio of income and not in absolute value. Following the savings rule, a value of Z_0 greater than zero would indicate that an economy is on a sustainable path. Accordingly, an economy would be considered as sustainable if and only if their savings are greater than the aggregate value of depreciation of man-made capital and natural capital. Since the value of depreciation of man-made capital and natural capital has been placed within brackets, substitution between the two forms of capital will be possible as long an increase in the other compensates a reduction in one of the components. The will be essential to ensure that the total value of depreciation does not become greater than savings. Based on the savings rule, the authors also developed an indicator of weak sustainability, illustrated in Equation 2.

$$Z_1 = \left(\frac{S}{Y}\right) - \left(\frac{\delta_M}{Y}\right) - \left(\frac{\delta_N}{Y}\right). \tag{2}$$

Thus, within Equation 2, Z_1 becomes a measure of marginal sustainability in which a negative value of Z_1 will become an indicator of unsustainability. Similar to Equation 1, Z_1 will be negative if the aggregated value of depreciation of man-made capital and natural capital becomes greater than the value of savings. The greater negative value that Z_1 holds, the more effort will be needed from an economy to achieve sustainable development.

Additionally, Pearce and Atkinson (1993) applied the indicator of weak sustainability to a set of developed and developing countries. Their results indicated that only 8 out of the 18 countries in their study exhibited a positive value of Z_1. Countries who demonstrated a positive value of Z_1, and "passed" the weak sustainability test, was among other Costa Rica, Japan, Poland and the United States. The authors concluded that a similar indicator could be developed for the concept of strong sustainability in which any decline in the stock of critical natural capital would be a sign of unsustainability. Such an indicator would be almost impossible to construct according to the authors since it would imply that all critical natural capital needs to be measured and given an accurate monetary value of their functions.

The crucial assumption within weak sustainability of a high degree of substitution between natural capital and man-made capital has been both advocated and criticised over time. Among others, Stiglitz (1974) argued that substitution between capitals should be seen as one of three great economic forces that could be used to target the limitations placed by exhaustible natural resources to the economic- and population growth. Contrary, Gutés (1996) raised that, by assuming perfect substitution, less emphasis will be placed on conserving natural resources and ensuring sustainable development since the function of natural capital within the economic system will be possible to replace with man-made capital. The author therefore suggested that the assumption should be limited to some forms of capital and occur at various degrees. Among others, the authors considered that critical capital should hold a degree of substitution closer or equal to zero to ensure that their function remains intact. Consequently, the author proposed an extension to the weak sustainability approach in which natural capital should enter the production function in three forms. Accordingly, natural capital should enter as critical natural capital, non-critical natural capital and man-made capital to allow for various degrees of substitution, and in which man-made capital accounts for the capital that has been substituted natural capital.

2.3 Genuine savings as a replacement of GDP

GDP, short for gross domestic product, is the most common measure of economic growth and development and demonstrates the total monetary value of the national economic activity, including all goods and services produced within the domestic borders at a particular time (Chappelow, 2020a). GDP is mainly studied and analysed on an annual basis, in total value and per capita, in which the latter accounts for the size of the population. Furthermore, GNP is the gross national product and unlike GDP only accounts for the production generated by the residents of a country by excluding the income earned by foreign workers (Chappelow, 2020b). By definition, neither GDP nor GNP takes into account whether the income is generated with any negative environmental impact. Instead, all economic activity will be accounted for following both measures, including human activities such as extraction of critical natural capital. Costanza, Hart, Posner and Talberth (2009, pp.3-4) enlightened how GDP per definition measures the national economic activity rather than the economic well-being and is not appropriate to use within discussions and studies of sustainable development. The economic literature has, however, not agreed upon whether GDP should be positively adjusted to account for factors related to sustainability or entirely replaced. Costanza et al. (2009, pp.11-12) further explained how several measures and indicators are using GDP or GNP as a foundation and either adds or subtracts factors related to economic, social and environmental issues that are considered to be lacking. [2]

The arising environmental issues in recent decades have resulted in an increasing environmental awareness and a constant search among researchers for suitable indicators of sustainable development. Victor (1991) explained how capital theory could be useful to analyse how the capital stock should be maintained. However, since the economic literature consists of several scholars, different approaches have been presented over time, in which the author highlighted the essential. The neoclassical school within economic theory is mainly concerned with utility maximisation and assumes that individuals are rational and make economic decisions that will provide them with the highest possible level of utility. Accordingly, the author stated that, what differentiates the neoclassical framework from other schools is how they assume a high degree of substitution between natural capital and man-made capital. Hence, no distinction is made between forms of capital within the neoclassical theory as both forms yield value into the production of goods and services. Stern (1997) enlightened two subfields within economic theory related to sustainability, environmental- and ecological economics, separated by the level of elasticity of

[2] There have been several attempts to include the value of environmental damage into GDP, among others by Hamilton (1994). However, as for today, no approach has successfully become mainstream.

substitution assumption for economic growth. The environmental economists Dasgupta and Heal (1974), argued that the elasticity of substitution between exhaustible resources and reproducible capital could become an essential determinant for the optimal rate of depletion of exhaustible resources. Argued was that the same hold for investments to sustain economic growth. Accordingly, the authors stated that, as long as the elasticity of capital is greater than the elasticity of resources, the output, and economic growth, will be at least constant over time, even with a declining stock of natural (exhaustible) resources. Accordingly, economists within the environmental field are advocates of weak sustainability. Contrary, Stern (1997) enlightened how ecological economists are considering that the neoclassical school are ignoring some essential functions that certain natural resources provides, and opposite, believes that extraction of these resources should be limited. Similar to the concept of strong sustainability, ecological economists are more restrictive to the assumption of perfect substitution.

In the 1990s, the World Bank (1995, pp.3-4) adopted a new approach within green national accounting to solve for the lack of accuracy within current measures of economic performance. Raised within the report was the importance of ensuring that environmental consequences are accounted for within national accountings and that enough wealth is accumulated through savings to achieve sustainable development. GS was accordingly presented within the report as a useful indicator to estimate whether enough wealth is generated and maintained for future generations. GS was defined within the report from 1997 as "..: *the true rate of savings in a nation after due account is taken of the depletion of natural resources and damages caused by pollution*" (World Bank, 1997, p.7). Based on the savings-rule following the concept of weak sustainability presented by Pearce and Atkinson (1993), Hamilton and Clemens (1999) introduced the first formal model of GS. The authors displayed GS as the sum of investments in produced assets and human capital minus the value of depletion of natural resources and the aggregate value of pollution from various emissions. Following the weak sustainability indicator, a negative value of GS will imply intergenerational *in*equality since the utility received by future generations will be less than the current due to high depreciation of natural capital or insufficient amount of savings and investments. Hence, a negative value of GS will serve as an indicator of an unsustainable trend of an economy and an indicator of that the current generation is consuming the capital stock of future generations, leaving them with fewer assets than the current. In contrast, a value of GS equal to or greater than zero will follow the Hartwick rule as the depreciation of natural capital is appropriately compensated by savings and investments. Accordingly, the concept of weak sustainability have been referred to as the "Hartwick rule" or the "Hartwick-Solow rule" (Gutés, 1996).

The relationship between changes in GS and changes in utility was analysed by Hamilton and Withagen (2007). The authors explained that the instantaneous utility received by a population would increase over time if GS is positive and either increases or decreases at a rate lower than the interest rate. The authors considered the opposite to hold and that increasing or decreasing GS at a rate lower than the interest rate when GS is negative will imply reducing instantaneous utility over time. Therefore, for sustainable development, the authors suggested positive GS to be a policy rule within each economy.

In addition to the formal model, Hamilton and Clemens (1999) presented the first empirical cross-country analysis of GS in developing countries, with and without educational investments. Following the results of their study, the high-income OECD region presented positive values throughout the whole period 1970-1993 while the Middle Eastern region presented negative values. Argued by the authors was that the difference appeared from their various dependency on natural resources, in which the Middle Eastern region holds a high dependency. Furthermore, the Sub-Saharan African region presented negative values throughout the whole period, in line with their poor results in various indicators of human well-being in accordance to the authors. When the educational investments was included into the model, the results for some regions remained almost unchanged. However, the OECD region and East Asian- and the Pacific region presented increased their share of GNP as GS from their substantial investments in education. The country-wise results indicated that GS as % GNP for Sweden decreased continuously over the period, from 18.3 % in 1970 to 5.6 % in 1993.

The World Bank has presented estimates of GS within several reports since the mid-1990s, and in which they sometimes refer to the indicator as Adjusted net savings (ANS) since being an adjustment of the gross national savings (World Bank, 2006, pp.35-37, Figure 3.1). Throughout this thesis, ANS will only be used when referring specifically to the data presented by the World Bank (2019a; 2019b; 2019c; 2019d; 2019e); otherwise, GS will be used consistently. Within the report from 2006 (World Bank, 2006), GS was presented as percentage share of GNI for 140 countries, and Sweden was ranked as the third wealthiest country in the world (p.20) with GS as 15.8 % of GNI in 2000 (p.168). Later on, in 2008, GS as percentage GNI for Sweden increased to 20.5 % (World Bank, 2011, p.193). As for today, the World Bank (2019b) presents annual estimates of ANS as a percentage share of GNI between 1990 and 2017. Figure 2 illustrates ANS including particulate emissions damage for Sweden as percentage share of GNI. The graph indicates that GS has been relatively constant since 1995 with a small increase and decrease around the financial crisis in 2008. [3]

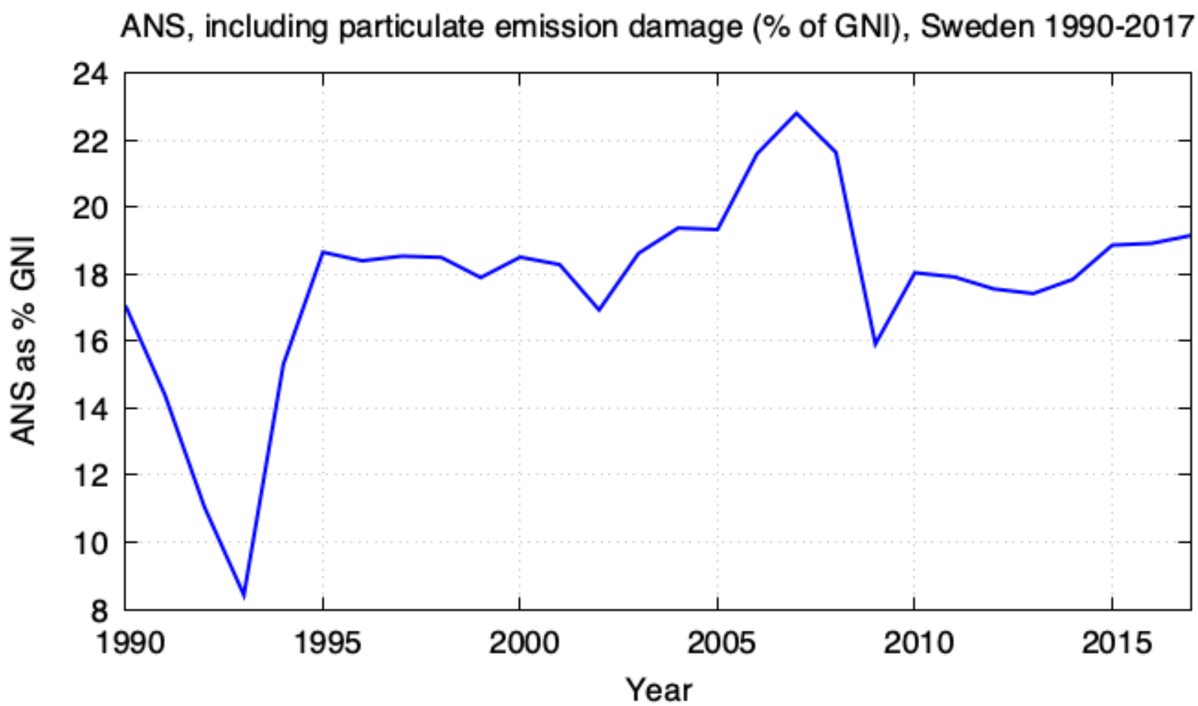

Figure 2. Adjusted net savings, including particulate emission damage (% of GNI), Sweden 1990-2017 (Own illustration with data from the World Bank, 2019b).

Blum, Ducoing and McLaughlin (2017) conducted a cross-country analysis of GS throughout the 20th century, including both developed- and resource-abundant countries. Initially, the authors explained how previous studies solely had presented single country analysis on countries with

[3] Within Figure 2, the drastic drop in ANS visualised at the beginning of the 1990s can be explained by the Swedish banking crisis. During this time, the Swedish economy went into a major recession and GDP dropped significantly between 1991-1993 (Englund, 1999).

favourable access to data, making comparisons between studies, and hence countries, difficult or almost impossible. Identified within the analysis was that some historical events such as the two World Wars and the Great Depression have negatively affected GS for the majority of the countries within their study, visualised by substantial losses in wealth at those times. Following the simple model of GS presented by Hamilton and Clemens (1999), Blum, Ducoing and McLaughlin (2017) extended the model to among others include the net present value of the total factor productivity (TFP). Explained by the authors was that TFP could serve as an indicator of technological progress and consumption possibilities of future generations. Identified within the results was that TFP became the single largest contributor to changes in GS, defined as including both human and social capital and the quality of formal and informal institutions.

Earlier, Lindmark and Acar (2013) addressed the need for taking social, economic and environmental factors into account within green national accounting. Enlightened by the authors was that previous measures of economic growth such as GDP lack accuracy and credibility since excluding some factors of sustainability and the cost of adverse environmental externalities generated from economic activities. Moreover, the authors identified a gap within the economic literature on GS and conducted an analysis of GS for Sweden between 1850-2000 to identify and understand the long-term determinants of change. For the model to apply to the current environmental problems, the authors extended the model of GS previously presented by the World Bank. Accordingly, the model proposed by Lindmark and Acar (2013) includes net investments in man-made capital, the stock of natural capital, analysed through net changes in standing timber volume and depletion of mineral reserves, the current educational expenditures and the flow of environmental damages. While the previous models of GS solely included CO_2 emission, the authors additionally included emissions from sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM_{10}), N-leakage and biologically infected water.

