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Sowing the Seeds of Growth

Swedish Natural Capital Growth Accounting from 1850 to 2010

by

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Abstract:

Exploring the contributing factors of economic growth is a long-standing research field in economic study. However, natural capital stock has been widely excluded from this investigation. This thesis attempts to include natural capital stock in an augmented Solow growth model utilizing Swedish national accounts from 1850 to 2010. The model found that Swedish natural capital stock played a limited role in economic growth from 1850 to 1900. However, from 1933 to 2010 Swedish natural capital stock played a significant role in economic growth. In addition to exploring Swedish natural capital stock's role in economic development, this thesis also attempts to categorize Swedish development as either weak sustainability or strong sustainability. Through the definitions of weak sustainability and strong sustainability, as well as the results from the model, Sweden's economic growth appears to be weak sustainability. The more robust strong sustainability criteria are not met due to the extensive net CO_2 emissions by Sweden in the overall time period.

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1 Introduction

Labor, capital and technology are the most fundamental inputs for economic growth (Dobija and Kurek, 2013). However, capital encompasses a wide variety of things, as Hicks (1987) defines it as "all of those goods, existing in present time which can be used in any way, so as to satisfy wants during the subsequent years,". For example, machinery, timber, intellectual property and financial assets all fall under the same term "capital". Due to the definition of capital being so broad, there are categorical differences between different types of capital. Some of the categories of capital include physical capital, human capital, financial capital and natural capital.

1.1 Research Problem

Understanding how the individual inputs contribute to economic growth has been long researched and studied (Solow, 1956). However, until more recently, capital has not been broken into the differentiating categories mentioned above. Through Mankiw, Romer and Weil's (1992) research, it became possible to disaggregate the different categories of capital in a Solow growth model. As this became possible, a plethora of studies have implemented different categories of capital into augmented Solow growth models (Iddrisu, 2019; Gemmell, 1995; McDonald and Roberts, 2002). However, most of these studies (other than Iddrisu, 2019) use this methodology to implement human capital into an augmented Solow growth model. The purpose of this paper is to disaggregate and include natural capital into an augmented Solow growth model. The inclusion of natural capital in this model can identify natural capital's contribution to economic growth.

For the purposes of this thesis, natural capital will be the main focus as it has properties that make it unique compared to other forms of capital as done in Costanza (1992) definition of Ecological Economics. There are both narrow and broad definitions for natural capital, the narrow definition is described well by Barbier, Jansson, Hammer, Koskoff, Folke, Costanza and Costanza (1994) as commercially available renewable and non-renewable natural resources. However, for this thesis a more complete broad definition will be implemented. The broad definition is best described in Wackernagel and Rees (1997) includes "all the biophysical resources and waste sinks needed to support the human economy… [and] the relationship among those entities and processes that provide life support to the ecosphere,". This definition of natural capital can be broken down further into renewable and non-renewable natural capital. Renewable natural capital includes self-producing capital like biomass, water, solar energy, or atmospheric ozone. Non-renewable natural capital includes fossil fuels (coal and oil), minerals and ores. Along with these categorical breakdowns, Ekins, Simon, Deutsch, Folke and De Groot (2003) define critical natural capital. Critical natural capital is the natural capital that is essential for environmental sustainability (Ekins et al., 2003). Natural capital totally encompasses the combination of these two categories (Wackernagel and Rees, 1997). Out of these two categories, this paper is more interested in the non-renewable natural capitals as by their nature they cannot be replenished. Natural capital, especially non-renewable natural capital, absolutely needs to be preserved in order for adequate ecological flows in the human economy (Wackernagel and Rees, 1997). Not only does natural capital need to be maintained in absolute terms, but it is also essential for it to be maintained on a per capita basis (Barbier et al., 1994). Understanding how natural capital has been implemented and exploited in the stages of development is important for working towards the next steps of the development process.

1.2 The Swedish Context

For this paper, Sweden's accounts of natural capital have been selected for several reasons. The first of these reasons is that Sweden is one of the few countries that has practiced 'ecological modernization', while keeping extensive historical record keeping of the natural capital stocks (Lidskog and Elander, 2012). With the existence of a sustainable development process and natural capital stock records, research on the role of natural capital in the development process becomes possible. The next reason Sweden's natural capital accounts are chosen is because there is considerable background research already done regarding natural capital in Sweden, specifically an Adjusted Net Savings calculation that can be used for reference. Along with this, Sweden's industrialization process took place during the 'second industrial revolution period' (Lindmark, Nguyen and Stage, 2018). The fact that the industrialization process took place later assists in the quality of natural capital stock accounting and the type of industrialization that took place. As emphasized in Schön and Krantz (2012), Sweden's development process heavily relied on the exploitation of Swedish natural capital. Due to these motivations, Swedish data will be utilized throughout this paper.

Sweden's economic development and industrialization was driven by growing economic sectors that focused on natural capital such as timber and iron ore (Lederman and Maloney, 2006). From this initial point of the Swedish economy, there has been significant diversification, leading to sectors without as much natural capital dependency (Lederman and Maloney, 2006). However, a sizable portion of Sweden's manufacturing sector is still reliant on Swedish natural capital (Lederman and Maloney, 2006).

The Swedish natural capital stock accounts implemented in this paper are estimated and collected by Lindmark and Andersson (2016). An issue with the estimation of natural capital stock for this paper is how one of the elements of natural capital stock is calculated (iron ore stock). The details of the issue are presented later in the paper. As it is only one factor in the calculation by Lindmark and Andersson (2016), and there are limited datasets that include Swedish natural capital stock for the selected time period, this paper will still utilize the data. A discussion on the issues of the data and how they can be remedied in the future take place in the discussion and conclusion sections.

1.3 Research Question

What role has natural capital played in Sweden's economic development from 1850 to 2010?

Sub-Question:

1. What type of growth has Sweden experienced during this time period in terms of weak sustainability and strong sustainability?

1.4 Outline of the Thesis

The rest of the paper is presented in the following order: Initially, the theoretical framework and theoretical approach are outlined and discussed. Within the discussion of the theoretical framework, a summarization of Swedish political and economic policy over the complete time period is provided. There are two motivations for this, the first is to provide context for the sustainable development process, and the second is to display the rationale behind the selected time periods. Next, the data that is utilized in this paper is reviewed and examined. After the data is presented, the econometric approach for displaying Swedish natural capital's correlation with Sweden's development is configured. With the econometric approach set, the empirical results from the model are shown along with the results from a robust model. Through the results of the model, a discussion take place from the findings with a particular discussion surrounding the hypotheses. Finally, the paper is concluded with the aims, results, limitations, practical implications and the future research prospects of this paper.

2 Theory

The theory section of the paper first presents the previous research related to Swedish natural capital, as well as the previous research conducted surrounding the use of augmented Solow growth models. Next, the paper discusses the framework involved in defining and identifying the classification of sustainability (i.e. weak sustainability and strong sustainability. Lastly, the paper provides the Swedish political and economic historical context and simultaneously creates the individual Swedish economic time periods.

2.1 Previous Research

Most of the research on natural capital has been done through the lens of a 'weak sustainability model', in order to identify sustainable development. The main question that is asked is in order to sustain economic growth is natural capital important enough to be preserved (Dietz and Neumayer, 2007). Weak sustainability, as explained in Neumayer (1999), is the assumption that natural capital stock is able to be replaced by other forms of capital stock like physical capital, human capital, etc. Strong sustainability, on the other hand, is the assumption that natural capital stock has inherent differences which makes it impossible to replace through other means of capital stock (Neumayer, 1999). The differences between these two assumptions is stark and critical when defining the steps to continue global development.

One of the most significant weak sustainability development metrics that is currently being researched was developed by Pearce & Atkinson (1993) and is referred to as both Adjusted Net Savings and Genuine Savings. Adjusted Net Savings is a metric that looks at the shifts in a nation's overall capital stocks (Pearce and Atkinson, 1993). The reason that Adjusted Net Savings is considered a weak sustainability metric is that it measures overall capital stock, thus treating natural capital stock and other capital stock as substitutable. Nonetheless, Adjusted Net Savings does incorporate natural capital stock into its calculation (Pearce and Atkinson, 1993). This metric has been calculated and analyzed for a plethora of different countries by Blum, Mclaughlin and Hanley (2019) and Greasley, Hanley, Kunnas, Mclaughlin, Oxley and Ward (2014). However, the most relevant calculation and testing of Adjusted Net Savings for this paper is the research by Lindmark, Nguyen and Stage (2018) that uses the case of Sweden with data from Lindmark (1998), Lindmark and Andersson (2014) and Lindmark and Andersson (2016). In the study by Lindmark, Nguyen and Stage (2018), Swedish Adjusted Net Savings is analyzed by its correlation with Swedish Present Value of Consumption (PVC) from 1850 to 2000. The PVC was implemented in this study as an indicator of long term well being. Ultimately in the study by Lindmark, Nguyen and Stage (2018), the only connection between Adjusted Net Savings and future economic well being found was using the weak sustainability literature. The anticipated one to one connection between Adjusted Net Savings and future well being, theorized by Weitzman (1976), was not found by the Lindmark, Nguyen and Stage (2018) study. The Weitzman (1976) theory has yet to be empirically identified in any academic research. Through the Adjusted Net Savings methodology utilized by Lindmark, Nguyen and Stage (2018), it is not possible to disaggregate natural capital to account for the impact on economic growth. This paper intends to implement a different methodological approach using an augmented Solow growth model that has the ability to separate different types of capital stock for their individual contributions on economic growth. With this different methodology, a clearer image of natural capital's contribution to economic growth is displayed.

Along with most of the work with natural capital being done through a 'weak sustainability model', most work with growth accounting has neglected the differentiation of produced capital and natural capital. The International Monetary Fund (IMF) has produced several growth accounting papers, like Senhadji (2000), that are mainly focused on the differences in total factor productivity (TFP) levels in different nations. The Senhadji (2000) research implements a Solow growth model with and without human capital, but does not include natural capital. In addition to the IMF's work with national growth accounting, Aghion and Howitt (2007) create a hybrid Solow growth model and Schumpeterian model in order to make TFP endogenous. However, like the prior research by Senhadji (2000), there is no inclusion of natural capital in the model utilized by Aghion and Howitt (2007). Jeon and Sickles (2004) implements a different methodology that uses piecewise linear and convex boundary function to discuss environmental damage with economic growth. Unfortunately, in this model, it is only able to identify negative results on the environment from pollution with economic growth, rather than account for how natural capital stock contributes to growth (Jeon and Sickles, 2004). In the Mankiw, Romer and Weil (1992) research developed an augmented Solow growth model that has the capability of including different variables such as human capital or natural capital. Iddrisu (2019) took this background research from Mankiw, Romer and Weil (1992) and growth accounted for 63 nations' data over a 15 year time period. Although a step in the right direction, this study by Iddrisu (2019) is only able to use short term data due to the implementation of World Bank natural capital data which is sporadic and incomplete. There has been no long term national growth accounting research that includes the augmented Solow growth model with natural capital.