Figure 3 illustrates GS as % GDP for Sweden between 1850 and 2000 following the data presented by Lindmark and Acar (2013). Within the figure, the thicker (red) line illustrates GS as % GDP in current prices while the thinner (green) line represents GS as % GDP in fixed 1912/1913 prices. From the historical analysis, the authors identified that Swedish GS changed from negative to positive first in 1910, and considered it to be the results of industrialisation. The authors labelled this time "The Great Transition of Swedish Sustainable Development". Additionally, two structural breaks were identified, in 1953 and 1975, in which the first was distinguished by a significant increase in the depletion of natural resources and pollutants from industrialisation. Contrary, in 1975, the emissions in Sweden drastically decreased, argued by the authors as a consequence of among other the environmental policy that was implemented in Sweden in the 1960s, the Environmental Protection Act. As net national savings increased at that time, the value of GS was improved.

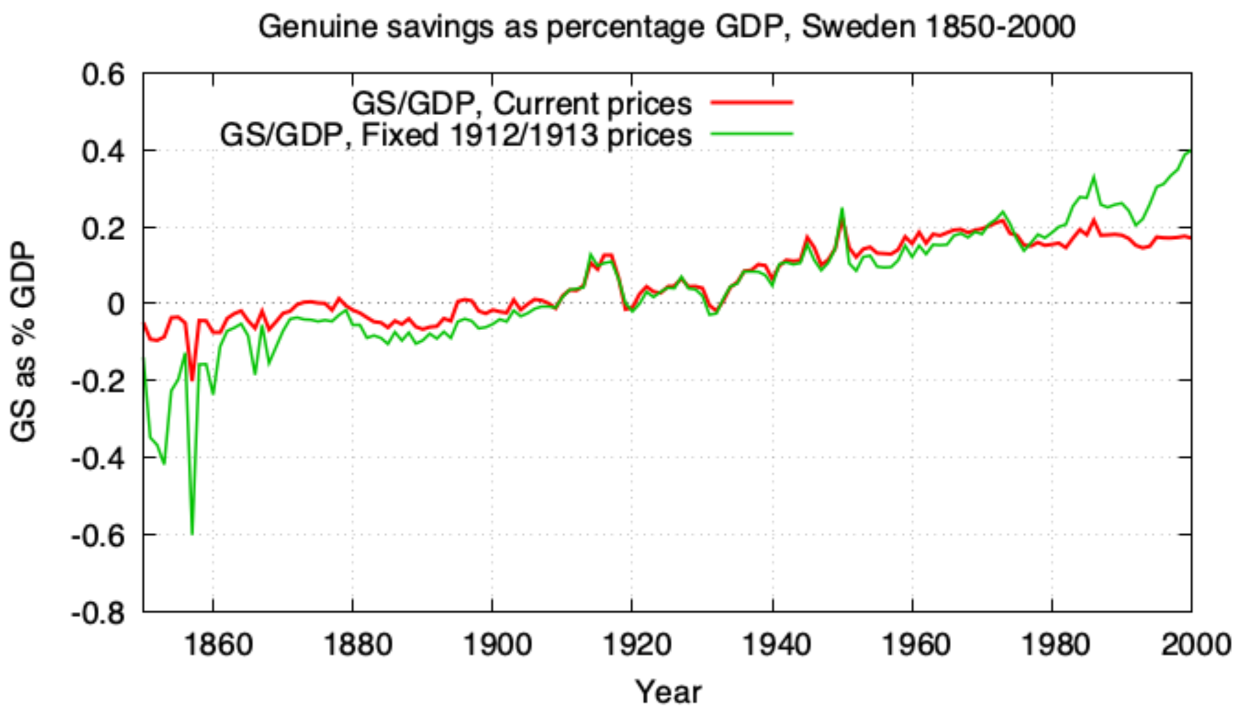

Figure 3. GS as % GDP in current prices and fixed 1912/1913 prices, Sweden 1850-2000 (Own illustration with data from Lindmark & Acar, 2013).

From the analysis, Lindmark and Acar (2013) concluded that Sweden successfully has managed to increase net savings following the concept of weak sustainability. By improving their human capital through among other investments in technology and reducing the social costs from pollution, Sweden have presented a positive value of GS since the beginning of the 20th century (Lindmark & Acar, 2013).

Based on the work by Lindmark and Acar (2013), Lindmark, Nguyen Thu and Stage (2018) generated two hypotheses to analyse whether GS could serve as a suitable indicator for future well-being in accordance to the concepts of weak and strong sustainability. The authors found evidence of a correlation between GS and economic well-being; however, not between GS and prosperity or that the relationship would become stronger over time. The authors presented three possible explanations to the weak support for weak sustainability; insufficient valuation of the stocks of capital, the assessment of the impact of GS on the well-being of future generations and lastly, that the concept of weak sustainability is flawed. The study was based on the standard approach of calculating GS and the authors concluded that despite explanation to their results, the deficiency would affect the entire existing literature of GS.

Lastly, Hanley, Oxley, Greasley, McLaughlin and Blum (2016) conducted a long-term empirical analysis of GS for three other countries, Great Britain, United States and Germany between 1870 and 2000. Following the concepts of weak and strong sustainability, the authors presented two hypotheses to analyse whether sustainable development per definition requires the *natural* wealth or the wealth received by the *total* capital stock to be non-declining over time. The results indicated that the hypothesis testing weak sustainability, could not be rejected when analysing a period up to 30 years ahead. However, using GS for analysing future consumption for longer horizons, between 30 to 50 years, will generate a less robust coefficient and less reliable results. In conclusion, GS as an indicator of weak sustainability is significant and suitable for shorter periods of up to 30 years.

3 Data

This section will present the data used for the quantitative analysis of this thesis. From the lack of existing long time-series of GS for Sweden extending to the current date, the procedure of elaborating already existing sources of GS into one will be outlined. In addition, some weaknesses with the data will be mentioned at the end of this section.

3.1 Population

Population statistics to estimate the total population of Sweden has been collected from Statistics Sweden, the government agency responsible for the official statistics of Sweden (Statistics Sweden, 2020c). Data on the total population of Sweden was collected from 1860 to 2019 to catch the long-term changes in the population over time (Statistics Sweden, 2019). However, within the construction of the three scenarios of population growth used for the forecast of GS, only the population statistics from the last two decades (1997-2017) was taken into consideration for credibility. Within the scenarios, the population structure of Sweden was not taken into consideration; only the total size of the population.

3.2 Genuine savings

In recent decades, extensive time-series of national historical accounting have been developed for Sweden over time (Lindmark, Nguyen Thu & Stage, 2018). Among others, Krantz and Schön (2007) and Schön and Krantz (2012; 2015) have presented historical estimates of GDP per capita in current and constant prices extending back to the mid-16th century. In terms of GS, Sweden is one of few countries who possess extensive estimates of GS along with reliable historical estimates of GDP (Lindmark, Nguyen Thu & Stage, 2018). Consequently, Sweden holds a favourable position and becomes suitable for analyses and forecasts within the topic.

However, historical estimates of GS for Sweden that extends to the current date is still lacking. So, for this thesis, data on GS for Sweden have been collected from two reliable sources to generate a long time-series of GS stretching from 1850 to 2017. Lindmark and Acar (2013) elaborated a historical estimation on GS for Sweden extending from 1850 to 2000 by assembling national accountings for Sweden from several sources and combining them into one consistent time-series. Within the dataset, Lindmark and Acar (2013) presented GS and GDP in million SEK respectively, in both current- and fixed 1912/1913 prices and also calculated GS as % GDP. As was shown in Figure 3, an apparent decoupling of the lines was identified after 1970 in which GS in current prices remained relatively constant while GS in fixed 1912/1913 prices increased, which indicates lack of reliability in the data after that point in time. To solve for this, data on ANS excluding particulate emission damage, presented in current US $, was collected from the World Bank (2019a) between 1970 and 2017. Following the calculation process of adjusted net savings presented by the World Bank (2006, pp.36-38), both damages caused by CO_2 emissions and PM_{10} should be subtracted from ANS for accuracy. However, in the data on ANS collected from the World Bank (2019a), only emissions caused by CO_2 was subtracted. Damage caused by PM_{10} was hence collected separately in current US $; however, only between 1990 and 2017 (World Bank, 2019c). From the existence of missing values in the necessary period, the share of total GDP being damage caused by PM_{10} was estimated separately. Accordingly, GDP in current US $ was collected from the World Bank (2019d) between 1970 and 2017. In 1990, damage caused by PM_{10} accounted for 0.06 % of GDP, since then, the share fell to 0.02 % in 2017 (World Bank, 2019c; 2019d). From the insignificant contribution that PM_{10} emission damage had overall, the variable was excluded from ANS to avoid problems in the data from missing values.

To allow for comparison between the series of GS and ANS, some modification of the data collected by the World Bank was necessary for consistency. ANS, as derived, was presented in current US $, was accordingly converted to constant US $ using a GDP-deflator to account for inflation. The GDP deflator was collected from the World Bank (2019e) by country with 2015 as the base year (2015=100). To generate ANS in constant value, ANS in current US $ was divided by the GDP deflator. The same calculation was conducted with GDP in current prices. Subsequently, ANS in constant US $ was divided by GDP in constant US $ to generate ANS as % GDP.

Consequently, to construct the long time series of GS for Sweden from 1850 to 2017, GS as % GDP generated by Lindmark and Acar (2013) was used from 1850 to 1969. Further, ANS as % GDP assembled from the data by the World Bank (2019a; 2019d; 2019e), was applied between 1970 and 2017. The long-term elaboration is illustrated in Figure 4, and is henceforth referred to as GS.

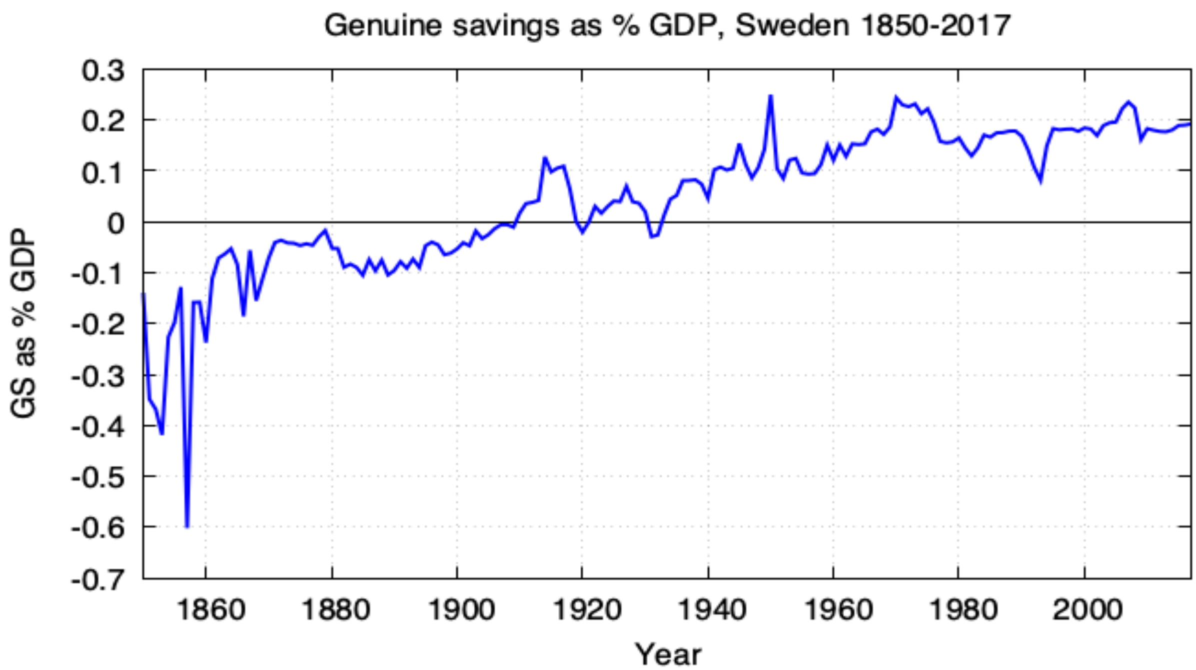

Figure 4. GS as % GDP, Sweden 1850-2017 (Own calculation and illustration with data from Lindmark & Acar, 2013 and the World Bank (2019a; 2019d; 2019e).

3.3 Weaknesses of the data

Assembling several sources of time-series data into one, as briefly outlined above, will generally imply some inconsistency. Since GS and ANS have initially been calculated in slightly different ways and have used various sources of primary data, combining the two series into one may result in some bias. Also, since the damage caused by emissions from PM_{10} was excluded from ANS, ANS as % GDP may become slightly smaller than the actual value. However, as previously presented, the share of GDP accounting for damage caused by PM_{10} emissions was considered as insignificant in the greater picture. The same conclusion was drawn regarding the additional pollutants included in GS by Lindmark and Acar (2013). All these limitations will be taken into consideration within the analysis and discussion.

4 Methodology

This section will first present the formal model of GS, followed by the methodology used to answer the two research questions of this thesis. Accordingly, the construction of three scenarios of population growth will be presented. Secondly, the process of forecasting GS will be outlined based on the three scenarios of population growth.

4.1 Genuine savings

GS was informally introduced by Pearce and Atkinson (1993) as an indicator of weak sustainability, and later by Hamilton (1994) as a green enhanced to GDP. However, the first formal model of GS was as mentioned, developed and presented by Hamilton and Clemens (1999). Hamilton and Clemens (1999) explained that despite definition, sustainable development could be achieved by maintaining constant or improved wealth through generations. Within economic theory, wealth is most commonly studied through the level of utility received by the total capital stock (World Bank, 2006, p.35). Within *green* national accounting, the total capital stock consist of produced-, human- and natural capital, in which natural capital contains of land, forests and subsoil resources (World Bank, 2006, p.35). Accordingly, Hamilton and Clemens (1999) displayed that GS includes "*... the investments in produced assets and human capital, less the value of depletion of natural resources and the value of accumulated pollutants*" (Hamilton & Clemens, 1999, p.336). A negative value of GS at some point in time will accordingly imply that the total value of the depreciation of capital is greater than the national savings and investments. Consequently, that future generations will receive less utility from the remaining capital stock.

GS is calculated from the value of gross national savings (GNS), and consequently, GS is sometimes referred to as adjusted net savings (ANS) (World Bank, 2006, pp.35-36). Based on the work presented by Hamilton and Clemens (1999), the model of ANS was presented by the World

Bank (2006, pp.154-157) following Equation 3. For an easier interpretation, the various steps of the calculation process have additionally been summarised and outlined below (World Bank, 2006, pp.36-38), resulting in Equation 3.

- Gross national savings (**GNS**) = GNI – private- and public consumption + current net transfers
- Net national savings (**NNS**) = GNS – depreciation of fixed capital
- NNS with educational investments (**NNSEE**) = NNS + current operational expenditure on education
- Adjusted net savings (**ANS**) = NNSEE – natural resource depletion (*including the depreciation of energy, metals, minerals and net forest*) – damage from pollutants (*including damage caused by* CO_2 *and* PM_{10})

$$\boldsymbol{ANS} = Net\ national\ savings + Educational\ expenditure - Energy\ depletion - Mineral\ depletion - Net\ forest\ depletion - CO_2\ damage - PM_{10}\ damage. \quad (3)$$

As previously explained, a negative value of GS could serve as an indicator of an unsustainable trend of an economy. However, presented within the 2006 report from the World Bank (2006, pp.38-39) was that interpreting a positive value of GS is not as straightforward. Enlightened within the report was that some decisive factors related to sustainable development has been omitted from GS due to the lack of existing data on some natural resources and stock of natural capital. Among others, fisheries have been excluded since the stock of fish is hard to estimate correctly. Since fishery can serve as a significant resource for an economy, when being excluded, the value of GS may become slightly biased. Furthermore, issues related to measuring soil erosion might become problematic for GS in agrarian countries. To accurately estimate soil erosion, exact data on the value of the physical loss of soil erosion is required, a highly challenging task in practice that can result in biased results. Consequently, a positive value of GS could appear from issues related to methodology or data collection and therefore, a positive value of GS could serve as a false indicator of sustainability (World Bank, 2006, p.38). Accordingly, identifying the kind of economic activity that is important within each economy will be essential for the accuracy of GS and to recognise whether that economic activity is included within the model of GS or not. Furthermore, Neumayer (2003, p.167) claimed that interpreting a positive value of GS should be done with care.

Enlightened by the author was that a positive value of GS should *not* serve as an indicator of sustainable economic performance. Instead, Pezzey (2004) presented GS (referred to as net investments) as a one-sided test for sustainability in which GS should be used to estimate the unsustainable trend of an economy that presents negative values of GS. Accordingly, the author concluded that with an initial value of GS being zero or negative, constant or falling GNNP (green net national product), will imply that the level of utility presented by the economy might not be able to sustain by the economy forever. Additionally, the author enlightened how the opposite does not hold; hence, GS should not serve as an indicator of sustainability.

The extended model presented by Lindmark and Acar (2013) was considered as more applicable to the current situation in the world based on some critical environmental issues identified throughout history. In addition to CO_2 and PM_{10}, the authors included the value of the damage caused by SO_2, NO_x, N-leakage and biologically infected water. The model of GS presented by Lindmark and Acar (2013) is outlined stepwise below and illustrated in Equation 4.

- Gross national savings (**GNS**) = GNI – private- and public consumption + current net transfers
- Net national savings (**NNS**) = GNS – depreciation of fixed capital
- NNS with educational investments (**NNSEE**) = NNS + current operational expenditure on education
- Genuine savings (**GS**) = NNSEE – natural resource depletion (*including the depreciation of energy, metals, mineral reserves and changes in standing timber volume*) – damage from pollutants (*including damage caused by CO_2, PM_{10}, SO_2, NO_x, N-leakage and biologically infected water*)

$$\boldsymbol{GS} = Net\ national\ savings + Current\ operating\ expenditures\ on\ education - Value\ of\ natural\ resource\ depletion - Value\ of\ damages\ from\ pollutants. \qquad (4)$$

4.2 Forecast of population growth

Following the first research question of this thesis, the first step of the quantitative analysis was to determine the population growth rate for each of the three scenarios. The purpose of using several scenarios within the study is to illustrate several possible outcomes for Sweden in terms of population growth and GS, and accordingly highlight the effect of population growth for sustainable development. Based on the population statistics collected from Statistics Sweden (2020b), the annual population growth rate was calculated accordingly for all years from 1861 to 2019. However, as previously presented, only the population growth rates of the last two decades from the base year were taken into consideration for high reliability when choosing the rates for the scenarios (1997-2017). The annual population growth rate of Sweden since 1861 to 2019 is presented in Figure 5.

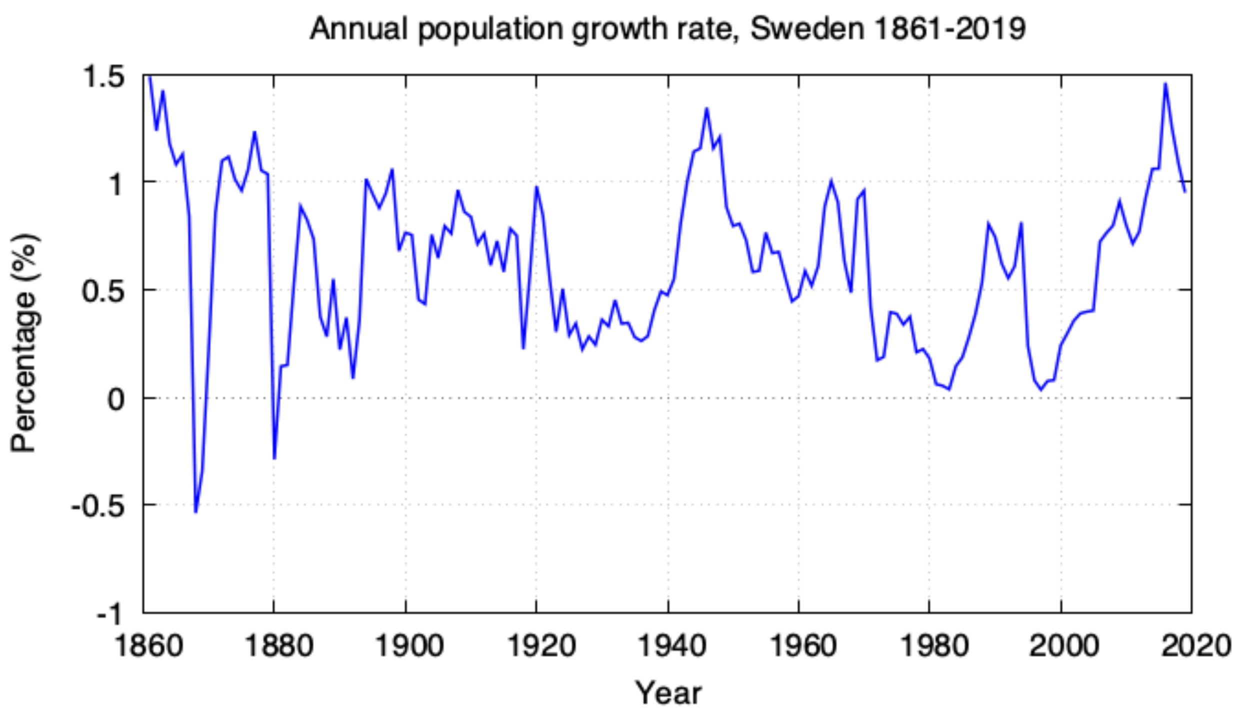

Figure 5. The annual population growth rates of Sweden, 1861-2019 (Own calculation and illustration with data from Statistics Sweden, 2020b).

Scenario 1 represents the most recent growth rate of Sweden, derived from 2019, a growth rate just below one percentage, 0.952 %. Further, the two additional scenarios represent two hypothetical scenarios for Sweden based on the historical growth rates and in which one is smaller than the current and the other greater than the current growth rate. Scenario 2 is an approximate of the population growth rate of 2000 in which the growth rate was close to zero, the lowest growth rate in the last two decades. Contrary, scenario 3 represents a high population growth rate, similar to the occurrence in 2015-2016 where Sweden experienced extensive immigration with more than 162 000 individuals applying for asylum in Sweden (Swedish Institute, 2020a; Swedish Migration Agency, 2020). Accordingly, the growth rate of scenario 3 will be approximate of 2016, with a growth rate of 1.5 %. The three scenarios with its respective population growth rate are presented in Table 1.

Table 1. Three future scenarios of population growth rates of Sweden (Own calculation with data from Statistics Sweden, 2019b).

	Growth rate
Scenario 1 (current growth rate)	0.952 %
Scenario 2 (hypothetical scenario A)	0.02 %
Scenario 3 (hypothetical scenario B)	1.5 %

The forecast of the total population was conducted for three future points in time, in 10, 20 and 30 years, respectively. Following previous studies of GS, among others, Hanley et al. (2016), GS as an indicator of sustainable development and future consumption was significant up 30 years forward. Consequently, to ensure robust results, the quantitative analysis will be conducted in line with their results and not exceed 30 years onwards.

4.3 Forecast of genuine savings

Adopting a historical perspective was raised by Lindmark and Acar (2013) as essential to capture the long-term determinants of change properly. The authors claimed that historical data on GS provides a deeper understanding and better forecasts of the future. Further, the authors argued that historical data is trustworthy to use when distinguishing how investments in various capital forms can lead to changes in the wealth of future generations. Accordingly, the quantitative analysis have been proceeded from the elaborated time-series of GS for Sweden presented in the previous section, extending from 1850 to 2017. As mentioned, 2017 was set to be used as a base year for the forecast since necessary data only was available up to that year. Still, 2017 can be considered as a good representative of the current time. Following the three scenarios previously presented, the second part of the analysis will forecast the necessary increase in GS for Sweden to maintain non-declining wealth over time. Similar to the outline of the first research question, the forecast of GS was generated and will be presented for 10, 20 and 30 years from the base year, separately for each scenario. Therefore, the forecast will be presented for the year 2027, 2037, 2047, in addition to the base year, 2017.

Accordingly, the second part of the quantitative analysis of this thesis was to estimate GS based on the three scenarios using a forecast function. All calculations and forecasts was accomplished using Gretl, a statistical package programme commonly used for econometric analyses. As explained within the previous section, GS has been elaborated to be available from 1850 to 2017. However, population statistics were only available between 1860 and 2047, and hence, the forecast of GS based on the three scenarios of population growth was conducted from 1860 and 2047, while the forecast of GS independently from 1850 to 2047. Accordingly, the forecast was generated using an OLS regression with GS as a dependent variable. A time trend (t) variable was generated within Gretl and consistently included to capture the trajectory of the variables within the model over time, and inserted into all models as an explanatory variable. The time trend variable takes the value $t = 1,2,3 \ldots N$ in which N is the number of observations within the dataset. Following the time trend variable, 1850 takes the value 1, and 2017 takes the value 168. The forecast of GS independently was based on 168 pre-observations, being the actual values of GS from 1850 and 2017. However, since data on population statistics only was available for Sweden from 1860, the forecast of GS with the scenarios of population growth was based on 158 pre-observations (1860-2017).

5 Empirical analysis

This section will present the results from the quantitative analysis, followed by a discussion related to previous literature on the topic. The results will be given separately following the two research questions, while the discussion will link them together in a deeper analysis.

5.1 Results

Both research questions will first be presented using descriptive statistics. Additionally, the second research question related to the forecast of GS will be analysed more thoroughly.

5.1.1 Forecast of the total population of Sweden

The first research question of this thesis concerns the size of the total population of Sweden in 10, 20 and 30 years from the base year for each of the three future scenarios. As 2017 constitutes base year for GS, the same follows for the size of the Swedish population. Accordingly, the total size of the population of Sweden in 2017 was estimated to 10 120 242 (Statistics Sweden, 2020b). The forecast of the total population is presented numerically in Table 2 and graphically in Figure 6.

Table 2. Estimated size of the Swedish population, 2027, 2037, and 2047 (Own calculation and illustration with data from Statistics Sweden, 2020b).

	Growth rate	**10 years**	**20 years**	**30 years**
Scenario 1 (current growth rate)	0.952 %	11 126 029	12 231 774	13 447 412
Scenario 2 (hypothetical scenario A)	0.02 %	10 324 478	10 532 836	10 745 399
Scenario 3 (hypothetical scenario B)	1.5 %	11 744 954	13 630 499	15 818 750

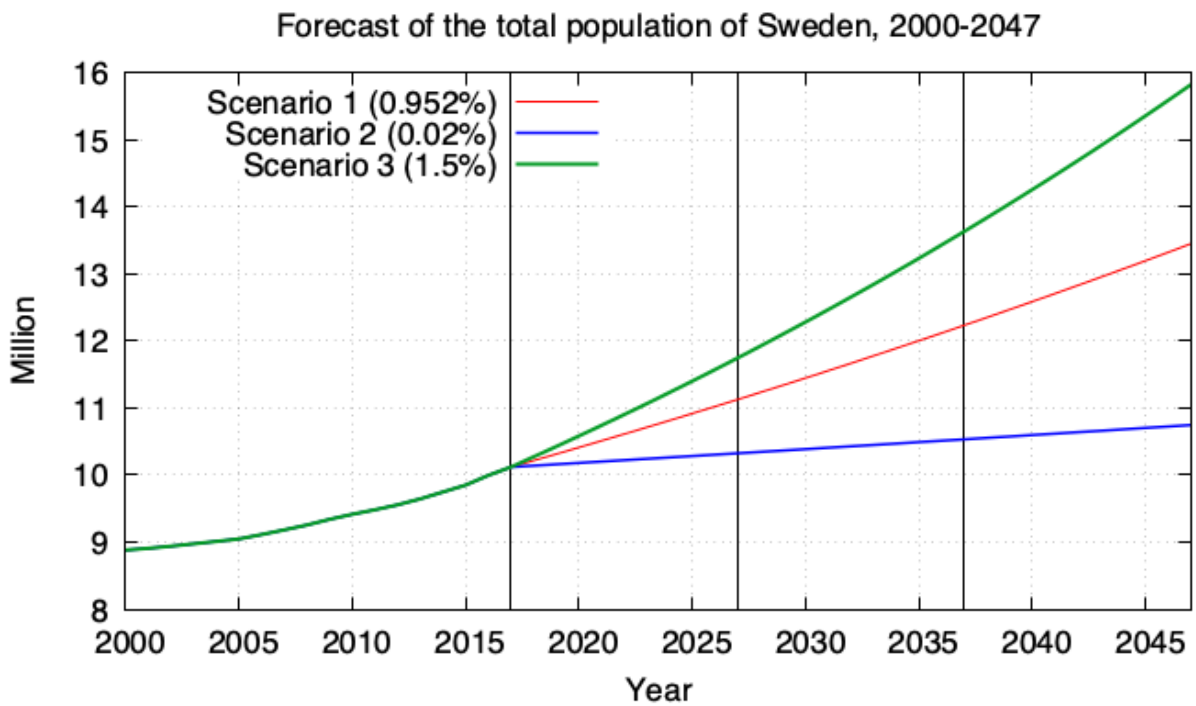

Figure 6. Forecast of the Swedish population, 2027, 2037, 2047 (Own calculation and illustration with data from Statistics Sweden, 2020b).