In addition to the previous work with augmented Solow growth models, Schön (2009) researched the role of the level of technology and productivity in Sweden from 1850 to 2005. Without the utilization of an augmented Solow growth model, Schön (2009) applies a similar approach to Swedish economic growth, but with the focus on total factor productivity. In this case, Schön (2009) argues that the processes of innovation, diffusion and structural change lead to 'creative destruction' in the wake of a crisis towards structural transformation. However, as the focus of this research is dedicated to technology and productivity, Schön (2009) takes a closer look at specific sectors (industrial sectors) rather than the entire economy. Moreover, there is no analysis emphasizing the role of natural capital contribution to economic growth in Schön (2009).

2.2 Theoretical Framework

There are four terms that will be implemented to describe the sustainability of the development process: weak sustainability, strong sustainability, very weak sustainability and very strong sustainability.

Weak Sustainability:

As previously mentioned, for there to be weak sustainability neither natural capital stock nor economic capital stock individually need to be maintained. Rather, for weak sustainability to be present overall capital stock needs to be maintained (Hediger, 1999). The background principle behind weak sustainability is that changes in the natural capital stock can be compensated for by other forms of capital (Hediger, 1999). The implication for this is that natural capital stock does not hold any greater importance to economic activity or well being when compared to any other form of capital.

Strong Sustainability:

As aforementioned, for there to be strong sustainability natural capital stocks need to be maintained (Hediger, 1999). The background principle behind strong sustainability is ecological conservation, due to natural capital stocks inherent unique qualities. Strong sustainability can be broken into two different criteria, physical and ecological (Hediger, 1999). Physical strong sustainability has the criteria of keeping physical natural capital stock, like minerals or ores, level. While ecological strong sustainability has the criteria of maintaining and protecting the natural environment.

Very Weak Sustainability:

Also known as "Solow Sustainability", only requires the "generalized productive capacity," of an economy to maintain constant levels of consumption for future generations (Hediger, 1999). The main requirement for Solow Sustainability is that the overall capital stock to "maintain a decent standard of living," (Hediger, 1999). The underlying principle of this is found in Hicks (1939), that consumption in the present does not damage consumption in the future. The implications of Solow sustainability is that it is completely unaware of the changing complexities of ecosystems and assumes all non-renewable natural capital is replaceable by different forms of capital stocks.

Very Strong Sustainability:

Very Strong Sustainability, unlike the other categories, is a stationary-state principle. For Very Strong Sustainability to be possible, it is necessary for human scale, both population growth and economic growth to be zero (Hediger, 1999).

Proxy for Environmental Degradation:

In order to examine the type of Swedish sustainability of the individual and overall time period, the implementation of a proxy measurement of environmental degradation is necessary. The chosen proxy for environmental degradation is CO_2 emissions. There is significant academic precedent for utilizing CO_2 emissions as the proxy for environmental degradation (Dinda, 2004; Altıntaş and Kassouri, 2020). However, this does not indicate that CO_2 emissions is a perfect proxy for environmental degradation. Rather, it is a significant pollutant (especially in industrial economies) that has been identified to cause severe environmental damage (Fang, Yu, Cheng, Zhu, Wang, Yan, Wang, Cao and Zhou, 2010). Along with this, CO_2 emissions as a metric is one of the only environmental degradation measures with academic precedent that has been estimated/collected from 1850 to 2010 in Sweden.

2.2.1 Swedish Economic Time Periods

Since the time period examined in this paper is 160 years long, it is important to discuss shifts in policy and practice to create “economic time periods” and provide the process of Swedish sustainable development. Although Schön (2009) creates different Swedish economic time periods based on savings rates and technological waves, this paper requires a different approach. By creating and categorizing time periods different from Schön (2009), the analysis of the specific role natural capital plays in economic growth will be clearer and less contaminated with changes in economic structure. Along with this, by looking more in-depth into Sweden’s change in economic policy, a sufficient foundation is built for the presentation of the data.

The first time period that will be discussed in Sweden’s economic history is from 1850 to 1865. In 1864, Sweden created new legislation called “näringsfrihet”, that deals with the freedom of entrepreneurship (Magnusson, 2000). Before this policy was enacted, Swedish workers needed to be a member of a guild as an apprentice or master to practice as an artisan (Magnusson, 2000). Without this restriction, artisan craft became widely more available to the general Swedish population. However, the reason the time period is extended one year longer is due to Sweden joining the European free trade system in 1865 (Magnusson, 2000). By joining a free trade system, the Swedish economy would drastically change as specialization was allowed to take place (Magnusson, 2000). As noted in Sandewall, Kassa, Wu, Khoa, He and Ohlsson (2015), Sweden faced severe deforestation from the timber agriculture industries which was booming during the time. Almost the entirety of central and southern had been deforested to make use of the land for agriculture (Sandewall et al., 2015). The policy that made this level of deforestation possible was that allowed private companies to own forests (Sandewall et al., 2015). In 1850, Sweden’s natural capital breakdown was 46 percent cropland, 53 percent timber and forest and 1 percent fish (Lindmark and Andersson, 2016).

In the 1866 to 1900 Swedish economic time period, it is seen that industrial labor was not yet heavily favored to agricultural labor (Lundh and Prado, 2015). As Magnusson (2000) notes, government intervention in this time period is relatively stable. The government intervention mainly centered around expanding infrastructure (e.g. roads, railroads and harbors), a limited welfare program centered around work injury and pension, and providing basic human services like health care and compulsory schooling (Magnusson, 2000). In 1870, Sweden’s natural capital breakdown was 50 percent cropland, 49 percent timber and forest and 1 percent fish (Lindmark and Andersson, 2016).

The next Swedish economic period is from 1901 to 1921. This period is characterized by Sweden transitioning its government to a democracy (Lewin and Lindvall, 2015). With the new governmental structure of Sweden, different economic policies were instituted with a higher focus on the population’s well being (Lewin and Lindvall, 2015). Due to the rapid deforestation that happened in the previous periods, Sweden enacted its first modern forest legislation in 1903 (Sandewall et al., 2015). This policy required all logged areas to be reforested, which still remains to present day (Sandewall et al., 2015). In 1910, Sweden’s natural capital breakdown was 50 percent cropland, 43 percent timber and forest, 3 percent fish stock and 3 percent energy and minerals (Lindmark and Andersson, 2016).

The following Swedish economic period is from 1922-1932. Lewin and Lindvall (2015) describe Sweden as transforming “from one of the poorest and least developed countries in Northern Europe to a fast-growing modern society whose high level of economic growth was driven by industrial innovations.” As Sweden’s Center-Right parties held the majority in the government in this period, there was an emphasis on interplaying market forces (Lewin and Lindvall, 2015). Along with this sentiment came an expansion of economic freedom with limited governmental support (Lewin and Lindvall, 2015). Although the beginning of this period was prosperous for the Swedish economy, by the end Sweden was facing the effects of the Great Depression (Lewin and Lindvall, 2015). Between the years

1930 and 1932, Sweden's real GDP per capita had decreased by five percent (Lewin and Lindvall, 2015). This downturn in economic fortune, along with new Keynesian economic theory, resulted in Sweden removing themselves from the Gold Standard in 1931 (Lundberg, 1985). The ending of this Swedish economic period is seen with the Swedish Social Democrats winning the election 1932 and Per Albin Hansson becoming Prime Minister (Lewin and Lindvall, 2015). In 1930, Sweden's natural capital breakdown was 42 percent cropland, 47 percent timber and forest, 4 percent fish stock, and 7 percent energy and minerals (Lindmark and Andersson, 2016).

The next Swedish economic period is from 1933-1945. Once the Swedish Social Democrats came together with the Agrarian party in 1932, and the following spring of 1933 they created what is now called the "Cow Trade" (Lewin and Lindvall, 2015). With this, Sweden became a forerunner of Keynesian economics taking a strategy in between that of nationalization and non-interventional economics (Lewin and Lindvall, 2015). Although the "Cow Trade" was a different approach, many scholars like Jonung (1977) and Helmersson (1972) disagree on the depth these policies actually had on the economy. No matter the actual depth of this specific policy, in comparison to other European nations this began Sweden's push towards more progressive economic policy (Lewin and Lindvall, 2015). World War II ravaged most of Europe during this time period, destroying both physical and natural capital (Auray, Eyquem and Jouneau-Sion, 2014). However, Sweden was able to avoid this wide scale destruction of capital through neutrality (Auray, Eyquem and Jouneau-Sion, 2014). By the end of the war, the Swedish Social Democrats wanted to move from solely maintaining full employment in the nation towards preventing unemployment crises through increased state involvement (Lewin and Lindvall, 2015; Barkin, 1968). This sparked a heated political debate within Sweden, leading to the next period, 1946 to 1973. Between the years 1930 and 1950, the breakdown of Sweden's natural capital drastically changed from 42 percent to 18 percent cropland, 47 percent to 60 percent timber and forest, no change in fish stock at 4 percent, and from 7 percent to 18 percent energy and minerals (Lindmark and Andersson, 2016).

The next Swedish economic period is from 1946 to 1973. Ultimately, the Swedish Social Democrats won the election in 1948 and dropped their original after-war plans of heightened governmental intervention. With general harmony in Swedish politics, the government was deemed the "Harpsund Democracy" through the Rehn-Meidner model (Lewin and Lindvall, 2015). In the prior time periods, there was a large emphasis on combating unemployment, however, in this time period there was a greater emphasis on managing extreme growth (Lewin and Lindvall, 2015). As noted by one of its founders, Rudolf Meidner, the Rehn-Meidner model was a model focused on optimizing the market (Lewin and Lindvall, 2015). This was mainly achieved through what is called "wage earner funds" which is the idea of taxing private company profits and creating a fund controlled by labor union representatives that buy shares of listed companies (Pontusson, 1992; Whyman, 2004). Ultimately, the Rehn-Meidner model allowed for important stakeholders (politicians, bureaucrats, worker unions and employer organizations) to collaborate on important matters like macroeconomic policy and wage bargaining (Lewin and Lindvall, 2015). Swenson (2002) suggests that compared to other countries during this time period, Sweden was leading in having economic policies that were labor market active. Although through this time period Sweden was rapidly growing, the productivity rate increases could not be sustained coinciding with the Oil Crisis of 1973 (Lewin and Lindvall, 2015). In this time period, Sweden became one of the frontrunners in Europe to "establish comprehensive environmental legislation," (Hysing, 2014). Establishment of Sweden's environmental institutions in 1967 and enactment of the Environmental Protection Act of 1969 solidified Sweden's place as frontrunners (Hysing, 2014). Sweden's environmental aspirations were not limited inside of their own national borders, as they hosted the world's first large international environmental conference (Hysing, 2014). In 1970, Sweden's natural capital breakdown was 24 percent cropland, 52 percent timber and forest, 4 percent fish stock, and 20 percent energy and minerals (Lindmark and Andersson, 2016).