Within Figure 6, the first vertical line to the left is an indicator of 2017 in which the forecast starts. Thus, the graph extends from 2000-2047 to get a small glimpse of the total population growth before the forecast begins. The two additional vertical lines within Figure 6 are indicators of 2027 and 2037; 10 and 20 years from the base year. Further, the top (green) line represents scenario 3, the middle line (red) represents scenario 2, and lastly, the bottom line (blue) represents scenario 1. Accordingly, where the line for each scenario cuts those vertical lines, the total size of the population at 10 and 20 years respectively can be read from the y-axis. Since the graph extends to 2047, the total population 30 years from the base year appears where the line for each scenario reaches the right side of the graph.

From both Table 2 and Figure 6, it becomes clear that a small increase in the annual population growth rate will have a substantial impact on the size of the total population, particularly in the long run. When the total increase between 2017 and 2047 was calculated for each scenario, the results from scenario 2 forecasted that the total population of Sweden would increase with 625 thousand to 2047 with a population growth rate similar to 2000. Contrary, as scenario 1 represents the most recent growth rate of the Swedish population, the results indicated that if no change of the current growth rate occurs, the total population will increase with 3.3 million to 2047. Lastly, the results from scenario 3 illustrates the outcome if Sweden would experience another large flow of immigrants or substantial changes in the natural population growth over a long time. Accordingly, the total increase in the population in 30 years from 2017 would be 5.7 million.

5.1.2 Forecast of genuine savings with population growth

The second research question aims to forecast the necessary increase in GS based on the three scenarios of population growth. Following the same structure as for the first research question, the results from the forecast of GS will be presented in 10, 20 and 30 years from the base year for each of the three future scenarios. Additionally, the forecast of GS without any scenario of population growth will be presented. The results for each scenario will be illustrated graphically, while the output from each OLS model is presented within Appendix A. In addition, all actual and predicted values of GS generated from the forecast is presented within Appendix B. To conclude, at the end of this subsection, a table will summarise the predicted values of GS in 2017, 2027, 2037 and 2047 illustrated in each graph. Each OLS model was significant at 1 % level (***), which implies that each variable included within each model are highly explanatory for changes in GS.

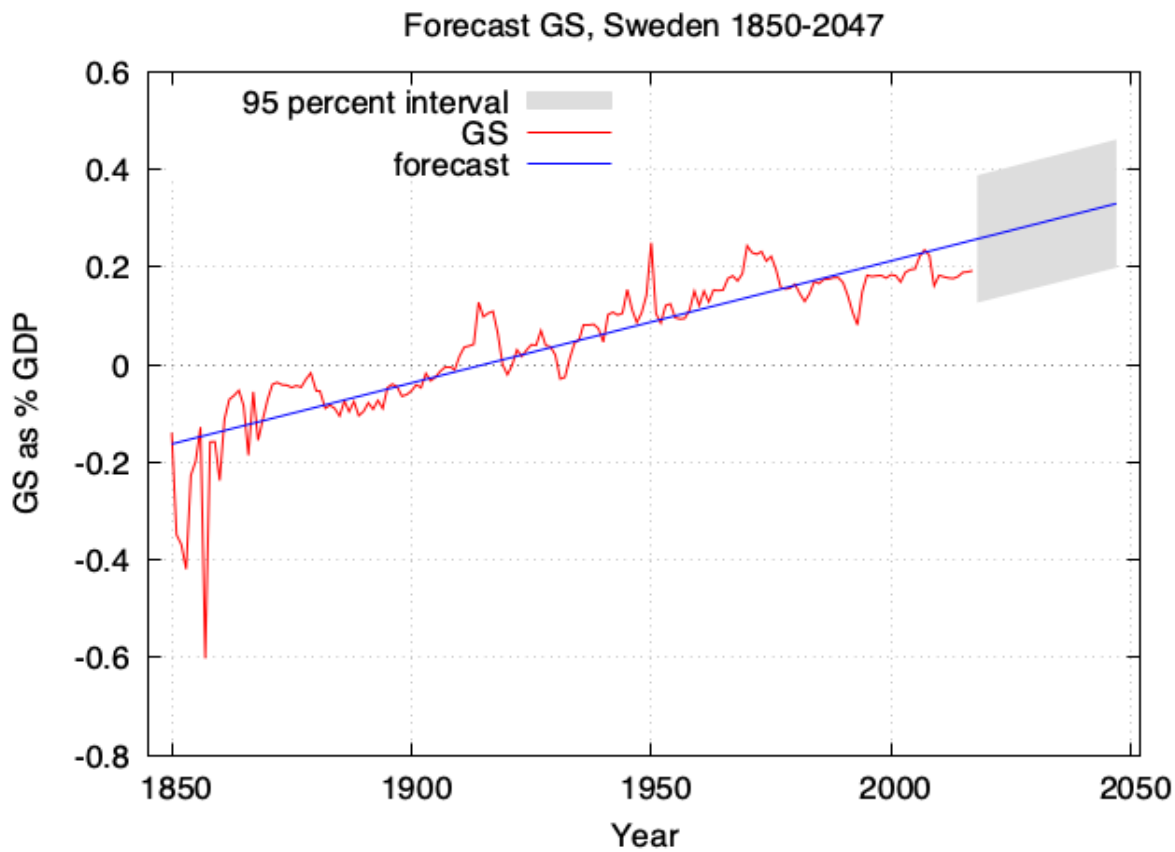

Figure 7. Forecast of GS, Sweden 1850-2047 Own calculation and illustration with elaborated data from Lindmark & Acar (2013), the World Bank (2019a; 2019d; 2019e) and Statistics Sweden (2020b), see text).

Figure 7 illustrates the forecast of GS independently without any of the three scenarios of population growth. The straight line (blue) represents the predicted value of GS while the fluctuated line (red) represents the actual value. The (grey) shaded area marks the 95 % confidence interval in which the predicted value should be located in to be significant. As the figure extends from 1850-2047, the (grey) shaded area also represents the forecast of GS. The same design follows for all scenarios below. Further, the actual and predicted value of GS without any scenario of population growth was derived from the forecast and will be presented in percentage. The actual value of GS in 2017 was 19.26 %, while the predicted value of GS was 25.51 %. The difference between the actual and predicted value is the residual of the regression, and a small residual indicates a good fit of the data. The actual value is the observed values of GS and only extends up to 2017, while the predicted values are based on the regression analysis and consequently extends to 2047. Based on the forecast, GS would need to increase to 28 % of GDP in 2027 and then to

30.5 % in 2037. In 2047, GS would need to represent 33 % of GDP when not taking population growth into account.

Figure 8, 9 and 10 illustrates the forecast of GS based on one scenario of population growth, respectively. Within each figure, the logarithmic value of the total population between 1860 and 2017 have been included into the OLS model independently. Including all variables for each of the three scenarios simultaneously would lead to multicollinearity. Since the size of the total population in 2017 is the same for each scenario, the actual value of GS within all three scenarios was 19.26 % in 2017 while the predicted value of GS was 23.43 %. In comparison to the residual above in the forecast of GS independently, the residual become smaller when including the population growth variable, indicating a better fit and less spread in the data.

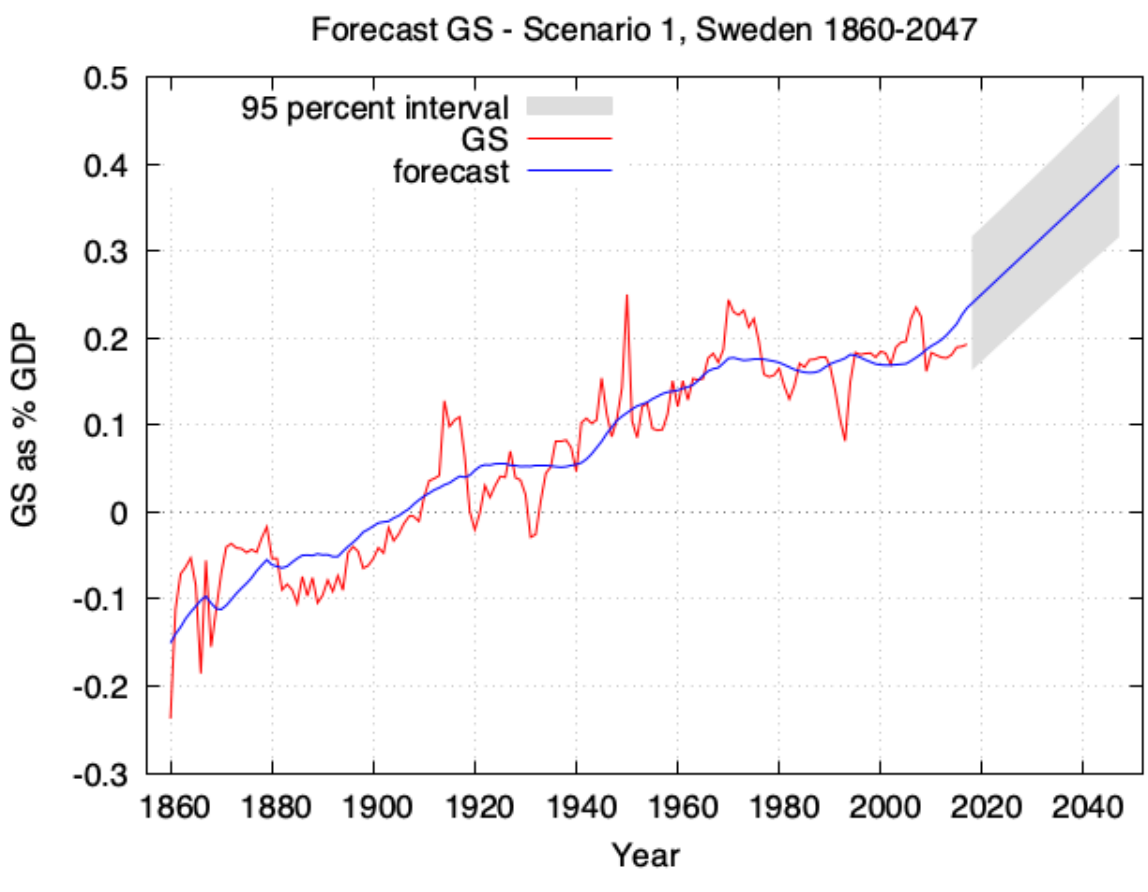

Figure 8. Forecast of GS - Scenario 1, Sweden 1860-2047 (Own calculation and illustration with elaborated data from Lindmark & Acar (2013), the World Bank (2019a; 2019d; 2019e) and Statistics Sweden (2020b), see text).

Figure 8 illustrates the forecast of GS for scenario 1, in which the population growth rate was set to 0.952 %. Following the predicted values of GS, the forecast indicates how GS would need to increase from 23.43 % in 2017 to 28.9 % in 2027. Further, in 2037, GS would need to account for 34.36 % of GDP and then 39.8 % in 2047 to offset a population growth similar to scenario 1. As scenario 1 represents the most recent annual population growth rate of Sweden, the forecast presented in Figure 8 illustrates how GS would need to increase by 69 % in 30 years from the current date if the same population growth rate as the current remains constant over time.

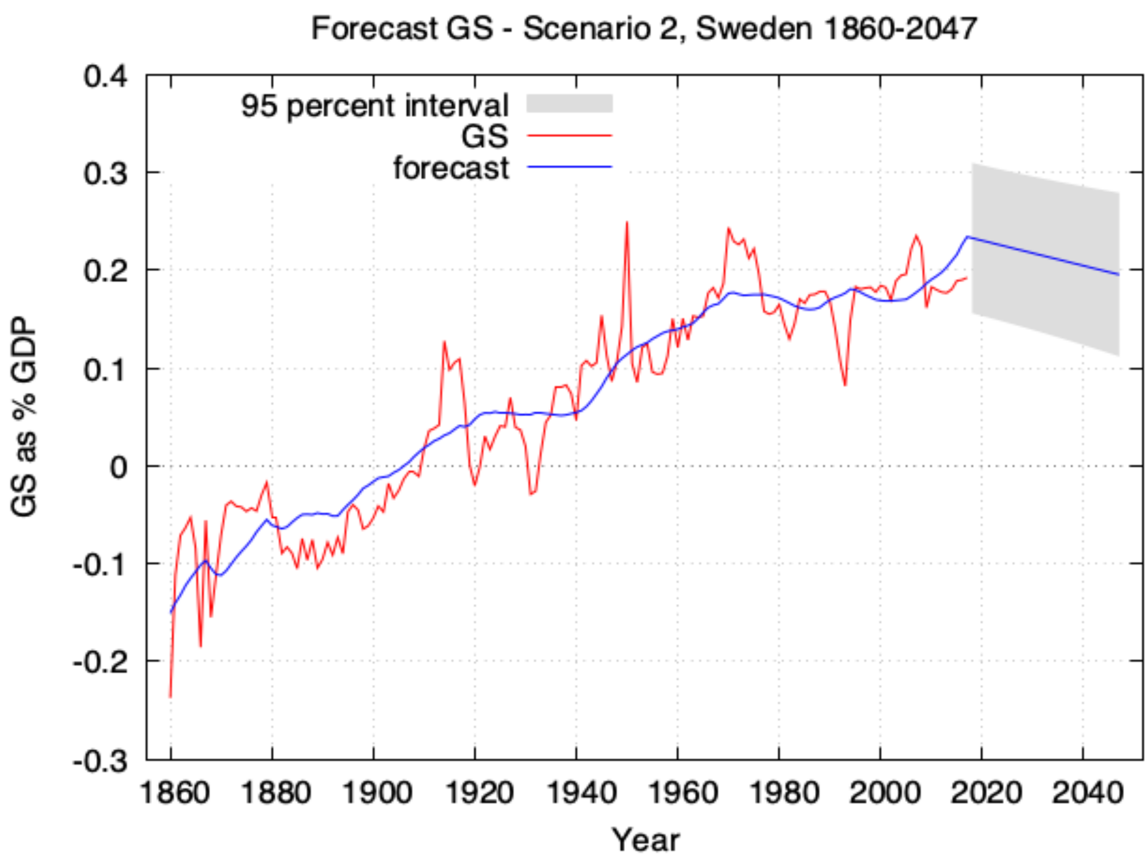

Figure 9. Forecast of GS - Scenario 2, Sweden 1860-2047 (Own calculation and illustration with elaborated data from Lindmark & Acar (2013), the World Bank (2019a; 2019d; 2019e) and Statistics Sweden (2020b), see text).

The forecast of GS following scenario 2 is presented in Figure 9, in which the population growth rate was set to be smaller than the current, a growth rate of 0.02 %. In contrast to the previous figure, the predicted value of GS is allowed to decrease over time. Important to take into consideration when analysing the results from the forecasts is that GS is presented as a % share of GDP and not in absolute value. Emerging from a predicted value of 23.43 % of GDP in 2017, within scenario 2, GS is allowed to decrease to 22 % in 2027, 20.85 % in 2037 and end up at 19.56 % in 2047. Notwithstanding, GS remains positive over time for Sweden following scenario 2.

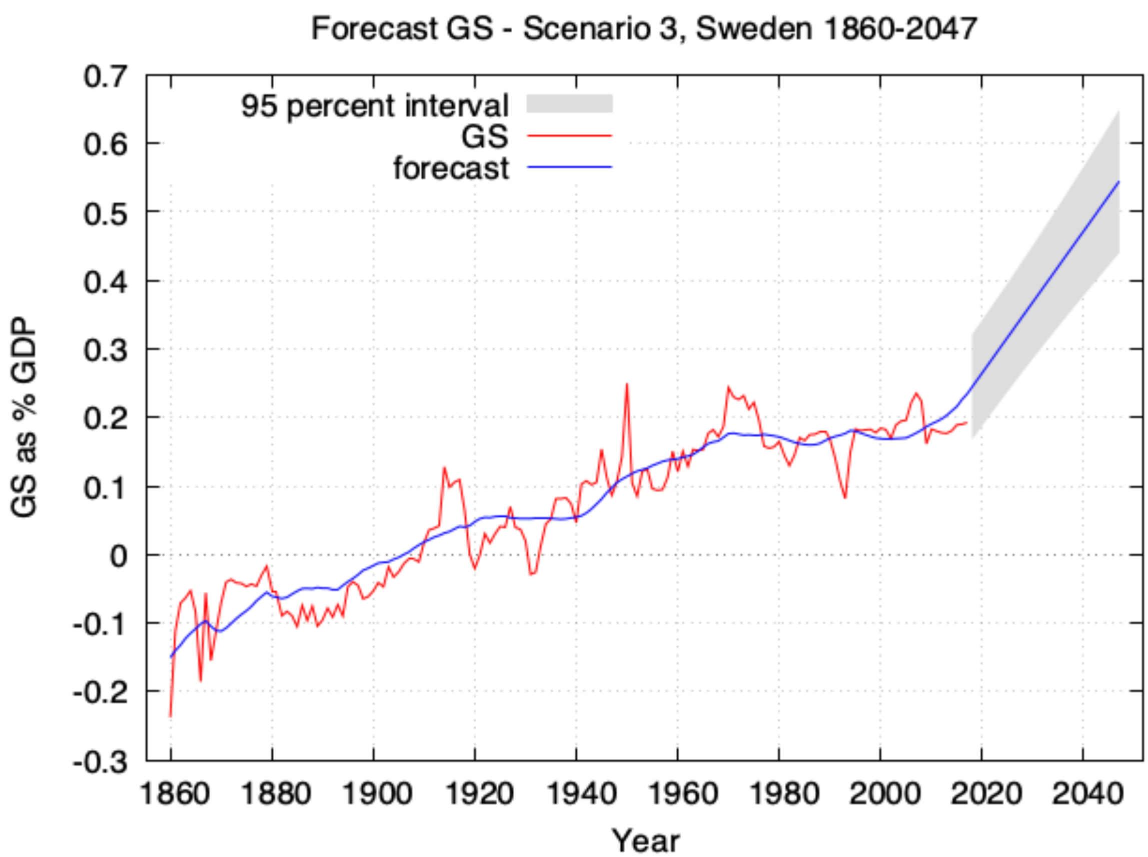

Figure 10. Forecast of GS - Scenario 3, Sweden 1860-2047 (Own calculation and illustration with elaborated data from Lindmark & Acar (2013), the World Bank (2019a; 2019d; 2019e) and Statistics Sweden (2020b), see text).

Figure 10 illustrates the forecast of GS based on a scenario with a substantially larger population growth rate than the current. As mentioned, this scenario represents the necessary increase in GS if Sweden would experience another large inflow of immigrants or significant changes in the natural population growth and is considered as a possible future scenario, at least for some period of time. In this case, the predicted values of GS indicates that GS would need to increase from 23.43 % in 2017 to 33.78 % in 2027. Further, GS would need to reach 44.13 % in 2037 and then end up at 54.48 % in 2047. This scenario implies that GS would need to increase from 23.43 % to 54.48 % in 30 years, indicating a total percentage increase in GS of 132 %.

Table 3. Predicted values of GS presented in GS as % GDP, 2017, 2027, 2037, 2047 and in total.

	2017 (base year)	**2027** (10 years)	**2037** (20 years)	**2047** (30 years)	**Total % increase 2017 -2047**
Forecast GS	25.51 %	28.01 %	30.51 %	33.01 %	29.39 %
Scenario 1	23.43 %	28.89 %	34.36 %	39.82 %	69.93 %
Scenario 2	23.43 %	22.14 %	20.85 %	19.56 %	-16.51 %
Scenario 3	23.43 %	33.78 %	44.13 %	54.48 %	132.52 %

In conclusion, Table 3 presents the predicted values of GS at the base year and in 10, 20 and 30 years from the base year following each scenario presented above. All values are presented as GS as % GDP. Also, the total percentage increase in GS between 2017-2047 is presented in Table 3. In summary, the results are indicating that GS as % GDP would need to increase significantly over time based on all scenarios except scenario 2 in which GS is predicted to decrease. From the forecast of GS, between 2017 and 2047, following scenario 2, with a population growth rate of 0.02 %, GS would be allowed to reduce to 16.5 % of GDP. In conclusion, the results are confirming that population growth will have a substantial impact on the necessary size of GS in the future. The largest increase in GS, as was expected, will be needed within scenario 3 in which the population growth rate was set to 1.5 %.

5.2 Discussion and suggestions for further research

Based on the results from the quantitative analysis presented above, this subsection will present a discussion and relate the results to the theoretical background on sustainable development and genuine savings. Following the stated research questions, the main aim of this thesis has been to analyse and forecast GS for Sweden, independently historically and by three constructed scenarios with different rates of future population growth. GS as an indicator of sustainable development was derived from the sustainability debate on how to achieve intergenerational equity and is an alternative measure to GDP. As for today, GDP or GNP is the most commonly used indicators of economic growth and development. Per definition, both measures are capturing the flow of national income and does not take into consideration whether the income is generated in an unsustainable way. Hence, using any of the two measures may lead to false results of economic success from the lack of accuracy. Consequently, the importance of including factors related to sustainability such as the cost of pollution and depreciation of environmental assets within national accounting and measures of economic performance has been increasingly highlighted within the literature in recent decades, and accordingly within this thesis. The discussions has moreover resulted in the development of multiple alternative measures that either adjusts or entirely replaced GDP, among other GS.

Accordingly, GS has been consistently considered as a good measure of sustainable development. However, the indicator was first developed at the beginning of 1990s and includes multiple factors that are hard to estimate and is still in need of further development and modification to be entirely consistent. Among others, Hanley et al. (2016), identified that GS only turned out to be significant when analysing future consumption up to 30 years ahead. To ensure credibility within the forecast, the identified deficits of GS was taken into consideration within this study and accordingly, the forecast was only presented for 10, 20 and 30 years from the base year 2017. Furthermore, as GS is dependent on the national economic activity and stock of capital, the indicator is not yet suitable to use within cross-country comparison since countries are not homogenous. However, GS is still a good indicator for single-country analyses. In terms of Sweden, the country is one out of few that have developed long time-series of GS and GDP extending back to the mid-19th century, and consequently, the country becomes a good starting point for adopting and developing GS.

1. ***Based on three scenarios of population growth, what will the size of the total Swedish population be in 10, 20 and 30 years from the current time?***

The results from the first research question of this thesis illustrated that even a small change in the population growth rate would contribute to substantial changes in the total size of the population. The forecast of the size of the Swedish population was conducted using three scenarios of population growth. The growth rate within each scenario was derived from the historical annual growth rates of Sweden in the last two decades and represented three possible future scenarios for Sweden. Provably, as presented in Figure 5, the annual growth rate of the population is not constant over time. Instead, the population growth rate is experiencing drastic fluctuations based on external and internal events over time. Nevertheless, the three scenarios were stated as hypothetical and can be seen as useful indicators to understand the power and implication of population growth in the near future.

As was raised within the report presented by the UN (2019), population growth and its rate will be an essential determinant of sustainable development. The statement can be considered as confirmed by the results from the first research question since indicating that even a small change in the population growth rate, despite direction, will lead to considerable changes in the total size of the Swedish population, in both the short- and long run. Scenario 1 was based on the most recent population growth rate of Sweden, 2019, and represents the outcome if the population growth of Sweden remains constant over time. The two additional scenarios were approximated of the population growth rate in 2000 and 2016, respectively. Scenario 2 holds a population growth rate close to zero, 0.02 %, representing a scenario if Sweden would experience a slower population growth than the current. By contrast, scenario 3 illustrates the outcome if Sweden would experience another substantial inflow of immigrants or changes in the natural population growth rate, and holds a population growth rate of 1.5 %. The total population of Sweden at the base year 2017 was estimated to 10 120 242 (Statistics Sweden, 2020b). Following the results, the increase between 2017 and 2047 was estimated to 625 thousand for scenario 1, 3.3 million for scenario 2 and 5.7 million for scenario 3. The impact of population growth following all scenarios will be essential; however, the most problematic scenario is the outcome from scenario 3 that implies more than 50 % increase of the current size of the Swedish population in less than 30 years from current time. Then again, the results are also indicating that if the growth rate changes at least slightly to the better (decreases), it can contribute to drastic changes in the future population and be used favourably.

2. ***Based on three scenarios of population growth, what will the necessary increase in GS be in 10, 20 and 30 years from the current time to ensure intergenerational equity?***

The second research question was answered with the values from the forecast of Swedish GS, with and without the scenarios of population growth. The forecast was generated by a long time-series of GS extending from 1850 to 2017, an elaboration of two sources of GS, Lindmark and Acar (2013) and the World Bank (2019a; 2019d; 2019e) that was outlined in Section 3. From the forecast of GS independently, the results illustrated how a total increase of 29 % in GS would be needed in 30 years from 2017. The predicated value of GS in 2017 was 25.52 % of GDP and accordingly, GS would need to reach 33.01 % by 2047 for intergenerational equity. When the variables for population growth was included in the model of GS, the results from the forecast changed. The results from scenario 1, in which the population growth rate was set to 0.952 %, illustrated a steeper trend in the forecast of GS. To offset the impact of population growth, GS would need to increase from 23.43 % in 2017 to 39.82 % in 2047, following scenario 1. That would imply a total increase of 69 % in 30 years from the base year. Further, the population growth rate within scenario 3 was set to 1.5 % and the results illustrated, as was expected, that an even steeper increase in GS would be needed over time. In total from 2017 to 2047, GS as % GDP would need to increase from 23.43 % to 54.48 % with a population growth rate similar to scenario 3. In total, that would entail an increase of 132 % in 30 years from the current time. The results are concluding that a faster-growing population would require a greater value of GS as % GDP to maintain constant wealth. These results seem reasonable since a larger population will require more land for housing and living and an increased extraction and use of natural resources for consumption. Consequently, more work will be needed in terms of savings and investments to offset the impact of the growing population and to achieve sustainable development. By contrast, the reliability of the exact values of GS as % GDP generated from the forecast becomes nevertheless hard to interpret and place into perspective. However, when taking the difference between the population growth rates and between the values of GS as % GDP into account, the ratio between the values can be considered as trustworthy.

The most interesting outcome from the quantitative analysis, and at first a bit unexpected, was the results from scenario 2 in which the population was set to grow at an annual rate of 0.02 %. The results from the forecast presented a decreasing trend from 23.42 % in 2017 to 19.56 % in 2047, implying a total decrease in GS as % GDP of 16.5 %. For a start, essential to note is that GS for Sweden within this scenario is still positive. Following the weak sustainability concept, the country is still considered to be on a sustainable path despite the decrease. However, to properly interpret the results of the changes in GS as % GDP, and mainly the decreasing trend, some factors have to be enlightened and taken into considerations. First, since GS is presented as % GDP, the interpretation of the results become slightly tricky since GS is not presented in absolute value.

Secondly, the results from the forecast are the predicted values of how large GS as % GDP *would need to be* in terms of the size of the population within each scenario. Accordingly, the results do *not* indicate what has happened. Therefore, a smaller population than the current, such as within scenario 2, would reasonably require less work to offset the environmental impact from human activities. The opposite goes for a population larger than the current, as was illustrated within the results from scenario 3. Hence, the results from scenario 2, indicating a small reduction of GS as % GDP, can be considered as plausible. However, this only holds as long as the initial value of GS is positive. A further reduction of GS when being negative will indicate an increasingly unsustainable trend of an economy.

There is still a long way to go for sustainable development on a national and global level. Accordingly, for scenario 1, an increase in GS as % GDP would practically be a better outcome than a decreasing trend. An increasing GS as % GDP with a slow-growing population would enable more compensation and an enhanced, rather than a constant, level of wealth received by the population over time. Hence, countries should always aim to improve their wealth over time and further reduce their negative environmental impact from human activities. However, as enlightened, the forecast only illustrates the increase in GS that would be needed to ensure constant wealth following the base year. Accordingly, one suggestion for further research would be to conduct a long time-series of GS presented in absolute value rather than as % GDP. Another suggestion would be to decompose GS into its various components, as was presented within Equation 3 and 4 (Equation of ANS and Equation of GS), which would enable a historical analysis of their changes over time. Such a scenario could contribute with meaningful insight on how much would be needed from each component over time to get a better understanding on how to practically achieve sustainable development and ensure intergenerational equity. Hence, applying the same or similar scenarios of population growth as within this study, with GS in absolute value, and as decomposed, would allow for comparisons of the results.

Lastly, according to the theory of weak sustainability and of using GS as an indicator of sustainable development, some concerns were raised within the literature on analysing positive values of GS. Rather than using GS to analyse positive values of GS, Pezzey (2004) argued that GS should only be used as a one-side test to analyse the unsustainable trend of an economy that presents negative values of GS. Accordingly, analysing a positive value of GS as % GDP such as above might become problematic. However, as stated, the results from this study can still be considered to provide a good indication of how much effort will be needed in the future to ensure intergenerational equity.