With the end of the extremely prosperous post-war period, the next Swedish economic time period is from 1974 to 1991. The economic downturn that resulted from steeply increasing oil prices coupled with continued investment in 'heavy industry' and the energy sector, causing Swedish economic policy to become fiscally expansionary in an attempt to bridge the gap left from decreasing international demand (Schön, 2012; Lewin and Lindvall, 2015). The Swedish government decided to prioritize maintaining full employment rather than keep the currency stable and a balanced current account (Lindvall, 2010). This economic strategy by the Swedish government was continued until 1980 following the second oil crisis (Lindvall, 2010). Following a global trend, the Swedish government stopped the macroeconomic tool that is fiscal policy, however, they were still unwilling to give up on full employment (Lewin and Lindvall, 2015). Attempting to maintain full employment, the Swedish government resorted to exchange rate manipulation (like many other European nations) with two major shifts in 1981 and 1982 at 10 percent and 16 percent devaluations respectively (Qian and Varangis, 1994; Eichengreen, 2019). With rising inflation possibly having adverse effects on the Swedish economy, the Swedish economic strategy turned to controlling inflation by the late 1980s (Lewin and Lindvall, 2015). This economic time period in Sweden ends with the commitment to have a fixed exchange rate for the Swedish kronor (Lewin and Lindvall, 2015). This change from a managed floating exchange rate to a currency basket to a fixed exchange rate pegged to the European Currency Unit (ECU) in 1991 was a turning-point in Swedish economic policy as it signified Sweden joining the European mainstream (Lindbeck, 1997; Eichengreen, 2019). However, this fixed exchange rate was only for a brief moment as it changed to a floating exchange rate in November of 1992 (Eichengreen, 2019). While Sweden was joining the European mainstream in traditional economic policy, they were also becoming early adopters of innovative environmental policy (Hysing, 2014). Between 1990 and 1991, Sweden introduced one of the first 'green taxes' that created a system to lower taxes on income and capital gains by increasing taxes on energy and emissions (Hysing, 2014). In 1990, Sweden's natural capital breakdown was 6 percent cropland, 77 percent timber and forest, 3 percent fish stock and 15 percent energy and minerals (Lindmark and Andersson, 2016).

The final Swedish economic time period examined in this paper is from 1992 to 2010 and can be described as crisis to crisis. Beginning in 1991 Sweden went through a difficult economic crisis (Lewin and Lindvall, 2015). From 1991 to 1993 Sweden experienced three consecutive years of negative GDP growth (Lewin and Lindvall, 2015). One of only three instances of this for democratic OECD countries between World War II and the financial crisis of 2008 (Lewin and Lindvall, 2015). Along with this, Swedish unemployment rose from only 2 percent of the labor force to around 10 percent of the labor force in this 3 year period (Lewin and Lindvall, 2015). This economic crisis affected Swedish economic policy as it forced the nation away from their post-war model. Since the early 1990s economic crisis Sweden has utilized monetary policy as its main macroeconomic tool (Lewin and Lindvall, 2015). The specific monetary policy was to aim for a target of 2 percent inflation per year (Lewin and Lindvall, 2015). The central bank of Sweden was essential for this monetary policy goal, and in order to prevent political motivations from interfering with this, the central bank became completely independent of the government in 1999 (Lewin and Lindvall, 2015). Along with this, the Swedish government incorporated a form of budgeting procedures to ensure the control of national spending. These are some of the reasons Sweden ultimately opted against joining the European Economic and Monetary Union (EMU) decided by a referendum in 2003 (Reade and Volz, 2009). In between the early 1990s crisis and the financial crisis of 2008 and 2009, the framework received wide scale plaudits from within and outside of Sweden (Lewin and Lindvall, 2015). However, when the 2008 and 2009 financial crisis did hit Sweden, the expansionary monetary policy response of the central bank was small compared to the earlier approaches taken by the Swedish government (Lewin and Lindvall, 2015). In 2010, Sweden's natural capital breakdown was 8 percent cropland, 47 percent timber and forest, 1 percent fish stock and 44 percent energy and minerals (Lindmark and Andersson, 2016). Over the course of this time period, Sweden was able to reduce its carbon emissions by about 10 percent (Hysing, 2014). Sweden was able to achieve this feat through the utilization of reduced fossil fuels use and carbon taxes (Hysing, 2014). Moreover, it was not only the national government of Sweden that played a crucial role in the environment, local governments also played an important role (Hysing, 2014). Local governments not only had the role of implementing new national policies regarding the environment, but they also held the responsibility of developing their own ecological projects (Eckerberg, Lafferty and Meadowcroft, 2000; Lundqvist, 2004; Olsson, 2009). The local government projects in the late 1990s were assisted by the national government with large scale investments (Eckerberg, Lafferty, and Meadowcroft, 2000; Lundqvist, 2004; Olsson, 2009). Throughout all of this, Sweden was not only concerned with their domestic environmental policy, they also took a strong stance in the international field (Hysing, 2014). At the Rio Earth Summit, Sweden acknowledged the developed world's role in environmental issues and placed their support behind rugged environmental protection (Eckerberg, Lafferty and Meadowcroft, 2000; Andersen and Liefferink, 1997). In addition to this, after Sweden joined the European Union (EU) in 1995, they brought their environmental policy experience with them (Kronsell, 2002). Under their first position as EU president in 2001, Sweden made sure to emphasize environmental issues and managed to unify the other EU member-states to maintain cooperation with the Kyoto Protocol (Kronsell, 2001). This concludes the last Swedish economic time period of significance to this paper.

2.3 Theoretical Approach

In order to take account of Sweden's natural capital contributions to growth, extensive economic research has had to take place prior. One of the most important theories for this paper is Solow's (1956) original growth model. Solow's (1956) growth model concludes that economic growth is rooted in two variables: Capital and Labor. Shortly after, Abramowitz (1956) saw the necessity to include the level of technology as the size of the residual played a major role in economic growth. For these parameters to fit, it is necessary that savings and investment decisions are not individually optimized, rather they are considered exogenous (Mankiw, Romer and Weil, 1992). Along with this, population growth and technological progress are also assumed to be exogenous (Mankiw, Romer and Weil, 1992). In this original model, neither land or natural capital is included in the reasons for growth (Solow, 1956). With this description of the model, a Cobb-Douglas function can be written as such:

(1) $$Y_{(t)} = K_{(t)}^{\alpha}(A_{(t)}L_{(t)})^{1-\alpha} \quad 0 < \alpha < 1$$

In this Cobb-Douglas function, $Y_{(t)}$ denotes GDP at time *t*, $K_{(t)}$ denotes capital at time *t*, $L_{(t)}$ denotes Labor at time *t* and $A_{(t)}$ denotes the level of technology at time *t*. Labor and the level of technology, as mentioned previously, are assumed to grow exogenously at rates that are denoted as *n* and *g* respectively (Mankiw, Romer and Weil, 1992). The equations that include these rates can be written as such:

(2) $$L_{(t)} = L(0)e^{nt}$$
(3) $$A_{(t)} = A(0)e^{nt}$$

From the equations (2) and (3) it is possible to derive the equations for output for each unit of labor and the stock of capital for each unit of labor to be $y_{(t)} = \left[\frac{Y_{(t)}}{A_{(t)}L_{(t)}}\right]$ and $k_{(t)} = \left[\frac{K_{(t)}}{A_{(t)}L_{(t)}}\right]$ respectively. Mankiw, Romer and Weil (1992) then derive the formula for the evolution of *k* as:

(4) $$k_{(t)} = sy_{(t)} - (n + g + \delta)k_{(t)}$$
$$k_{(t)} = sk_{(t)} - (n + g + \delta)k_{(t)}$$

In this equation, *s* denotes the constant savings rate and denotes the depreciation rate. Mankiw, Romer and Weil (1992) show that equation (4) shows that *k* converges to a steady-state at the value *k**, which can be written as such:

(5) $$k^* = [s/(n + g + \delta]^{1/(1-\alpha)}$$

In order to use the Solow (1956) growth model for this paper, it is necessary to add another variable into the model for natural capital. The paper by Iddrisu (2019) has developed this augmented Solow growth model that includes both natural capital and human capital. For the purpose of this paper, the augmented Solow growth model will only include natural capital without the inclusion of human capital. The augmented Solow growth model with the inclusion of natural capital ($E_{(t)}$) can be written as such (Iddrisu, 2019):

(6) $$Y_{(t)} = K_{(t)}^{\alpha} E_{(t)}^{\beta} (A_{(t)}L_{(t)})^{1-\alpha-\beta} \qquad 0 < \alpha + \beta < 1$$

In this equation, *Y, K, A*, and *L* still denote the values of output, capital, level of technology and labor respectively with *t* still being the time period. The equations (2) and (3) for exogenous labor and level of technology growth still hold true for the augmented Solow growth model. Due to this, we can also define the output per effective unit of labor, the capital per effective unit of labor and the natural capitals per effective unit of labor as $y_{(t)} = \left[\frac{Y_{(t)}}{A_{(t)}L_{(t)}}\right]$, $k_{(t)} = \left[\frac{K_{(t)}}{A_{(t)}L_{(t)}}\right]$and $\dot{e}_{(t)} = \left[\frac{E_{(t)}}{A_{(t)}L_{(t)}}\right]$respectively. Through these definitions the evolution of the economy from the accumulation of capital and natural capital can be written as such:

(7) $$\dot{k}_{(t)} = s_k y_{(t)} - (n + g + \delta)k_{(t)} = s_k k_{(t)}^{\alpha} - (n + g + \delta)k_{(t)}$$
(8) $$\dot{e}_{(t)} = s_e y_{(t)} - (n + g + \delta)e_{(t)} = s_e \dot{e}_{(t)}^{\beta} - (n + g + \delta)\dot{e}_{(t)}$$

In the equations above, s_k and $s_{\dot{e}}$ denote the savings rates for both capital and natural capital respectively at time *t*. As the same in equation (5) δ denotes the depreciation. Both equations (7) and (8) imply that capital ($k_{(t)}$) and natural capital ($\dot{e}_{(t)}$) converge towards a steady state (*k* and ė**) which can be written as such (Iddrisu, 2019):

(9) $$k^* = \left[\frac{s_k^{1-\beta} s_{\dot{e}}^{\beta}}{(n+g+\delta)}\right]^{\frac{1}{1-\alpha-\beta}}$$

(10) $$\dot{e}^* = \left[\frac{s_k^{1-\alpha} s_{\dot{e}}^{\alpha}}{(n+g+\delta)}\right]^{\frac{1}{1-\alpha-\beta}}$$

2.3.1 Hypotheses

Hypothesis 1 (H_1):

The first hypothesis is that natural capital stock's contribution to GDP will become increasingly important to economic growth throughout the time periods. The background behind this hypothesis is that Sweden severely diminished the national natural capital stock in the early time periods (1850 to 1865 and 1866 to 1900). As Sandewall et al. (2015) notes, Sweden significantly reduced its natural capital stock through deforestation. Having so heavily exploited the stock of natural resources, it is unlikely that the stock was able to play a large role in economic development. However, as noted in Hysing (2014), Kronsell (2001, 2002), Andersen and Liefferink (1997), Eckerberg, Lafferty and Meadowcroft (2000), Lundqvist (2004) and Olsson (2009), in the later periods (1974 to 1991 and 1992 to 2010) Sweden became more engaged in preserving the environment. Therefore, it is logical to conclude that Sweden's natural capital stock will increase from higher levels of protection of the environment. This hypothesis is also backed by Lindmark and Andersson (2016) finding an increase in Sweden's natural capital stock in these time periods.

Hypothesis 2 (H_2):

The second hypothesis is that throughout the entire time period, Sweden's type of sustainability can be categorized as weak sustainability. This hypothesis is rooted in the fact that in the earlier time periods (1850 to 1865, 1866 to 1900, 1901 to 1921 and 1922 to 1932) natural capital stock is heavily exploited (Lindmark and Andersson, 2016; Sandewall et al., 2015). While on the other hand, produced capital in these time periods experienced growth and the Swedish economy grew. Although Sweden's overall growth is expected to resemble weak sustainability, the later time periods (1974 to 1991 and 1992 to 2010) are expected to resemble closer to strong sustainability. This expectation is rooted in the works of Hysing (2014), Kronsell (2001, 2002), Andersen and Liefferink (1997), Eckerberg, Lafferty and Meadowcroft (2000), Lundqvist (2004) and Olsson (2009) that show Sweden took both preservation and environmental protection more seriously through awareness and laws.

3 Data

The data that is applied to the theoretical approach, outlined above, is Swedish time-series data from 1850 to 2010 has been collected from several different Swedish national accounts and databases. With 160 years of different variables necessary for the augmented Solow growth model, it is imperative to start with any necessary explanation and breakdown of the key variables, paired with the data visually represented in graph format. Then it is essential to provide the descriptive statistics of the key variables in totality and by time period.

3.1 Variable Breakdown

The first variable that will be discussed is Swedish total hours worked, calculated with data from Schön and Krantz (2012). In the Schön and Krantz (2012) paper, they have collected average number of hours worked and total employed persons, so through simple multiplication of these two variables total hours worked by Swedish employees. The variable has been put in millions for better understanding. This variable will be implemented in the model as a proxy for labor input in the augmented Solow growth model. In 1850, there were 2,955 million hours of work done in Sweden and by 2010 this figure rose to 7,354 million hours worked. Although the total number of hours worked increased, the average number of hours worked per person decreased from 2,220 hours to around 2,013 hours. What this implies is that total hours worked growth was driven by the increasing number of people employed, rather than hours worked by individuals. In addition to this, the ratio of total employment to total population remain relatively stable throughout the entire time period (Schön and Krantz, 2012). The conclusion is that Swedish total hours worked have increased due to an increasing Swedish population size. Here is a graph of Swedish total hours worked from 1850 to 2010:

Figure 1: Swedish Total Hours Worked in Millions of Hours from 1850 to 2010 (Schön and Krantz, 2012)

The next variable that will be discussed is Swedish Gross Domestic Product (GDP) from 1850 to 2010 which is collected from Schön and Krantz (2012). GDP is an international measurement for the value of all things produced (both goods and services) in a country over a certain period of time (Coyle, 2015). In this measurement of GDP, the data was collected annually. In order to remove any changes in the price levels of the Sweden, the GDP is put into constant price of 1910/1912 Swedish Kronor (SEK). Along with this, the GDP data has been recorded in millions of SEK for a better understanding of the variable. The GDP variable will be implemented in the augmented Solow growth model as a proxy for the economic growth that took place in Sweden, as done in Iddrisu (2019). In 1850, the Swedish GDP began at 869 million SEK and rose drastically to 50,225 million SEK by 2010. Here is a graph of Swedish from 1850 to 2010:

Figure 2: Swedish GDP in Millions of SEK from 1850 to 2010 (Schön and Krantz, 2012)

The next variable that will be discussed is Swedish capital stock from 1850 to 2010 collected from Lindmark and Andersson (2016). The capital stock variable measures the value of the produced capital stock in Sweden in millions of 1910/1912 SEK. The capital stock value has been indexed for the 1930 value of capital for the understanding of the change in stock overtime. The Lindmark and Andersson (2016) paper values the capital stock of Sweden by using insurance data. The reason for the use of insurance data is that there is a clear replacement evaluation of the capital stock providing the capital's value (Lindmark and Andersson, 2016). Although an accepted way to measure the value of capital stock, it is expected that the evaluation is lower than the true value of the capital stock (Lindmark and Andersson, 2016). In 1850, Sweden's capital stock was valued at 2,458 million SEK (4.735 when indexed) by 2010 the capital stock in Sweden was valued at 17,557,938 million SEK (33,816 when indexed).

The final variable that will be discussed that will be implemented into the model is the Swedish natural capital stock from 1850 to 2010 collected from Lindmark and Andersson (2016). This variable is measured in value of millions of 1910/1912 SEK and is also indexed for the value in 1930. The natural capital stock variable is calculated as the combination of value from agricultural land, timber and forests, fish stock and subsoil assets. The value of agricultural land is measured by multiplying the annual average price of land and the total amount of agricultural land (Lindmark and Andersson, 2016). The value of timber is measured through the average price of timber in a given year and the volume of standing timber (Lindmark and Andersson, 2016). However, since timber prices are set for trees that are ready to be cut (called the stumpage price), there is an additional evaluation necessary for the value of forests not intended/ready to be cut down (Lindmark and Andersson, 2016). The forest capital price is calculated by multiplying the average insurance replacement price of a forest and the total size of forest land (Lindmark and Andersson, 2016). The value of the fish stock is calculated by the present discounted values of fishing rents (Lindmark and Andersson, 2016). The calculation for subsoil assets only considers iron ore. To obtain the value of the iron ore, Lindmark and Andersson (2016) use the 'net-price' method. This method is multiplying the resource rent per unit of iron ore and the amount of iron ore extracted (Lindmark and Andersson, 2016). By using this methodology for obtaining the value of iron ore, when new iron ore deposits are discovered and extracted the value of the iron ore stock increases. Ultimately, all of these value estimates are added together to create the natural capital value. In 1850, Sweden's natural capital stock was valued at 2,728 million 1910/1912 SEK (28.4 when the 1910/1912 SEK value is indexed at 1930 = 100) and by 2010 the natural capital stock had grown to 1,409,606 million 1910/1912 SEK (14,683 when the 1910/1912 SEK value is indexed at 1930 = 100). For a graph of both produced capital and natural capital from 1850 to 2010 see *Figure 3*.

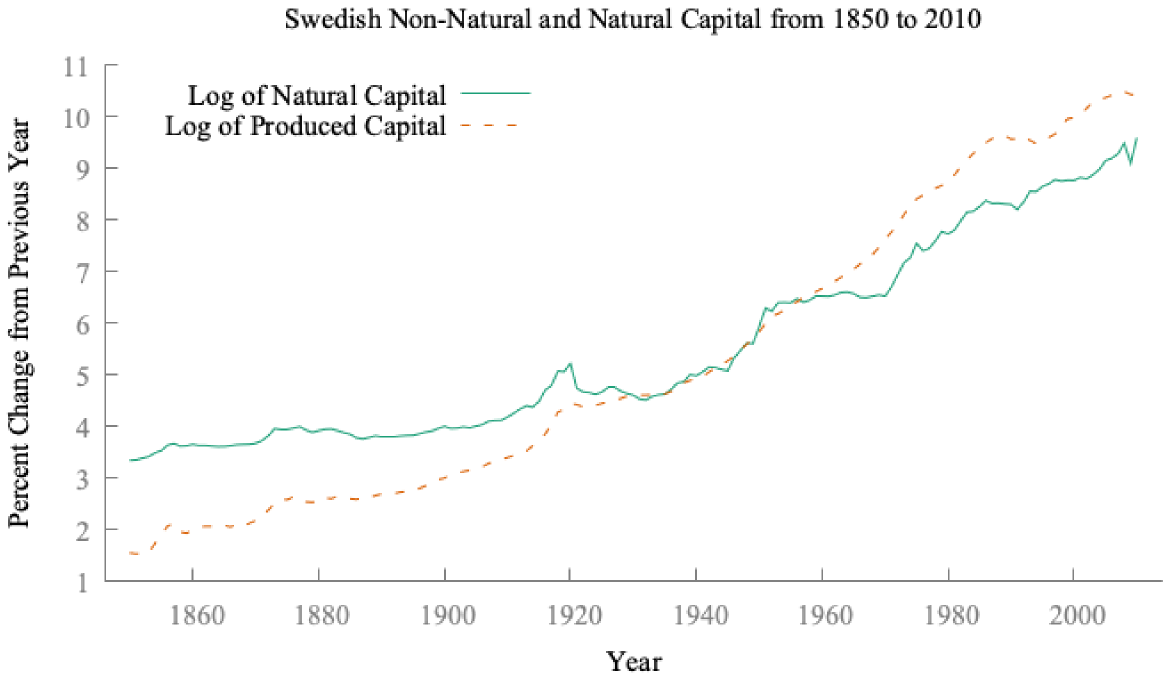

Figure 3: Swedish Non-Natural Capital and Natural Capital Stock from 1850 to 2010 (Lindmark and Andersson, 2016)

There is a single additional variable that will not be found in the model, but is imperative for the purpose of the thesis, that is Swedish net CO_2 emissions from 1850 to 2010 collected from Kander (2002) and the Global Carbon Project (GCP) (2022). This variable is measured in millions of CO_2 tonnes emitted. Kander (2002) estimated the net CO_2 emissions of Sweden through aggregating all fossil fuel-based CO_2 emissions and subtracted it by the amount of CO_2 captured by the forest from 1850 to 1995. The following fifteen years of the data is provided by the GCP (2022). This data has been collected annually by the GCP from nationally reported data. For a graph of Swedish net CO_2 emissions in millions of tonnes from 1850 to 2010 see *Figure 4*.