6 Conclusion

By elaborating a long time-series extending from 1850 to 2017, this thesis has presented a forecast of the necessary increase in GS, an alternative measure to GDP, to offset the environmental impact from population growth and ensure intergenerational equity within the next three decades. Sustainable development as intergenerational equity is achieved by maintaining or improving the amount of wealth received by the population from the national capital stock, including both produced-, human- and natural capital, throughout generations. Following three constructed scenarios of population growth rates of Sweden, the results from the analysis visualised that the magnitude and growth rate of the population will have a substantial impact on what will be needed in terms of savings and investments to achieve sustainable development in the near future. A population growth rate similar to the most recent or greater will first and foremost imply a rapidly increasing national population in total size. Additionally, it will require GS as % GDP to rise with at least 69 % in 30 years from the current time. In contrast, the results from a population growth rate close to zero would allow for GS as % GDP to decrease.

To quantitatively analyse and continuously communicate the environmental impact of human activities is essential for sustainable development. Accordingly, using GDP or GNP per definition may lead to a false indication of the national economic performance since not including factors such as sustainability effort, depreciation of natural resources and the cost of damage caused by pollution. Thus, this thesis has highlighted GS as a more accurate measure to use within national accounting and to measure economic performance. In conclusion, the definition of human activity within the Anthropocene, the proposed geological epoch of current time, as a *geological force* stated by Crutzen and Stoermer (2000) can somewhat be confirmed by the results from this thesis. From now on, we have to learn and ensure that this force will be used in the right way.

References

Anthropocene Films. (2018). *ANTHROPOCENE: The Human Epoch. The Documentary.* The Anthropocene Project. Available: https://theanthropocene.org/film/. [Accessed 2020-04-21].

Anthropocene: The Human Epoch. (2018). [Documentary Film]. Directors: Baichwal, J., Burtynsky, E. & de Pencier, N. Ottawa: Mercury Films.

Beckerman, W. (1994). *'Sustainable Development': Is it a Useful Concept?.* Environmental Values. Vol. 3, No. 3, pp. 191-209. Available: https://www.ingentaconnect.com/content/whp/ev/1994/00000003/00000003/art00001. [Accessed 2020-03-30].

Blum, M., Ducoing, C. & McLaughlin, E. (2017). *A Sustainable Century? Genuine Savings in Developing and Developed Countries, 1900-2000*. Chapter 5 in: Hamilton, K. & Hepburn, C. (2017). *National Wealth: What is Missing, Why it Matters.* Oxford Scholarship Online. Available: https://www.oxfordscholarship.com/view/10.1093/oso/9780198803720.001.0001/oso-9780198803720-chapter-5. [Accessed 2020-03-30].

Chappelow, J. (2020a). *Gross Domestic Product - GDP.* Investopedia. Available: https://www.investopedia.com/terms/g/gdp.asp. [Accessed 2020-04-27].

Chappelow, J. (2020b). *Gross National Product (GNP).* Investopedia. Available: https://www.investopedia.com/terms/g/gnp.asp. [Accessed 2020-04-27].

Costanza, R., Hart, M., Talberth, J. & Posner, S. (2009). *Beyond GDP: The Need for New Measures of Progress.* The Pardee Papers. No. 4. Available: https://pdxscholar.library.pdx.edu/iss_pub/11/. [Accessed 2020-05-04].

Costanza, R. & Daly, H. E. (1992). *Natural Capital and Sustainable Development.* Conservation Biology. Vol. 6, No. 1, pp. 37-46. Available: https://www.jstor.org/stable/2385849?seq=1#metadata_info_tab_contents. [Accessed 2020-04-14].

Crutzen, P. J. (2002). *Geology of mankind.* Nature. Vol. 415, p. 23. Available: https://www.nature.com/articles/415023a. [Accessed 2020-04-09].

Crutzen, P. J. & Stoermer, E. F. (2000). *The "Anthropocene".* IGBP Newsletter. No. 41, pp. 17-18. Available: http://www.igbp.net/download/18.316f18321323470177580001401/1376383088452/NL41.pdf. [Accessed 2020-04-09].

Dasgupta, P. & Heal, G. (1974). *The Optimal Depletion of Exhaustible Resources.* The Review of Economic Studies. Vol. 41, pp. 3-28. Available: https://www.jstor.org/stable/2296369?casa_token=0P-

GMV16njQAAAAA:f3mCzCeP29zPmfvOE4ZQVxmboGAaa6WM2J06kHfIS00nfz14WlZHZD37fFLTe_3JThuq6TegAD8WsmYDXMGC_7Qso6LRFtgFeCJciIypOG-bIfQSULz1&seq=1#metadata_info_tab_contents. [Accessed 2020-04-27].

Englund, P. (1999). *The Swedish banking crisis: roots and consequences.* Oxford Review of Economic Policy. Vol. 15, No. 3, pp. 80-97. Available: https://www.jstor.org/stable/23606686?seq=1#metadata_info_tab_contents. [Accessed 2020-05-26].

EPI. (2020). *Sweden. Environmental Performance Index.* Yale Center for Environmental Law & Policy. Available: https://epi.envirocenter.yale.edu/epi-country-report/SWE. [Accededd 2020-05-06].

Fairbridge, R. W. & Agenbroad, L. D. (2018). *Holocene Epoch.* Encyclopedia Britannica. Available: https://www.britannica.com/science/Holocene-Epoch. [Accessed 2020-04-21].

Gutés, M. C. (1996). *The concept of weak sustainability.* Ecological Economics. Vol. 17, Issue. 3, pp. 147-156. Available: https://www.sciencedirect.com/science/article/pii/S0921800996800036. [Accessed 2020-04-14].

Hamilton, K. (1994). *Green adjustment to GDP.* Resource Policy. Vol. 20, Issue, 3, pp. 155-168. Available: https://www.sciencedirect.com/science/article/pii/0301420794900485. [Accessed 2020-05-05].

Hamilton, K. & Clemens, M. (1999). *Genuine Savings Rates in Developing Countries.* The World Bank Economic Review. Vol. 13, Issue. 2, pp. 333-356. Available: https://academic.oup.com/wber/article-abstract/13/2/333/1639463?redirectedFrom=fulltext. [Accessed 2020-03-31].

Hamilton, K. & Withagen. C. (2007). *Savings growth and the path of utility.* Canadian Journal of Economics. Vol. 40, No. 2, pp. 703-713. Available: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2966.2007.00427.x. [Accessed 2020-05-19].

Hanley, N., Oxley, L., Greasley, D., McLaughlin, E. & Blum, M. (2016). *Empirical Testing of Genuine Savings as an Indicator of Weak Sustainability: A Three-Country Analysis of Long-Run Trends.* Environmental and Resource Economics. Vol. 63, pp. 313-338. Available: https://link.springer.com/article/10.1007/s10640-015-9928-7. [Accessed 2020-04-28].

Hartwick, J. M. (1978a). *Investing returns from depleting renewable resource stocks and intergenerational equity.* Economics Letters. Vol. 1, Issue. 1, pp. 85-88. Available: https://www.sciencedirect.com/science/article/abs/pii/0165176578901027. [Accessed 2020-04-24].

Hartwick, J. M. (1978b). *Substitution Among Exhaustible Resources and Intergenerational Equity.* The Review of Economic Studies. Vol. 45, No. 2, pp. 347-354. Available: https://www.jstor.org/stable/2297349?seq=1#metadata_info_tab_contents. [Accessed 2020-04-24].

Hartwick, J. M. (1977). *Intergenerational Equity and the Investing of Rents from Exhaustible Resources.* The American Economic Review. Vol. 67, No. 5, pp. 972-974. Available: https://www.jstor.org/stable/1828079?seq=1#metadata_info_tab_contents. [Accessed 2020-04-06].

Krantz, O. & Schön, L. (2007). *Swedish Historical National Accounts 1800-2000.* Lund Studies in Economic History 41, Lund. Available through the Department of Economic History, Lund University: https://www.ekh.lu.se/en/research/economic-history-data/shna. [Accessed 2020-05-16].

Lindmark, M. & Acar, S. (2013). *Sustainability in the making? A historical estimate of Swedish sustainable and unsustainable development 1850-2000.* Ecological Economics. Vol. 86, pp. 176-187. Available: https://www.sciencedirect.com/science/article/pii/S0921800912002625. [Accessed 2020-04-02].

Lindmark, M., Nguyen Thu, H. & Stage, J. (2018). *Weak support for weak sustainability: Genuine savings and long-term wellbeing in Sweden, 1850-2000.* Ecological Economics. Vol. 145, pp. 339-345. Available: https://www.sciencedirect.com/science/article/pii/S0921800917305955. [Accessed 2020-04-27].

Neumayer, E. (2003). *Weak versus Strong Sustainability. Exploring the Limits of Two Opposing Paradigms.* 2nd Edition. Northampton: Edward Elgar Publishing Limited.

OECD. (2018). *Gross domestic spending on R&D.* OECD Data. Available: https://www.google.com/url?q=https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm&sa=D&ust=1589627386730000&usg=AFQjCNF4hPtCWM9rB1V6Nm0_sK6kdyqs5A. [Accessed 2020-05-14].

Pearce, D. W. & Atkinson, G. D. (1993). *Capital theory and the measurement of sustainable development: an indicator of "weak" sustainability.* Ecological Economics. Vol. 8, Issue. 2, pp. 103-108. Available: https://www.sciencedirect.com/science/article/pii/0921800993900399. [Accessed 2020-03-31].

Pearce, D., Markandya, A. & Barbier, E. B. (1989). *Blueprint for a Green Economy.* A report. London: Earthscan Publications Ltd.

Pezzey, J. C.V. (2004). *One-sided sustainability tests with amenities, and changes in technology, trade and population.* Journal of Environmental Economics and Management. Vol. 48, Issue 1, pp. 613-631. Available: https://www.sciencedirect.com/science/article/pii/S0095069603001219. [Accessed 2020-05-19].

Pezzey, J. (1992). *Sustainable Development Concepts*: *an economic analysis (English)*. World Bank Environment Paper, No. 2. Washington, DC: The World Bank. Available: http://documents.worldbank.org/curated/en/237241468766168949/Sustainable-development-concepts-an-economic-analysis. [Accessed 2020-04-13].

Schön, L. & Krantz, O. (2015). *New Swedish Historical National Accounts since the 16th Century in Constant and Current Prices.* Lund Papers in Economic History 140, Lund

University. Available through the Department of Economic History, Lund University: https://www.ekh.lu.se/en/research/economic-history-data/shna. [Accessed 2020-05-16].

Schön, L. & Krantz, O. (2012). *Swedish Historical National Accounts 1560-2010.* Lund Papers in Economic History 123, Lund University. Available through the Department of Economic History, Lund University: https://www.ekh.lu.se/en/research/economic-history-data/shna. [Accessed 2020-05-16].

Solow, R. M. (1986). *On the Intergenerational Allocation of Natural Resources.* The Scandinavian Journal of Economics. Vol. 88, No. 1, pp. 141-149. Available: https://www.jstor.org/stable/3440280?seq=1#metadata_info_tab_contents. [Accessed 2020-04-06].

Solow, R. M. (1974). *Intergenerational Equity and Exhaustible Resources.* The Review of Economic Studies. Vol. 41, Issue. 5, pp. 29-45. Available: https://www.jstor.org/stable/2296370?seq=1#metadata_info_tab_contents. [Accessed 2020-04-06].

Statistics Sweden. (2020a). *Immigrations and emigrations by country of citizenship and sex. Year 2000-2019.* Statistics Sweden. Available: http://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BE__BE0101__BE0101J/ImmiEmiMedb/?rxid=2666095a-bd5a-4e73-8db4-096ad78e620a. [Accessed 2020-05-08].

Statistics Sweden. (2020b). *Population by age and sex. Year 1860-2019.* Statistics Sweden. Available: http://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BE__BE0101__BE0101A/BefolkningR1860/. [Accessed 2020-03-31].

Statistics Sweden (2020c). *About Statistics Sweden.* Statistics Sweden. Available: https://www.scb.se/en/About-us/. [Accessed 2020-05-11].

Statistics Sweden. (2019). *Drought slows the increase of Swedish extraction of natural resources.* Statistical New. Statistics Sweden. Available: https://www.scb.se/en/finding-statistics/statistics-by-subject-area/environment/environmental-accounts-and-sustainable-development/system-of-environmental-and-economic-accounts/pong/statistical-news/environmental-accounts---economy-wide-material-flow-accounts-19982018/. [Accessed 2020-05-26].

Statistics Sweden. (2018). *Swedish extraction of natural resources increased sharply.* Statistical News. Statistics Sweden. Available: https://www.scb.se/en/finding-statistics/statistics-by-subject-area/environment/environmental-accounts-and-sustainable-development/system-of-environmental-and-economic-accounts/pong/statistical-news/environmental-accounts---economy-wide-material-flow-accounts-19982017/. [Accessed 2020-05-06].

Steffen, W. & Crutzen, P. J. & McNeill, J. R. (2007). *The Anthropocene: Are Humans Now Overwhelming the Great Force of Nature?.* Ambio. Vol. 36, No. 8, pp. 614-621. Available: https://www.jstor.org/stable/25547826?seq=1#metadata_info_tab_contents. [Accessed 2020-04-09].

Steffen, W., Grinevald, J., Crutzen, P. & McNeill, J. (2011). *The Anthropocene: conceptual and historical perspectives*. Philosophical Transactions of the Royal Society A, Mathematical, Physical and Engineering Science. Vol. 369, pp. 842-867. Available: https://royalsocietypublishing.org/doi/10.1098/rsta.2010.0327. [Accessed 2020-04-09].

Stern, D. I. (1997). *Limits to substitution and irreversibility in production and consumption: A neoclassical interpretation of ecological economics.* Ecological Economics. Vol. 21, Issue. 3, pp. 197-215. Available: https://www.sciencedirect.com/science/article/abs/pii/S0921800996001036. [Accessed 2020-05-02].

Stiglitz, J. (1974). *Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths.* The Review of Economic Studies. Vol. 41, pp. 123-137. Available: https://www.jstor.org/stable/2296377?casa_token=YWzyTeNx-MoAAAAA:v4KdM9qM0BQXzQtzC5Kue2oxcnXmasguXFdVf2aQGf5lDtNTWvQMnTfL42HFSveClN2vNJRjYNq6p3xbO2N4j6PliZV_CWBNki37iJpArxUGw6wkk7h7&seq=1#metadata_info_tab_contents. [Accessed 2020-04-30].