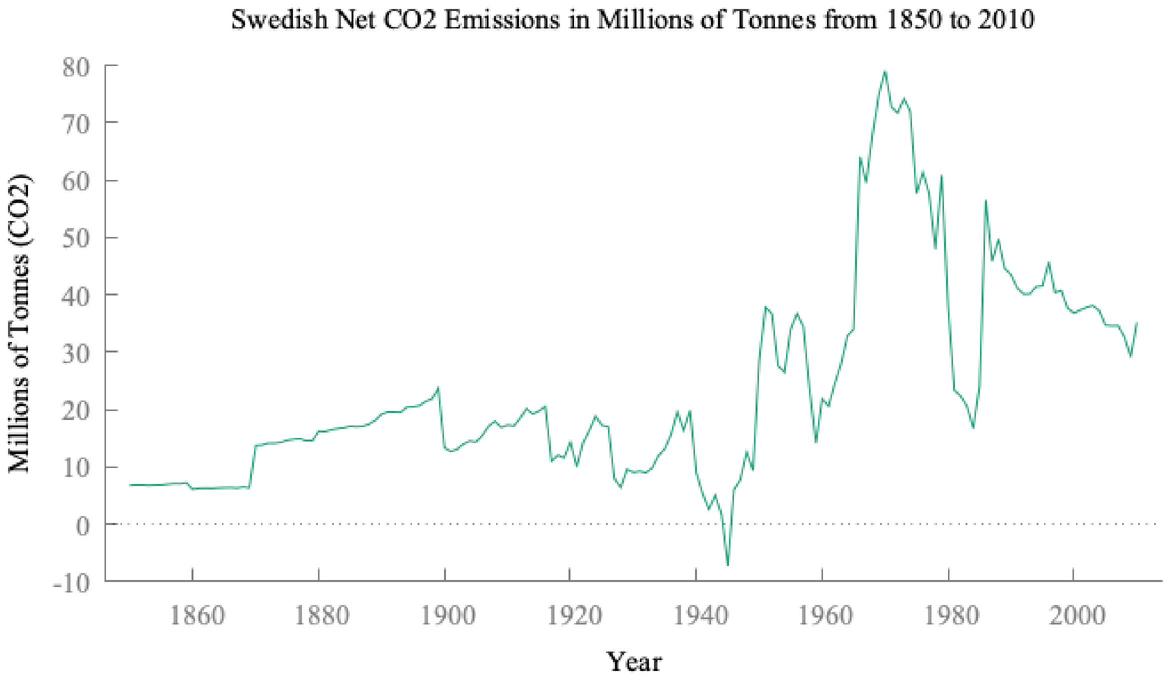

Figure 4: Swedish Net CO_2 Emissions in Millions of Tonnes from 1850 to 2010 (Kander, 2002; GCP, 2022)

3.2 Descriptive Statistics

Table 1 Summary of Variables

Variable	Unit of Measurement	Source	Measurement Period
GDP	Millions of SEK constant price 1910 / 1912 price level	Schön and Krantz (2012)	Annual
Natural Capital stock	Millions of SEK constant price 1910 / 1912 price level (Indexed)	Lindmark and Andersson (2016)	Annual
Capital Stock	Millions of SEK constant price 1910 / 1912 price level (Indexed)	Lindmark and Andersson (2016)	Annual
Total Hours worked	Number in Millions	Schön and Krantz (2012)	Annual
Net CO_2 Emissions	Millions of emitted tonnes of CO_2	Kander (2002) GCP (2022)	Annual

Table 2 Descriptive Statistics for All Variables from 1850 to 2010 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	160	12,784	14,158	849	50,714
Natural Capital Stock	160	1,400	2,683	28	14,683
Capital Stock	160	4,110	8,490	5	35,689
Total Hours Worked	160	5,467	1,365	2,955	7,381
Net CO_2 Emissions	160	23.69	17.58	-7.23	79.04

The descriptive statistics for GDP, natural capital stock, capital stock, total hours worked and population for each of the eight time periods can be found in Appendix E.

4 Methods

In this section of the paper, the augmented Solow growth model is presented in the form that is utilized for analysis of the data. In addition to the presentation of the model, the expected results of the peripheral variables (capital stock, labor and total factor productivity) are exhibited.

4.1 Augmented Solow Growth Model

The first step to identifying capital, natural capital, labor and total factor productivity's contribution to the growth of GDP is to calculate the compound growth rates of GDP (Y), capital (K), natural capital (E) and labor (L). The formula for calculating these compound growth rates are shown below in formulas (11), (12), (13) and (14):

(11) $$\dot{Y} = \left(\frac{Y_{Final}}{Y_{Begin}}\right)^{\frac{1}{t}} - 1$$

(12) $$\dot{K} = \left(\frac{K_{Final}}{K_{Begin}}\right)^{\frac{1}{t}} - 1$$

(13) $$\dot{E} = \left(\frac{E_{Final}}{E_{Begin}}\right)^{\frac{1}{t}} - 1$$

(14) $$\dot{L} = \left(\frac{L_{Final}}{L_{Begin}}\right)^{\frac{1}{t}} - 1$$

These formulas for compound growth will be done for all nine time periods selected in this paper. The next step for identifying the variables' contribution to GDP growth is to multiply the compound growth of each capital, natural capital and labor by their respective savings rates. The savings rates of capital, natural capital and labor add up to exactly 1. The savings rates implemented are shown in *Table* 3.

Table 3: Saving Rates

Variable	1850 - 1865	1866 - 1900	1901-1921	1922-1932	1933 - 1945	1946 - 1973	1974 - 1991	1992 - 2010	1850 - 2010
Capital Saving rate	0.17	0.17	0.19	0.21	0.27	0.28	0.31	0.34	0.24
Natural Capital Saving Rate	0.08	0.09	0.09	0.11	0.13	0.13	0.15	0.17	0.12

Labor Saving Rate	0.75	0.74	0.72	0.68	0.60	0.59	0.54	0.49	0.64
Total	1	1	1	1	1	1	1	1	1

The formulas for calculating the contribution to GDP for the variables are shown below in formulas (15), (16) and (17):

(15) $$Capital\ (K)\ Contribution\ to\ GDP = s_K \left(\frac{\dot{K}}{K}\right)$$

(16) $$Natural\ Capital\ (E)\ Contribution\ to\ GDP = s_E \left(\frac{\dot{E}}{E}\right)$$

(17) $$Labor\ (L)\ Contribution\ to\ GDP = s_L \left(\frac{\dot{L}}{L}\right)$$

In order to observe technology's role in the growth of GDP, it is necessary to subtract the other three variable contributions to GDP growth. The formula for calculating TFP's contribution to GDP growth is shown below in formula (18):

(18) $$TFP\ (A)\ Contribution\ to\ GDP = \frac{\dot{Y}}{Y} - s_K \left(\frac{\dot{K}}{K}\right) - s_E \left(\frac{\dot{E}}{E}\right) - s_L \left(\frac{\dot{L}}{L}\right)$$

4.2 Expected Results

Presented in this section are the expected results from the outside variables (capital stock, labor and total factor productivity) from the focus of this paper.

The first expected result is that labor's contribution to economic growth will be large in the earlier periods (1850 to 1865 and 1865 to 1900). The background to this expectation is that the number of total hours worked in Sweden during these time periods is larger than that of capital and natural capital (Schön and Krantz, 2012; Lindmark and Andersson, 2016). For these time periods, Sweden had not yet begun its extensive capital accumulation, so the main driver of growth is unlikely to come from either capital stock or natural capital stock (Lundh and Prado, 2015; Magnusson, 2000; Sandewall et al., 2015).

The second expected result is that the TFP's contribution to economic growth in the time period from 1974 to 1991 will be severely negative. The background behind this expectation is due to two different factors: capital accumulation and economic recession. Lindmark and Andersson (2016) display that both natural capital stock and produced capital stock were rapidly accumulated in this period. Although two factors that impact economic growth were rapidly increasing, there was no resulting rapid growth in GDP. Likely caused by the two international oil crises that took place in this period, restructuring the economy decreased the level of technology/productivity of the factors of production (Lewin and Lindvall, 2015). Along with this, Sweden's economic policy at the time was to prioritize employment which is seen in the stability of total hours worked in the time period, meaning that it is unlikely a faltering in employment that decreased GDP growth (Lewin and Lindvall, 2015; Lindmark and Andersson, 2016).

The final expected result of this paper is that produced capital stock will over all time periods have the largest contribution to economic growth. As seen in Lindmark and Andersson (2016), the produced capital stock has grown extensively through the entire time period. Along with this, Lundh and Prado (2015) shows that the industrial sector (a sector that relies heavily on produced capital) in Sweden became very prominent to the economy around

1910. As more workers are employed in the industrial sector, more produced capital is needed for function. Although, as previously stated in the first expected result, labor's contribution is expected to be more prominent in the first two periods, the capital stock's growth has been larger over the total time period (Lindmark and Andersson, 2016).

5 Empirical Analysis

In this section of the paper, the results of the augmented Solow growth model and the Swedish data from 1850 to 2010 are presented. Along with this, a robust model that implements robust savings rates for produced capital and natural capital stock is presented.

5.1 Results

The first table presented is the breakdown of all the variables that are necessary to run the model (*Table* 3). In order to create clarity, two different results tables are presented (*Table 4* and *Table 5*). The first, *Table 4* shows the variables capital stock, natural capital stock, labor and TFP's contributions to GDP in the actual magnitude. The second, *Table 5* displays the variables capital stock, natural capital stock, labor and TFP's contributions to GDP as a percentage of GDP growth.