Swedish Institute. (2020a). *Sweden and Migration.* Swedish Institute. Available: https://sweden.se/migration/#2015. [Accessed 2020-05-08].

Swedish Institute (2020b). *Innovation in Sweden.* Swedish Institute. Available: https://sweden.se/business/innovation-in-sweden/. [Accessed 2020-05-14].

Swedish Migration Agency. (2020). *History. About the Migration Agency.* Swedish Migration Agency. Available: https://www.migrationsverket.se/English/About-the-Migration-Agency/Migration-to-Sweden/History.html. [Accessed 2020-05-12].

UN. (2019). *World Population Prospects 2019. Highlights.* (ST/ESA/SER.A/423). Department of Economic and Social Affairs. Population Division. United Nations.

UN. (2017). *Sweden. Voluntary National Review 2017. Main Messages.* United Nations. Available: https://sustainabledevelopment.un.org/memberstates/sweden. [Accessed 2020-05-05].

Victor, P. A. (1991). *Indicators of sustainable development: some lessons from capital theory.* Ecological Economics. Vol. 4, Issue. 3, pp. 191-213. Available: https://www.sciencedirect.com/science/article/pii/092180099190051F. [Accessed 2020-03-31].

Wendling, Z. A., Emerson, J. W., Esty, D. C., Levy, M. A. & de Sherbinin, A. (2018). *2018 Environmental Performance Index.* New Haven, CT: Yale Center for Environmental Law & Policy. Available: https://epi.envirocenter.yale.edu/epi-downloads. [Accessed 2020-05-06].

Worldometer. (2020). *World Population by Year.* Worldometer. Available: https://www.worldometers.info/world-population/world-population-by-year/. [Accessed 2020-04-03].

World Bank. (2019a). *Adjusted net savings, excluding particulate emission damage (current US$) - Sweden.* The World Bank. Available: https://data.worldbank.org/indicator/NY.ADJ.SVNX.CD?locations=SE. [Accessed 2020-05-04].

World Bank. (2019b). *Adjusted net savings, including particulate emission damage (% of GNI) - Sweden.* The World Bank. Available: https://data.worldbank.org/indicator/NY.ADJ.SVNG.GN.ZS?locations=SE. [Accessed 2020-05-04].

World Bank. (2019c). *Adjusted savings: particulate emission damage (current US$) - Sweden.* The World Bank. Available: https://data.worldbank.org/indicator/NY.ADJ.DPEM.CD?locations=SE. [Accessed 2020-05-11].

World Bank. (2019d). *GDP (current US$) - Sweden.* The World Bank. Available: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=SE. [Accessed 2020-05-11].

World Bank. (2019e). *GDP deflator (base year varies by country) - Sweden.* The World Bank. Available: https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?locations=SE. [Accessed 2020-05-11].

World Bank. (2011). *The Changing Wealth of Nations. Measuring Sustainable Development in the New Millenium.* Washington, DC: The World Bank.

World Bank. (2006). *Where is the Wealth of Nations? Measuring Capital for the 21st Century.* Washington, DC: The World Bank.

World Bank. (1997). *Expanding the measure of wealth: indicators of environmentally sustainable development (English).* Environmentally sustainable development studies and monographs series, No. 17. ESSD Environmentally & Socially Sustainable Development Work in Progress. Washington, DC. The World Bank.

World Bank. (1995). *Monitoring environmental progress: a report on work in progress (English).* ESSD Environmentally & Socially Sustainable Development Work in Progress. Washington, DC. The World Bank.

WCED. (1987). *Our Common Future. Report of the World Commission on Environment and Development.* United Nations. Available: https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf. [Accessed 2020-03-30].

Zalasiewicz, J., Williams, M., Haywood, A. & Ellis, M. (2011). *The Anthropocene: a new epoch of geological time?.* Philosophical Transactions of the Royal Society A, Mathematical, Physical and Engineering Science. Vol. 369, Issue. 1938, pp. 835-841. Available: https://royalsocietypublishing.org/doi/full/10.1098/rsta.2010.0339#pane-pcw-details. [Accessed 2020-04-21].

Zalasiewicz, J., Williams, M., Smith, A., Barry, T. L., Coe, A. L., Brown, P. R., Brenchley, P., Cantrill, D., Gale. A., Gibbard, P., Gregory, F. J., Hounslow, M. W., Kerry, A. C., Pearson, P., Knox, R., Powell, J., Waters, C., Marshall, J., Oates, M., Rawson, P. & Stone, P. (2008). *Are we now living in the Anthropocene?.* GSA Today. Vol. 18, No. 2, pp. 4-8.

Appendix A

Appendix A presents the OLS regression output for each of the four models used within the quantitative analysis. Accordingly, Model 1 is the forecast of GS independently while Model 2-4 is the forecast of GS with the constructed scenarios. Model 2 represents Scenario 1, Model 3 represents Scenario 2 and Model 4 represents Section 3. The dependent variable used within all models is GS (GS as % GDP). Furthermore, α ($const$) is the intercept while $time$ is the time trend variable outlined within section 3, included as an explanatory variable within each model. Model 1, following the below equation, solely includes the variable time and represents the model of GS independently.

$$GS_0 = \beta * time$$

Model 2-4, following the below equations, is the models for each of the constructed scenarios. Within each of the models, the logarithmic variable of the total population size as outlined within section 3 has been included ($\log(Scenario1)$, $\log(Scenario2)$, $\log(Scenario3)$).

$$GS_1 = \beta_1 * time + \beta_2 * \log(Scenario1)$$

$$GS_2 = \beta_1 * time + \beta_2 * \log(Scenario2)$$

$$GS_3 = \beta_1 * time + \beta_2 * \log(Scenario3)$$

```
Model 1: OLS, using observations 1850-2017 (T = 168)
Dependent variable: GS

             coefficient   std. error    t-ratio   p-value
  --------------------------------------------------------
  const      -0.164847     0.0101156     -16.30    2.85e-36 ***
  time        0.00249997   0.000103827    24.08    4.88e-56 ***

Mean dependent var   0.046401   S.D. dependent var   0.137917
Sum squared resid    0.707061   S.E. of regression   0.065264
R-squared            0.777411   Adjusted R-squared   0.776070
F(1, 166)            579.7677   P-value(F)           4.88e-56
Log-likelihood       221.1490   Akaike criterion    -438.2979
Schwarz criterion   -432.0500   Hannan-Quinn        -435.7622
rho                  0.514258   Durbin-Watson        0.970884
```

```
Model 2: OLS, using observations 1860-2017 (T = 158)
Dependent variable: GS

                coefficient    std. error    t-ratio   p-value
  --------------------------------------------------------------
  const         -13.8101       2.01549       -6.852    1.62e-10 ***
  time          -0.00309316    0.000780304   -3.964    0.0001   ***
  logScenario1   0.902917      0.133014       6.788    2.27e-10 ***

Mean dependent var   0.066706   S.D. dependent var   0.108985
Sum squared resid    0.228907   S.E. of regression   0.038429
R-squared            0.877249   Adjusted R-squared   0.875665
F(2, 155)            553.8591   P-value(F)           2.51e-71
Log-likelihood       292.2335   Akaike criterion    -578.4669
Schwarz criterion   -569.2791   Hannan-Quinn        -574.7356
rho                  0.621820   Durbin-Watson        0.725252
```

```
Model 3: OLS, using observations 1860-2017 (T = 158)
Dependent variable: GS

                coefficient    std. error    t-ratio   p-value
  --------------------------------------------------------------
  const          -13.8101      2.01549       -6.852    1.62e-10 ***
  time           -0.00309316   0.000780304   -3.964    0.0001   ***
  logScenario2    0.902917     0.133014       6.788    2.27e-10 ***

Mean dependent var   0.066706   S.D. dependent var   0.108985
Sum squared resid    0.228907   S.E. of regression   0.038429
R-squared            0.877249   Adjusted R-squared   0.875665
F(2, 155)            553.8591   P-value(F)           2.51e-71
Log-likelihood       292.2335   Akaike criterion    -578.4669
Schwarz criterion   -569.2791   Hannan-Quinn        -574.7356
rho                  0.621820   Durbin-Watson        0.725252
```

```
Model 4: OLS, using observations 1860-2017 (T = 158)
Dependent variable: GS

                coefficient    std. error    t-ratio   p-value
  --------------------------------------------------------------
  const         -13.8101      2.01549       -6.852    1.62e-10 ***
  time          -0.00309316   0.000780304   -3.964    0.0001   ***
  logScenario3   0.902917     0.133014       6.788    2.27e-10 ***

Mean dependent var   0.066706   S.D. dependent var   0.108985
Sum squared resid    0.228907   S.E. of regression   0.038429
R-squared            0.877249   Adjusted R-squared   0.875665
F(2, 155)            553.8591   P-value(F)           2.51e-71
Log-likelihood       292.2335   Akaike criterion    -578.4669
Schwarz criterion   -569.2791   Hannan-Quinn        -574.7356
rho                  0.621820   Durbin-Watson        0.725252
```

Appendix B

Appendix B presents the actual and predicted value from the forecast following above presented OLS regressions. In addition, the standard error and 95% confidence interval is presented. Accordingly, Model 1 is the forecast of GS independently while Model 2-4 is the forecast of GS with the constructed scenarios. Model 2 represents Scenario 1, Model 3 represents Scenario 2 and Model 4 represents Section 3. Since the actual and predicted value of GS is identical between 1850 and 2017, the values between 1850-2016 have been excluded from Model 3 and 4. Those values can be taken from the forecast for Model 2.

Model 1: OLS, using observations 1850-2017 (T=168)
Dependent variable: GS
Forecast GS
For 95% confidence intervals, t(166, 0.025) = 1.974

	GS	prediction	std. error	95% interval
1850	-0.139211	-0.162347		
1851	-0.348377	-0.159847		
1852	-0.368442	-0.157347		
1853	-0.418643	-0.154847		
1854	-0.226479	-0.152347		
1855	-0.197260	-0.149847		
1856	-0.128022	-0.147347		
1857	-0.601747	-0.144847		
1858	-0.158268	-0.142347		
1859	-0.157729	-0.139847		
1860	-0.237282	-0.137347		
1861	-0.111423	-0.134847		
1862	-0.071028	-0.132347		
1863	-0.063178	-0.129847		
1864	-0.052734	-0.127347		
1865	-0.084013	-0.124847		
1866	-0.185478	-0.122347		
1867	-0.055666	-0.119847		
1868	-0.154773	-0.117347		
1869	-0.112244	-0.114847		
1870	-0.070849	-0.112347		
1871	-0.040204	-0.109847		
1872	-0.036253	-0.107347		
1873	-0.041245	-0.104847		
1874	-0.042018	-0.102347		
1875	-0.046514	-0.099847		
1876	-0.043067	-0.097347		
1877	-0.046167	-0.094847		
1878	-0.029749	-0.092347		
1879	-0.017007	-0.089847		
1880	-0.053262	-0.087347		
1881	-0.053319	-0.084848		
1882	-0.089328	-0.082348		
1883	-0.082909	-0.079848		
1884	-0.089421	-0.077348		
1885	-0.105090	-0.074848		
1886	-0.074229	-0.072348		

1887	-0.096291	-0.069848
1888	-0.075349	-0.067348
1889	-0.104373	-0.064848
1890	-0.095603	-0.062348
1891	-0.078181	-0.059848
1892	-0.091113	-0.057348
1893	-0.073127	-0.054848
1894	-0.089699	-0.052348
1895	-0.046803	-0.049848
1896	-0.039773	-0.047348
1897	-0.045168	-0.044848
1898	-0.064518	-0.042348
1899	-0.061385	-0.039848
1900	-0.053342	-0.037348
1901	-0.041008	-0.034848
1902	-0.046983	-0.032348
1903	-0.017954	-0.029848
1904	-0.032947	-0.027348
1905	-0.025248	-0.024848
1906	-0.013431	-0.022348
1907	-0.005537	-0.019848
1908	-0.005510	-0.017348
1909	-0.010605	-0.014848
1910	0.017234	-0.012348
1911	0.035934	-0.009848
1912	0.038358	-0.007348
1913	0.041974	-0.004848
1914	0.127793	-0.002348
1915	0.098256	0.000152
1916	0.105606	0.002652
1917	0.109368	0.005152
1918	0.064384	0.007652
1919	0.000761	0.010152
1920	-0.020306	0.012652
1921	-0.000775	0.015151
1922	0.030460	0.017651
1923	0.016962	0.020151
1924	0.030132	0.022651
1925	0.040989	0.025151
1926	0.039906	0.027651
1927	0.069898	0.030151
1928	0.039510	0.032651
1929	0.036799	0.035151
1930	0.020086	0.037651
1931	-0.028936	0.040151
1932	-0.025752	0.042651
1933	0.012884	0.045151
1934	0.044560	0.047651
1935	0.052023	0.050151
1936	0.081457	0.052651
1937	0.081476	0.055151
1938	0.082683	0.057651
1939	0.073938	0.060151
1940	0.046497	0.062651
1941	0.102579	0.065151
1942	0.107616	0.067651
1943	0.101925	0.070151
1944	0.105561	0.072651
1945	0.154016	0.075151
1946	0.112954	0.077651
1947	0.086493	0.080151
1948	0.106487	0.082651
1949	0.142707	0.085151

1950	0.249922	0.087651
1951	0.104645	0.090151
1952	0.085359	0.092651
1953	0.121253	0.095151
1954	0.124672	0.097651
1955	0.096039	0.100151
1956	0.093865	0.102651
1957	0.094793	0.105151
1958	0.112460	0.107651
1959	0.150713	0.110151
1960	0.121157	0.112651
1961	0.150882	0.115150
1962	0.128726	0.117650
1963	0.153271	0.120150
1964	0.151981	0.122650
1965	0.153228	0.125150
1966	0.176916	0.127650
1967	0.182189	0.130150
1968	0.171831	0.132650
1969	0.186579	0.135150
1970	0.243773	0.137650
1971	0.229739	0.140150
1972	0.226329	0.142650
1973	0.231847	0.145150
1974	0.212359	0.147650
1975	0.222096	0.150150
1976	0.195921	0.152650
1977	0.158176	0.155150
1978	0.155308	0.157650
1979	0.157156	0.160150
1980	0.165071	0.162650
1981	0.145015	0.165150
1982	0.129773	0.167650
1983	0.145441	0.170150
1984	0.170648	0.172650
1985	0.166381	0.175150
1986	0.174903	0.177650
1987	0.175463	0.180150
1988	0.178421	0.182650
1989	0.178468	0.185150
1990	0.168113	0.187650
1991	0.141435	0.190150
1992	0.107256	0.192650
1993	0.081635	0.195150
1994	0.149387	0.197650
1995	0.183254	0.200150
1996	0.180794	0.202650
1997	0.182052	0.205150
1998	0.182686	0.207650
1999	0.177843	0.210150
2000	0.184446	0.212650
2001	0.182414	0.215149
2002	0.169444	0.217649
2003	0.189173	0.220149
2004	0.194777	0.222649
2005	0.196169	0.225149
2006	0.222196	0.227649
2007	0.235279	0.230149
2008	0.223946	0.232649
2009	0.161613	0.235149
2010	0.183110	0.237649
2011	0.180136	0.240149
2012	0.177752	0.242649