Table 4: Variable Breakdown

Variable	1850 - 1865	1866 - 1900	1901-1921	1922-1932	1933 - 1945	1946 - 1973	1974 - 1991	1992 - 2010	1850 - 2010
Compound GDP Growth	2.00	2.26	2.16	3.00	2.63	3.82	1.29	2.38	2.57
Compound Capital Stock Growth	3.63	2.82	6.98	2.28	5.64	10.70	7.80	4.61	5.70
Compound Natural Capital Stock Growth	1.83	1.09	3.98	-1.54	4.23	7.07	5.64	7.18	3.98
Compound Labor Growth	1.09	0.86	0.49	1.11	1.37	-0.19	0.45	0.46	0.57
Capital Stock's Average Savings Rate	0.17	0.17	0.19	0.21	0.27	0.28	0.31	0.34	0.24
Natural Capital Stock's Average Savings Rate	0.08	0.09	0.09	0.11	0.13	0.14	0.15	0.17	0.12
Labor's Average Savings Rate	0.75	0.74	0.72	0.68	0.60	0.59	0.54	0.49	0.64

Table 5 Results Table: Contribution to GDP

Actual Contribution to GDP	1850 - 1865	1866 - 1900	1901-1921	1922-1932	1933 - 1945	1946 - 1973	1974 - 1991	1992 - 2010	1850 - 2010
GDP Growth	1.99	2.27	2.17	3.01	2.62	3.83	1.29	2.38	2.57
Capital Stock	0.60	0.49	1.30	0.48	1.50	2.96	2.39	1.57	1.35
Natural Capital Stock	0.15	0.10	0.37	-0.16	0.56	0.98	0.86	1.22	0.47
Labor	0.82	0.64	0.36	0.76	0.82	-0.11	0.25	0.22	0.37
TFP	0.42	1.04	0.14	1.93	-0.26	0.00	-2.21	-0.63	0.38
Total	1.99	2.27	2.17	3.01	2.62	3.83	1.29	2.38	2.57

Table 6 Results Table: Percentage of Contribution to GDP

Contribution as percent of GDP	1850 - 1865	1866 - 1900	1901-1921	1922-1932	1933 - 1945	1946 - 1973	1974 - 1991	1992 - 2010	1850 - 2010
Capital Stock	30.14	21.81	60.00	15.99	57.06	77.33	185.55	65.88	52.62
Natural Capital Stock	7.58	4.22	17.10	-5.39	21.40	25.55	67.05	51.24	18.37
Labor	41.09	28.11	16.50	25.22	31.28	-2.87	19.04	9.40	14.34
TFP	21.19	45.87	6.41	64.18	-9.73	-0.01	-171.63	-26.52	14.67
Total	100	100	100	100	100	100	100	100	100

In the first time period, 1850 to 1865, it is clear that labor was the most significant factor in the growth of Sweden's GDP with over 40 percent. Along with labor, capital stock and technological advancement combined to contribute over 90 percent. It is clear that in this first period natural capital stock played a limited role in Sweden's growth.

In the second time period, 1865 to 1900, the most significant contributor to economic growth was technological advancement with over 45 percent. Once again, the combination of capital stock, labor and technological advancement contribute to over 90 percent of the growth in the period. Natural capital stock provides less than the period before dropping from 7.58% to only 4.22%.

In the third time period, 1901 to 1921, technological advancement drops in its contribution to GDP growth from over 45 percent in the prior period to under 7 percent. In this period, capital stock was the main driver of economic growth with it providing over 60 percent of the growth. For the first time, natural capital's contribution to economic growth was above 10 percent at 17.10 percent.

In the fourth time period, 1922 to 1932, technological advancement bounces back from the previous time period and contributed to over 64 percent of the economic growth. Together with capital stock and labor, technological advancement contributed more than 100 percent of the growth. The reason this is possible is because the natural capital stock negatively contributed to economic growth by over 5 percent.

In the fifth period, 1933 to 1945, the main driver of economic growth is from capital stock, as over 57 percent can be attributed to capital stock. Along with this, both natural capital and labor's respective contributions increased from the last period. However, the technological advancement from the previous period to this period had a massive drop from more than 64 percent to a negative contribution of 9.73 percent.

In the sixth time period, 1946 to 1973, only two variables had positive contributions which were capital stock and natural capital stock. Capital stock was the main driver of the two as it contributed over 77 percent of the economic growth in the time period, but natural capital stock also contributed over 25 percent of the economic growth. On the other hand, both labor and technological advancement contributed negatively to economic growth. Although small negative value, labor negatively contributed just over 2 percent and technological advancement negatively contributed only 0.01 percent to economic growth.

In the seventh time period, 1974 to 1991, capital stock made an immense contribution to economic growth with an over 185 percent contribution. However, this contribution from the capital stock was almost entirely canceled out by the negative contribution of technological advancement at over 171 percent. Both natural capital stock and labor made significant contributions in this time period as well with over 67 percent and 19 percent respectively. In this time period, natural capital made its highest contribution to economic growth.

In the eighth time period, 1992 to 2010, capital stock remained the highest contributor to economic growth, however, at a much lower level than the previous period. The capital stock contribution dropped from 185 percent to around 65 percent. The natural capital stock's contribution also dropped from the previous period, in a less dramatic amount, from 67.05 percent to 51.24 percent. Along with this, labor's contribution dropped from the previous period starting at 19.04 and falling to 9.40 percent. The largest change between periods came from the contribution of technological advancement which fell from a negative 171 percent to a negative 26.52 percent contribution.

In the complete time period, 1850 to 2010, it is by no small margin that capital stock contributed the most to economic growth, having 52.62 percent contribution. The next largest contributor to the overall time period is natural capital stock with 18.37 percent contribution. Both labor and technological advancement contributed roughly the same amount over the entire time period with 14.34 percent and 14.67 percent contribution respectively.

5.2 Robustness Check

In order to create clarity, two different results tables are presented (*Table 3* and *Table 4*). The first, *Table 5* shows the variables capital stock, natural capital stock, labor and TFP's contributions to GDP with robust savings rates in the actual magnitude. The second, *Table 6* displays the variables capital stock, natural capital stock, labor and TFP's contributions to GDP with robust savings rates as a percentage of GDP growth

Table 7 Robustness Check Results Table

Actual Contribution to GDP	1850 - 1865	1866 - 1900	1901-1921	1922-1932	1933 - 1945	1946 - 1973	1974 - 1991	1992 - 2010	1850 - 2010
GDP Growth	1.99	2.27	2.17	3.01	2.62	3.83	1.29	2.38	2.57
Capital Stock	0.69	0.57	1.56	0.67	1.83	3.35	2.93	1.76	1.55
Natural Capital Stock	0.13	0.08	0.30	-0.14	0.46	0.74	0.71	0.92	0.37
Labor	0.82	0.63	0.35	0.67	0.77	-0.11	0.23	0.22	0.36
TFP	0.37	0.99	-0.06	1.81	-0.44	-0.15	-2.58	-0.52	0.29
Total	1.99	2.27	2.17	3.01	2.62	3.83	1.29	2.38	2.57

Table 8 Robustness Check Results Table: Percentage of Contribution to GDP

Contribution as percent of GDP	1850 - 1865	1866 - 1900	1901-1921	1922-1932	1933 - 1945	1946 - 1973	1974 - 1991	1992 - 2010	1850 - 2010
Capital Stock (Robust Savings rate)	34.65	25.09	72.73	22.38	69.98	87.60	227.60	73.95	60.51
Capital Stock (Original Savings rate)	(30.14)	(21.81)	(60.00)	(15.99)	(57.06)	(77.33)	(185.55)	(65.88)	(52.62)
Natural Capital Stock (Robust Savings rate)	5.81	3.24	13.82	-5.03	17.50	19.29	54.83	38.34	14.08
Natural Capital Stock (Original Savings rate)	(7.58)	(4.22)	(17.10)	(-5.39)	(21.40)	(25.55)	(67.05)	(51.24)	(18.37)
Labor (Robust Savings rate)	40.79	27.88	16.00	22.38	29.41	-2.85	17.58	9.42	14.17
Labor (Original Savings rate)	(41.09)	(28.11)	(16.50)	(25.22)	(31.28)	(-2.87)	(19.04)	(9.40)	(14.34)
TFP (Robust savings rate)	18.74	43.80	-2.55	60.27	-16.89	-4.04	-200.00	-21.71	11.24

TFP (Original Savings rate)	(21.19)	(45.87)	(6.41)	(64.18)	(-9.73)	(-0.01)	(-171.63)	(-26.52)	(14.67)
Total	100	100	100	100	100	100	100	100	100

As displayed in the table above, the contributions of the different factors (capital, natural capital, labor and TFP) on economic growth change when different savings rates are implemented. The robust savings rate is the most conservative estimate in regards to natural capital's role in economic growth. As produced capital's savings rate increases due to this conservative estimation of natural capital's importance, it is clear that the contribution from produced capital increases over all time periods.

Along with this natural capital contribution decreases in every time period. The largest change of natural capital's contribution is in the time period 1992 to 2010, where the contribution changes from 51.24 percent originally to 38.34 percent with the robust savings rate. It is important to note that at no point does natural capital's contribution to economic growth change from a positive contribution to a negative contribution or vice versa. The conclusion that can be made from this is that the results from the econometric approach are significant.

Along with natural capital's decreasing contribution from the robust savings rates, labor's contribution to economic growth also decreases over all time periods barring the time period 1992 to 2010. In 1992 to 2010, labor's contribution slightly increased from the original savings rate to the robust savings rate by .02 percent.

The most volatile factor contributing to economic growth is technological advancement. In the first four time periods (1850 to 1865, 1866 to 1900, 1901 to 1921 and 1922 to 1932), technological advancement's contribution to economic growth decreased. With a special emphasis on the time period 1901 1921, when the contribution goes from a positive 6.41 percent to a negative 2.55 percent. This means that technological advancement's contribution in this time period cannot be considered a significant factor on economic growth. In the next three time periods (1933 to 1945, 1946 to 1973 and 1974 to 1991), the contribution of technological advancement increased. However, in all of these time periods the contribution of technological advancement became larger negative contributions. In the final two time periods (1992 to 2010 and 1850 to 2010) technological advancement's contribution once again decreased.

5.3 Discussion

The discussion is broken down into different segments, the first of these segments is discussion focused around the two hypotheses. Secondly, a discussion of how natural capital is estimated and collected and its impact on the results is discussed. Next, the expectations from the outside variables are acknowledged and compared to the previous research of Schön (2009). Lastly, the Swedish environmental policy is connected with the results from the model.

5.3.1 Hypothesis Discussion

The first hypothesis, as outlined in the theory section of the paper, states that natural capital stock's importance to economic growth will increase throughout the time periods. As seen in *Table 5*, in both of the first two time periods (1850 to 1865 and 1866 to 1900) natural capital stock's contribution to GDP was less than ten percent, the lowest of all the variables in the model. As mentioned in the rationale behind this hypothesis, the natural capital stock likely did not contribute to economic growth in this period due to the exploitation of natural capital stock. The specific natural capital stock that was exploited was forest and timber stocks, which saw most of southern and central Sweden completely deforested (Sandewall et al., 2015).

Moving forward, in the third time period (1901 to 1921) natural capital stock's contribution to economic growth greatly increased to over 17 percent. With less exploitation of the timber and forest natural capital stocks, Sweden was able to more than double the timber and forest natural capital stock (Lindmark and Andersson, 2016). However, the growth of natural capital stocks contribution to economic growth was unable to

maintain this rise as in the time period directly after (1922 to 1932) natural capital stock's contribution was negative. Although unanticipated in the hypothesis, this time period saw Sweden move from an agricultural focused economy towards an industrial one (Lewin and Lindvall, 2015). During this transitional phase in the Swedish economy, it appears that the natural capital stock was heavily exploited in order to create economic growth, thus depleting the natural capital stock.

The next two time period (1933 to 1945 and 1946 to 1973) saw Swedish natural capital stock's contribution to economic growth reemerge as a high contributor, with over 20 percent and 25 percent of the contribution to GDP growth respectively. Over these time periods, the distribution of the natural capital stock radically changed, away from cropland and towards timber, forests and minerals. The natural capital stock accumulation of timber, forests and minerals was able to increase faster than the accumulation of agricultural land.

In the last two time periods (1974 to 1991 and 1992 to 2010), natural capital stock made its highest contributions to economic growth at 67 percent and 51 percent respectively. As new environmental policy was introduced in 1990 and 1991, the natural capital stock (specifically timber and forest natural capital stock) had a compound growth of over 5 percent. As more awareness surrounded the maintenance of natural capital stock, the stock was able to grow and contribute more to economic growth.

The second hypothesis, as outline in the theory section of the paper, states that Swedish economic growth in the overall time period is within the scope of weak sustainability and that the later time periods (1974 to 1991 and 1992 to 2010) comes closer to strong sustainability. Beginning with the first part of the second hypothesis, for there to be weak sustainability, as defined by Hediger (1999), overall capital stock (natural capital stock plus non-natural capital stock) levels need to be maintained. It is clear from the overall time period (1850 to 2010) results (*See Tables 4 and 5*) that overall capital stock was not only maintained, but also grew. The only time period where either natural capital stock or non-natural capital stock was negative was in 1922 to 1932, when the negative natural capital stock growth was lower than the positive non-natural capital stock growth. From these results, it appears that Sweden's economic growth from 1850 to 2010 can be considered weakly sustainable.

Moving onto the second part of the second hypothesis, in order to classify Swedish economic development as strong sustainability, natural capital stock specifically needs to be maintained for ecological conservation (Hediger, 1999). While noted earlier that Swedish natural capital stock, in the time periods 1974 to 1991 and 1992 to 2010, increased, strong sustainability cannot be seen. The reason strong sustainability cannot be seen in this study is the CO_2 emissions proxy for environmental degradation. For there to be strong sustainability, there cannot be environmental degradation in these time periods. As seen in

Figure 4, the Swedish net CO_2 emissions in both 1974 to 1991 and 1992 to 2010 are positive values. In fact, the only year in which Sweden had negative net CO_2 emissions was in 1945, a year not in either time period. With these results in conjunction to Swedish environmental degradation, it cannot be concluded that Sweden's economic development can be described as strong sustainability from 1974 to 1991 or 1992 to 2010.

5.3.2 Natural Capital Stock's Estimation Implications

As described in the data section of this paper, the natural capital stock estimation by Lindmark and Andersson (2016) is an aggregation of several natural capital stock values (agricultural land, timber and forests, fish stock and subsoil assets). In this aggregation of stock values, one facet of the natural capital stock is unlike the others: subsoil assets. The main subsoil asset Lindmark and Andersson (2016) include in the natural capital stock calculation is iron ore. The calculation of the value of iron ore stock is done through multiplying the resource rent by the amount of iron ore extracted. However, the issue with this method is that when iron ore is extracted in Sweden rather than decreasing the natural capital stock it actually increases the natural capital stock. Since iron ore deposits are a non-renewable natural capital stock, the stock of iron ore in Sweden in 1850 should be the higher than the stock of iron ore in 2010 (Pustov, Malanichev and Khobotilov, 2013). Instead, through the Lindmark and Andersson (2016) estimation of the value iron ore stock is at 1 million 1910 / 1912 SEK in 1850 and 464,206 millions of 1910 / 1912 SEK in 2010. The implication of this estimation method for iron ore stock is that the overall natural capital stock is underestimated at the beginning of the time period and overestimated at the end of the time period. Specifically, the years in which new iron ore deposits were discovered and extracted are the years that are overestimated.

5.3.3 Expected Results Comparison to Schön (2009)

The expected results, outlined previously in the methods section, discussed the outside variables' (non-natural capital stock, labor and TFP) expected contributions to economic growth. Beginning with the results for labor's contribution to economic growth, the expected result was that labor's contribution in the earlier time periods be larger than natural capital stock and non-natural capital stock's contribution. As seen in *Table 5*, labor's contribution to economic growth from 1850 to 1865 was the highest of all the variable at 41 percent and second largest, behind only TFP, from 1866 to 1900. As mentioned previously, this result was expected for two reasons: Sweden's economic structure and lack of capital accumulation. As mentioned in Lundh and Prado (2015), Sweden's economic structure before 1900 was labor intensive, rather than capital intensive. What this means is that for economic growth additional labor hours ultimately produced more for economic growth than capital.

The next result is TFP's contribution to economic growth, with the expected results being that the contribution of TFP to economic growth will be severely negative in the time period from 1974 to 1991. As seen in *Table 5*, TFP's contribution to economic growth from 1974 to 1991 was negative 171 percent. A negative TFP residual insinuates that the combination of other factors in the economy lost efficiency. A potential reason behind such a large negative TFP contribution are the oil crises that took place during this time period. Due to the oil crises, the Swedish economy lagged in investment decisions and restructuring causing productivity losses (Lewin and Lindvall, 2015). As the Swedish government prioritized full-employment (keeping total hours work from falling) and both natural capital stocks and non-natural capital stocks grew, the residual (TFP) aggregates all of the unexplained lack of growth.

The last result is non-natural capital stock's contribution to economic growth, with the expected results being that in the overall time period from 1850 to 2010 non-natural capital stock will have the highest contribution to economic growth. As seen in *Table 5*, in the overall time period, non-natural capital's contribution to economic growth is around 52 percent. With over 50 percent of the contribution to economic growth, it is clear that non-natural capital has been the most important contributing factor to Swedish economic growth. Noted in Lundh and Prado (2015), Swedish economic growth has been reliant on non-natural capital since 1910.

As Schön (2009) also discusses Swedish economic growth over a similar time period (1850 to 2005) with a focus on TFP, it is important to note the differences found in this paper. In the Schön (2009) research, the TFP growth calculation is done from 1890 to 2000 with 20 year time periods (except for the last time period which is only 10 years). While this paper finds several time periods of negative TFP growth (See *Table 4*) in the time periods 1933 to 1945, 1974 to 1991 and 1992 to 2010. Meanwhile, Schön (2009) finds none of the time periods to have a negative TFP growth (the closest it came to negative was the timer period between 1930 and 1950). The main reasoning behind this difference is that since this paper implements an additional variable (natural capital stock) the residual TFP from the augmented Solow growth model will be lower than if no natural capital stock is included.

5.3.4 Environmental Policy and Natural Capital Stock

As mentioned in the introduction, Swedish political and environmental policy has been included in order to examine the relationship between natural capital stock and environmental policy. The first important environmental policy by the Swedish government was introduced in 1903 and required all land utilized for timber to be replanted (Sandewall et al., 2015). In conjunction to this policy, Swedish natural capital stock's contribution to economic growth rose by over 300 percent (See *Table 4*). Along with this, in 1903 Sweden was at a 30 year low for net CO_2 emissions (Kander, 2002).

The next important environmental policy enacted in Sweden that is discussed in this paper is the Environmental Protection act of 1969 (Hysing, 2014). With this policy put into place near the end of the time period 1946 to 1973, it appears to have assisted in Sweden's largest natural capital stock growth at that point. However, when considering the size of net CO_2 emissions, the year after this act was passed, Sweden net emitted the most CO_2 in the 160 year time period. Although net CO_2 emissions increased to an all-time high the following year, Sweden's CO_2 emissions steadily decreased until 1984 (See *Figure 4*) (Kander, 2002).

The next significant environmental policy enacted by the Swedish government were green taxes on energy usage and emissions between 1990 and 1991 (Hysing, 2014). With the policy enacted directly at the end of the time period from 1974 to 1991, it appears to have assisted the highest natural capital stock growth in the entire 160 year period. With the green taxes directly relating to emissions, Sweden's net CO_2 emissions directly fell in the following 5 years (Kander, 2002).

The final significant environmental policies enacted in Sweden were further carbon emission taxes between 2000 and 2010 (Hysing, 2014). Once again, this appears to have benefited Sweden's natural capital stock as in the time period between 1992 and 2010

Sweden had their second largest increase in the natural capital stock. On the side of net CO_2 emissions, Sweden from the years 1999 to 2010 was able to emit less than 40 million tonnes per year, which had not been done since 1985 (Kander, 2002).

6 Conclusion

This final section aims to reiterate the purpose and results of the research, as well as discuss any practical implications and limitations. The culmination of this section will discuss potential future research opportunities.

The aim of this paper was to identify the absolute role natural capital stock has played in the economic development of Sweden from 1850 to 2010. First, it was necessary to define what exactly natural capital is and how it has previously been compared to economic development. By identifying how natural capital is inherently different from other forms of capital (produced, institutional or human), the justification for disaggregating natural capital stock from non-natural capital stock was made. This disaggregation allows for this paper to use the augmented Solow growth model methodology developed by Mankiw, Romer and Weil (1992) and Iddrisu (2019). With the ability to use this model, the role of natural capital stock is possible to find. The sub-question that was aimed to be answered in this paper is what type of development has Sweden experienced in terms of weak and strong sustainability. In order to answer this question, it was first necessary to define both weak and strong sustainability. Along with the augmented Solow growth model, net CO_2 emissions in Sweden estimated and collected by Kander (2002) and GCP (2022) to proxy for environmental degradation.