2013	0.176936	0.245149		
2014	0.180761	0.247649		
2015	0.189330	0.250149		
2016	0.190176	0.252649		
2017	**0.192600**	**0.255149**		
2018		0.257649	0.066043	0.127256 - 0.388042
2019		0.260149	0.066057	0.129728 - 0.390570
2020		0.262649	0.066071	0.132201 - 0.393097
2021		0.265149	0.066085	0.134673 - 0.395625
2022		0.267649	0.066100	0.137144 - 0.398154
2023		0.270149	0.066114	0.139616 - 0.400682
2024		0.272649	0.066129	0.142087 - 0.403211
2025		0.275149	0.066144	0.144557 - 0.405740
2026		0.277649	0.066159	0.147028 - 0.408270
2027		**0.280149**	0.066174	0.149498 - 0.410800
2028		0.282649	0.066189	0.151967 - 0.413330
2029		0.285149	0.066205	0.154437 - 0.415861
2030		0.287649	0.066220	0.156906 - 0.418392
2031		0.290149	0.066236	0.159375 - 0.420923
2032		0.292649	0.066252	0.161843 - 0.423454
2033		0.295149	0.066268	0.164311 - 0.425986
2034		0.297649	0.066285	0.166779 - 0.428518
2035		0.300149	0.066301	0.169247 - 0.431050
2036		0.302649	0.066318	0.171714 - 0.433583
2037		**0.305149**	0.066334	0.174181 - 0.436116
2038		0.307649	0.066351	0.176648 - 0.438649
2039		0.310149	0.066368	0.179114 - 0.441183
2040		0.312649	0.066385	0.181580 - 0.443717
2041		0.315148	0.066403	0.184046 - 0.446251
2042		0.317648	0.066420	0.186511 - 0.448786
2043		0.320148	0.066438	0.188976 - 0.451321
2044		0.322648	0.066456	0.191441 - 0.453856
2045		0.325148	0.066474	0.193905 - 0.456392
2046		0.327648	0.066492	0.196369 - 0.458927
2047		**0.330148**	0.066510	0.198833 - 0.461464

Model 2: OLS, using observations 1860-2017 (T=158)
Dependent variable: GS
Forecast Scenario 1
For 95% confidence intervals, t(155, 0.025) = 1.975

	GS	prediction	std. error	95% interval
1860	-0.237282	-0.150421		
1861	-0.111423	-0.140137		
1862	-0.071028	-0.132106		
1863	-0.063178	-0.122390		
1864	-0.052734	-0.114884		
1865	-0.084013	-0.108251		
1866	-0.185478	-0.101188		
1867	-0.055666	-0.096717		
1868	-0.154773	-0.104687		
1869	-0.112244	-0.110885		
1870	-0.070849	-0.111859		
1871	-0.040204	-0.107263		
1872	-0.036253	-0.100481		
1873	-0.041245	-0.093527		
1874	-0.042018	-0.087509		
1875	-0.046514	-0.081965		
1876	-0.043067	-0.075546		
1877	-0.046167	-0.067532		
1878	-0.029749	-0.061147		

1879	-0.017007	-0.054917
1880	-0.053262	-0.060623
1881	-0.053319	-0.062417
1882	-0.089328	-0.064154
1883	-0.082909	-0.062433
1884	-0.089421	-0.057549
1885	-0.105090	-0.053223
1886	-0.074229	-0.049704
1887	-0.096291	-0.049413
1888	-0.075349	-0.049963
1889	-0.104373	-0.048096
1890	-0.095603	-0.049192
1891	-0.078181	-0.048939
1892	-0.091113	-0.051259
1893	-0.073127	-0.051111
1894	-0.089699	-0.045073
1895	-0.046803	-0.039669
1896	-0.039773	-0.034848
1897	-0.045168	-0.029418
1898	-0.064518	-0.022958
1899	-0.061385	-0.019922
1900	-0.053342	-0.016127
1901	-0.041008	-0.012427
1902	-0.046983	-0.011426
1903	-0.017954	-0.010613
1904	-0.032947	-0.006897
1905	-0.025248	-0.004161
1906	-0.013431	-0.000092
1907	-0.005537	0.003667
1908	-0.005510	0.009244
1909	-0.010605	0.013907
1910	0.017234	0.018360
1911	0.035934	0.021686
1912	0.038358	0.025448
1913	0.041974	0.027879
1914	0.127793	0.031332
1915	0.098256	0.033490
1916	0.105606	0.037455
1917	0.109368	0.041123
1918	0.064384	0.040052
1919	0.000761	0.042098
1920	-0.020306	0.047834
1921	-0.000775	0.052328
1922	0.030460	0.054256
1923	0.016962	0.053909
1924	0.030132	0.055369
1925	0.040989	0.054881
1926	0.039906	0.054886
1927	0.069898	0.053805
1928	0.039510	0.053270
1929	0.036799	0.052376
1930	0.020086	0.052539
1931	-0.028936	0.052418
1932	-0.025752	0.053407
1933	0.012884	0.053401
1934	0.044560	0.053431
1935	0.052023	0.052857
1936	0.081457	0.052127
1937	0.081476	0.051600
1938	0.082683	0.052162
1939	0.073938	0.053506
1940	0.046497	0.054693
1941	0.102579	0.056552

1942	0.107616	0.060720
1943	0.101925	0.066617
1944	0.105561	0.073781
1945	0.154016	0.081084
1946	0.112954	0.090077
1947	0.086493	0.097385
1948	0.106487	0.105158
1949	0.142707	0.110022
1950	0.249922	0.114092
1951	0.104645	0.118267
1952	0.085359	0.121747
1953	0.121253	0.123905
1954	0.124672	0.126113
1955	0.096039	0.129913
1956	0.093865	0.132854
1957	0.094793	0.135845
1958	0.112460	0.137756
1959	0.150713	0.138682
1960	0.121157	0.139831
1961	0.150882	0.142028
1962	0.128726	0.143607
1963	0.153271	0.146018
1964	0.151981	0.150903
1965	0.153228	0.156835
1966	0.176916	0.161904
1967	0.182189	0.164513
1968	0.171831	0.165804
1969	0.186579	0.170992
1970	0.243773	0.176539
1971	0.229739	0.177230
1972	0.226329	0.175689
1973	0.231847	0.174293
1974	0.212359	0.174770
1975	0.222096	0.175176
1976	0.195921	0.175129
1977	0.158176	0.175421
1978	0.155308	0.174217
1979	0.157156	0.173146
1980	0.165071	0.171675
1981	0.145015	0.169135
1982	0.129773	0.166524
1983	0.145441	0.163766
1984	0.170648	0.161978
1985	0.166381	0.160563
1986	0.174903	0.159991
1987	0.175463	0.160400
1988	0.178421	0.162102
1989	0.178468	0.166254
1990	0.168113	0.169869
1991	0.141435	0.172381
1992	0.107256	0.174277
1993	0.081635	0.176682
1994	0.149387	0.180918
1995	0.183254	0.179985
1996	0.180794	0.177607
1997	0.182052	0.174833
1998	0.182686	0.172423
1999	0.177843	0.170054
2000	0.184446	0.169135
2001	0.182414	0.168715
2002	0.169444	0.168824
2003	0.189173	0.169247
2004	0.194777	0.169740

2005	0.196169	0.170283		
2006	0.222196	0.173703		
2007	0.235279	0.177487		
2008	0.223946	0.181584		
2009	0.161613	0.186680		
2010	0.183110	0.190797		
2011	0.180136	0.194133		
2012	0.177752	0.197968		
2013	0.176936	0.203242		
2014	0.180761	0.209694		
2015	0.189330	0.216152		
2016	0.190176	0.226174		
2017	**0.192600**	**0.234311**		
2018		0.239773	0.038917	0.162896 - 0.316650
2019		0.245235	0.038929	0.168336 - 0.322134
2020		0.250697	0.038946	0.173763 - 0.327630
2021		0.256159	0.038969	0.179179 - 0.333138
2022		0.261621	0.038999	0.184583 - 0.338659
2023		0.267083	0.039034	0.189975 - 0.344191
2024		0.272545	0.039076	0.195355 - 0.349735
2025		0.278007	0.039124	0.200722 - 0.355291
2026		0.283469	0.039177	0.206078 - 0.360859
2027		**0.288931**	0.039237	0.211423 - 0.366438
2028		0.294392	0.039302	0.216755 - 0.372030
2029		0.299854	0.039374	0.222076 - 0.377633
2030		0.305316	0.039451	0.227385 - 0.383248
2031		0.310778	0.039535	0.232682 - 0.388874
2032		0.316240	0.039624	0.237968 - 0.394512
2033		0.321702	0.039718	0.243243 - 0.400162
2034		0.327164	0.039819	0.248506 - 0.405822
2035		0.332626	0.039925	0.253758 - 0.411494
2036		0.338088	0.040037	0.258999 - 0.417177
2037		**0.343550**	0.040155	0.264229 - 0.422871
2038		0.349012	0.040278	0.269447 - 0.428577
2039		0.354474	0.040407	0.274655 - 0.434293
2040		0.359936	0.040541	0.279852 - 0.440019
2041		0.365398	0.040680	0.285039 - 0.445757
2042		0.370860	0.040825	0.290215 - 0.451505
2043		0.376322	0.040975	0.295380 - 0.457263
2044		0.381784	0.041130	0.300535 - 0.463032
2045		0.387246	0.041291	0.305680 - 0.468811
2046		0.392708	0.041457	0.310815 - 0.474600
2047		**0.398170**	0.041627	0.315939 - 0.480400

Model 3: OLS, using observations 1860-2017 (T=158)
Dependent variable: GS
Forecast Scenario 2
For 95% confidence intervals, t(155, 0.025) = 1.975

	GS	prediction	std. error	95% interval
2017	**0.192600**	**0.234311**		
2018		0.233022	0.038932	0.156115 - 0.309928
2019		0.231733	0.038959	0.154773 - 0.308692
2020		0.230444	0.038993	0.153418 - 0.307469
2021		0.229154	0.039033	0.152049 - 0.306260
2022		0.227865	0.039080	0.150667 - 0.305064
2023		0.226576	0.039134	0.149271 - 0.303881
2024		0.225287	0.039195	0.147863 - 0.302712
2025		0.223998	0.039262	0.146440 - 0.301555
2026		0.222709	0.039336	0.145005 - 0.300412
2027		**0.221420**	0.039416	0.143557 - 0.299282

2028	0.220131	0.039504	0.142096 - 0.298165
2029	0.218841	0.039597	0.140622 - 0.297061
2030	0.217552	0.039697	0.139135 - 0.295970
2031	0.216263	0.039804	0.137635 - 0.294891
2032	0.214974	0.039917	0.136123 - 0.293825
2033	0.213685	0.040036	0.134598 - 0.292772
2034	0.212396	0.040162	0.133061 - 0.291731
2035	0.211107	0.040294	0.131511 - 0.290702
2036	0.209817	0.040432	0.129949 - 0.289686
2037	**0.208528**	0.040576	0.128376 - 0.288681
2038	0.207239	0.040726	0.126790 - 0.287688
2039	0.205950	0.040882	0.125193 - 0.286708
2040	0.204661	0.041044	0.123584 - 0.285738
2041	0.203372	0.041212	0.121963 - 0.284781
2042	0.202083	0.041385	0.120331 - 0.283834
2043	0.200794	0.041564	0.118688 - 0.282899
2044	0.199504	0.041749	0.117034 - 0.281975
2045	0.198215	0.041940	0.115369 - 0.281062
2046	0.196926	0.042135	0.113693 - 0.280160
2047	**0.195637**	0.042337	0.112006 - 0.279268

Model 4: OLS, using observations 1850-2017 (T=158)
Dependent variable: GS
Forecast Scenario 3
For 95% confidence intervals, t(155, 0.025) = 1.975

	GS	prediction	std. error	95% interval
2017	**0.192600**	**0.234311**		
2018		0.244661	0.038923	0.167774 - 0.321548
2019		0.255011	0.038970	0.178030 - 0.331992
2020		0.265361	0.039055	0.188213 - 0.342509
2021		0.275711	0.039176	0.198323 - 0.353099
2022		0.286061	0.039334	0.208361 - 0.363761
2023		0.296411	0.039528	0.218327 - 0.374495
2024		0.306761	0.039758	0.228224 - 0.385299
2025		0.317111	0.040023	0.238051 - 0.396172
2026		0.327461	0.040322	0.247810 - 0.407112
2027		**0.337811**	0.040654	0.257503 - 0.418119
2028		0.348161	0.041019	0.267132 - 0.429191
2029		0.358511	0.041416	0.276698 - 0.440325
2030		0.368861	0.041844	0.286202 - 0.451520
2031		0.379211	0.042302	0.295648 - 0.462775
2032		0.389561	0.042789	0.305036 - 0.474087
2033		0.399911	0.043305	0.314368 - 0.485455
2034		0.410261	0.043847	0.323647 - 0.496875
2035		0.420611	0.044415	0.332875 - 0.508348
2036		0.430961	0.045008	0.342053 - 0.519870
2037		**0.441311**	0.045626	0.351183 - 0.531440
2038		0.451661	0.046266	0.360268 - 0.543055
2039		0.462011	0.046929	0.369309 - 0.554714
2040		0.472362	0.047613	0.378308 - 0.566415
2041		0.482712	0.048317	0.387266 - 0.578157
2042		0.493062	0.049041	0.396187 - 0.589937
2043		0.503412	0.049784	0.405070 - 0.601753
2044		0.513762	0.050544	0.413918 - 0.613605
2045		0.524112	0.051321	0.422732 - 0.625491
2046		0.534462	0.052115	0.431515 - 0.637408
2047		**0.544812**	0.052924	0.440266 - 0.649357