As previously mentioned, the model implemented to determine the absolute tole natural capital stock has played in economic development of different Swedish economic periods was an augmented Solow growth model developed by Mankiw, Romer and Weil (1992) and Iddrisu (2019). The additional natural capital stock variable in the augmented Solow growth model allowed the analysis to examine the contribution of natural capital stock on economic growth. From the results of the model, it is seen that natural capital stock played a limited role in economic development in the first two time periods, both with less than 10 percent contribution to economic growth. However, in the third time period, natural capital stock made a large leap in contribution with 17 percent contribution to economic growth. The fourth period was the only negative natural capital contribution to economic growth time period found in the model. The following two time periods, natural capital stock's contribution was strong with both being over 20 percent of economic growth. The final two time periods saw the highest contribution to economic growth from natural capital stock with both having over 50 percent contribution. The overall time period results displayed that natural capital stock's contribution to economic growth was the second largest at around 18 percent. When examining the type of development Sweden experienced in this time period, Sweden's overall capital stock (non-natural capital stock and natural capital stock) did not decrease over any of the time periods. With this result, it is possible to describe Sweden's development as weak sustainability. However, when applying the strong sustainability requirements to Sweden's development process, the requirements were not met. Ultimately, leading this paper to conclude that it is not possible to describe Sweden's development process as strong sustainability.

There are several practical implications that surround the research done in this paper. The first of these practical implications is how strong environmental policies impact natural capital stock. Since the 1903 act that prohibited deforestation of an area without replanting, Swedish natural capital stock has significantly increased. This phenomenon is coupled with the further strong environmental policies in Sweden from the 1960s and 1970s. From these periods onward, as seen in Figure 4, Swedish natural capital stock has increased by a large amount. As shown from the results of the study, an increasing natural capital stock has contributed to economic growth. This finding challenges the belief in the Environmental Kuznets Curve (EKC), which states that as countries grow their environmental damage increases until a certain turning point when the environmental damage decreases (Dinda, 2004). Instead these findings align with Dasgupta, Hamilton, Pandey, and Wheeler (2006) that find strong environmental governance can impact environmental damage. Beyond implicating that more environmental policies are necessary for increasing the natural capital stock,

There are a number of limitations in this paper due to the model, the proxies used in the model and the data implemented. The first critique commonly raised to the Solow growth model, and at the augmented Solow growth model by association, is that a microeconomic production function is not capable of being aggregated and implemented for the economic growth of a country (Pasinetti, 2000; Hulten, 2010). Although there are some unanswered questions over if a production function can adequately represent growth on a national level, there are countless papers that implement the Solow growth model like Rao (2010), Iddrisu (2019) and Barossi-Filho, Silva and Diniz (2005). Another common critique of the Solow growth model is the simplicity, but this is not a major issue with the augmented Solow growth model which is more complex (Pasinetti, 2000). Unfortunately, there are still a plethora of other factors that can be implemented into the augmented Solow growth model contributions more accurately like human capital. Due to the aim of this paper being focused on natural capital's contribution to economic growth, it was unnecessary to create a more complex model.

In the augmented Solow growth model, the variables for economic growth, capital stock, natural capital stock labor and the level of technology are all essential for calculation. However, several of these variables are difficult to measure in order to include them in the model. The first proxy included in the model is GDP as the representation of economic growth. There are no inherent issues with using GDP in this manner as it is widely common to use GDP in this way (Ciobanu, Petrariu and Bumbac, 2013). The next proxy included is the proxy for labor's contribution to economic growth. This paper implemented hours of work as the proxy for labor's contribution to economic growth. Although the best fit proxy for labor's contribution, Ohanian and Raffo (2012) finds that hours worked as a proxy is insufficient due to the "volatility of total hours [worked]," compared to the productivity of the hours worked. This volatility is especially noticeable in times of recession due to business cycles (Ohanian and Raffo, 2012). Unfortunately, there is no better current metric to be used as a proxy for labor's contribution that has been collected since the year 1850, so the total number of hours worked remains in this paper. The final proxy implemented is for natural capital's contribution to economic growth. The proxy that has been developed by Lindmark and Andersson (2016), consists of value calculations for natural assets that are "controlled by institutional units (e.g., households, companies and governments)." However, as previously mentioned, natural capital consists of assets that reach far beyond natural capital stock that is owned like agricultural land, timber and forests, fish stock or subsoil resources. Unfortunately, measuring un-owned natural capital, especially in the beginning years of the collected data is incredibly difficult, if not impossible. As a result, the true natural capital stock is likely underrepresented in the model. Net CO_2 emissions as a proxy for environmental degradation is also not a perfect fit. As described in Altıntaş and Kassouri (2020), net CO_2 emissions do not include degradation to natural capital stock and do not take into consideration other pollutants.

The data is a limitation in this paper due to how the data has been collected in the earlier years of the dataset. Since modern economic data collection did not truly begin until the mid 1900s, the data from before this time had to be estimated (Abramitzky, 2015). Lindmark and Andersson (2016) utilized, for the variables capital stock and natural capital stock, insurance evaluation estimates to produce values of the stocks. The problem with insurance estimates for capital and natural capital stocks is that it is likely under-estimated due to how the insurance market functions (Lindmark and Andersson, 2016). Specifically, for natural capital stock, the data collected by Lindmark and Andersson (2016), does not fully encompass all forms of natural capital. As mentioned previously, natural capital encompasses more than just the natural capital forms included by Lindmark and Andersson (2016). However, with the limited data for the time period available, the Lindmark and Andersson (2016) data collection was the most comprehensive in terms of natural capital stock. In addition, the limitation of the iron ore stock calculation mentioned in the discussion is a limiting factor. Along with the capital and natural capital stock estimates, Schön and Krantz's (2012) estimation of Swedish GDP includes a vast amount of assumptions and technical difficulties. An estimation for aggregation of all production of goods and services in a country for a time period over one hundred years is a difficult task. For example, multiple estimates of Swedish GDP over the time period have been calculated in multiple other papers such as Krantz and Schön (2007), Krantz (1997) and Schön (2000). Schön and Krantz (2012) is the most up-to-date version of estimating Swedish GDP for the time period 1850 to 2010. Seeing as there have been several updates to the estimation already, as new data become available it is likely the GDP estimate will be updated further.

With the completion of this research there are two directions the future research needs to take. The first of these is the completion of an 1850 to 2010 national account dataset that includes a natural capital stock evaluation which encompasses all forms of natural capital. With this complete dataset, a holistic estimate for natural capital stocks contribution to economic development can be calculated. The contribution to economic development by the natural capital stock will likely drastically change with the addition of a complete natural capital stock estimate. This coincides with a new estimation methodology for iron ore, to have the iron ore stock decrease over time as more iron ore is extracted. In addition, revamping the natural capital stock evaluation, the creation of a new augmented Solow growth model is necessary. Along with this, developing a long term Ecological Footprint estimation for Sweden from 1850 to 2010 would provide a better approximation of environmental degradation for the time period. In the current augmented Solow growth model, all natural capital stock is combined into one variable. As mentioned previously there are multiple categorical differences between varying types of natural capital. One suggestion would be to create an augmented Solow growth model that creates two different variables for natural capital that signifies the difference between renewable natural capital stock and non-renewable natural capital stock. This additional variable would allow the model to display how different forms of natural capital stock contribute to economic growth.

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Appendix A

Table 9 Appendix A: Descriptive Statistics from 1850 to 1865 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	15	991	106	849	1,169
Natural Capital Stock	15	35	4	28	39
Capital Stock	15	7	1	5	8
Total Hours Worked	15	3,176	178	2,955	3,479
Population	15	3,740,495	202,693	3,461,914	4,092,101

Table 10 Appendix A: Descriptive Statistics from 1866 to 1900 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	34	1,703	364	1,086	2,485
Natural Capital Stock	34	47	5	38	55
Capital Stock	34	13	3	8	20
Total Hours Worked	34	4,044	337	3,325	4,624
Population	34	4,592,878	292,119	4,137,409	5,116,922

Table 11 Appendix A: Descriptive Statistics from 1901 to 1921 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	20	3,411	558	2,551	4,286

Natural Capital Stock	20	87	40	53	185
Capital Stock	20	41	21	22	85
Total Hours Worked	20	4,867	203	4,591	5,306
Population	20	5,531,441	246,123	5,155,835	5,929,403

Table 12 Appendix A: Descriptive Statistics from 1922 to 1932 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	10	5,233	618	4,251	6,058
Natural Capital Stock	10	105	8	92	117
Capital Stock	10	91	8	81	101
Total Hours Worked	10	5,584	291	5,140	6,045
Population	10	6,077,045	64,971	5,970,918	6,176,405

Table 13 Appendix A: Descriptive Statistics from 1933 to 1945 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	12	7,046	602	5,832	7,960
Natural Capital Stock	12	138	28	98	173
Capital Stock	12	137	32	100	196
Total Hours Worked	12	6,313	293	5,667	6,669
Population	12	6,360,510	135,317	6,200,965	6,635,549

Table 14 Appendix A: Descriptive Statistics from 1946 to 1973 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	27	15,679	4,826	8,844	24,346
Natural Capital Stock	27	628	226	206	1,305
Capital Stock	27	1,025	790	213	3,317
Total Hours Worked	27	6,774	132	6,440	6,918
Population	27	7,473,801	421,005	6,718,717	8,136,775

Table 15 Appendix A: Descriptive Statistics from 1974 to 1991 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	17	29,405	2,781	26,072	33,909
Natural Capital Stock	17	2991	1,015	1,435	4,339
Capital Stock	17	9,484	4,212	4,000	15,435
Total Hours Worked	17	6,678	258	6,354	1,179
Population	17	8,346,766	119,912	8,160,544	8,617,333

Table 16 Appendix A: Descriptive Statistics from 1992 to 2010 (Schön and Krantz, 2012; Lindmark and Andersson, 2016)

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
GDP	18	41,776	6,204	32,299	50,714
Natural Capital Stock	18	7,742	2,764	4,218	14,684

Capital Stock	18	24,111	8,302	13,101	35,690
Total Hours Worked	18	6,964	235	6,551	7,381
Population	18	8,961,473	200,022	8,668,033	9,396,192