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SCHOOL OF
ECONOMICS AND
MANAGEMENT

Does natural resource extraction compromise future well-being? Norwegian Genuine Savings 1865-2018

Johanna Fink and Cristián Ducoing

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Does natural resource extraction compromise future well-being?

Norwegian Genuine Savings 1865-2018 *

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September 28, 2021

Abstract

Over recent years Genuine Savings (GS) has emerged as an indicator for weak sustainability and predictor of socio-economic well-being. This paper presents the first long-term GS estimates for Norway, covering the period from 1865 until 2019. The preliminary results indicate unsustainable development throughout most of the period leading up to the Second World War and sustainable development ever since 1946. This result is rather surprising since the discovery of oil and natural gas fields in 1969 resulted in substantial natural resource depletion, which is usually associated with negative levels of GS. However, in a particularity compared to most natural resource exporters, Norway managed to achieve sustainable development by compensating natural resource depletion with high investments into human and physical capital.

JEL Codes: N53, N54, N13, Q56, Q33

Keywords: Norway; Natural Resources, Genuine Savings, Oil, Well-being

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List of Abbreviations

EC	Emission Costs
EE	Education Expenditure
GDP	Gross domestic product
GS	Genuine Savings
GSTFP	Genuine Savings augmented by technological change
HC	Human capital
NNS	Net National Savings
NRD	Natural resource depletion
SSB	Statistisk Sentralbyrå
UK	United Kingdom
UN	United Nations
US	United States of America
USD	U.S. Dollar
WW1	World War One
WW2	World War Second

1 Introduction

Norway is currently considered by the UN (2020) as the most developed country in terms of the Human Development Index (HDI). Moreover, it ranks among the richest countries in terms of GDP per capita. Norway's GDP per capita of \$92,500 is only surpassed by Luxembourg and Bermuda (World Bank, 2021). However, what should be emphasized is that neither the GDP nor the HDI accounts for well-being of future generations in terms of income and natural resource depletion (NRD) (Klugman et al., 2011; Qasim and Grimes, 2021; Stern and Stiglitz, 2021). Since a significant fraction of Norwegian wealth is derived from the petroleum sector, which has been criticized for generating unsustainable development (Dietz et al., 2007; Grytten, 2020), there is a present and future problematic for Norwegian development path. Consequently, with reference to GDP and HDI alone it cannot be determined whether Norway's achievements are in fact a result of *unsustainable development*.

An alternative to measure sustainable development is Genuine Savings (GS), which is also referred to as *comprehensive wealth* or *adjusted net savings*. Hartwick (1977) developed the concept of weak sustainability, which serves as the theoretical basis for the GS framework. According to the *Hartwick rule*, future generations must have similar or greater consumption possibilities than current generations. In other words, physical and human capital (HC) investment must be sufficiently high to compensate for NRD. GS have been heavily propagated by the World Bank (2021), providing estimates for most countries and territories from the 1970s. Moreover, evidence from a growing body of long-term studies identifies GS as a good indicator for future well-being for periods up to 100 years (Greasley et al., 2014).

Most countries relying on the petroleum sector experienced unsustainable development due to massive NRD. Dietz et al. (2007) point out that oil rents raise incentives for corruption, which negatively affects institutional quality and GS estimates. This effect is especially prominent among developing countries like Iraq and Angola, which experienced extended periods of negative GS. This paper presents the first long term GS estimates for Norway, covering the period from 1865 until 2018. In difference to the World Bank methodology summarized in Bolt et al. (2002), this study allows for negative natural resource rents and includes fishery rents. Moreover, like most long-term GS studies this paper includes GSTFP estimates, which account for technological change

over time (Blum et al., 2017; Greasley et al., 2014; Qasim et al., 2020).

The results indicate that Norway experienced unsustainable development throughout most of the period leading up to World War Second (WW2). Surprisingly, GS estimates turned consistently positive after 1946 despite of massive NRD since the discovery of oil and natural gas fields in 1969 (Sollund, 2012) as Norway compensated NRD by increased investment in physical and HC according to the Hartwick rule. Though GS are merely a one-sided sustainability indicator, useful for identifying unsustainable development (Pezzey, 2004), the results suggest that economic development in Norway was weakly sustainable after WW2.

The paper is organized as follows. Section 2 provides a short overview over Norwegian economic history. The GS framework is introduced in section 3. The data set and the estimation results are presented in section 4 and 5. In section 6 estimation results are compared to World Bank as well as Dutch and Swedish estimates. The final seventh section summarizes the main findings of this paper (7).

2 Historical Background

Natural resources were of great importance for the Norwegian economy long before the discovery of oil and natural gas in 1969 (Grytten, 2020). Since the middle ages, the Norwegian economy has been dominated by the marine and fishing industry (Gullestad et al., 2014; Schwach, 2013). Moreover, the forestry sector and the extraction of mining products such as iron, copper, silver, and coal are historically of great importance (Ducoing et al., 2018; Historisk Statistikk, 2021).

Hunnes and Grytten (2021) observe that the state traditionally controls natural resource extraction to prevent exhaustion. In the forestry sector governmental restrictions were already imposed during the 18th century. According to Schwach (2013) and Gullestad et al. (2014), Norwegian authorities recognized the limitation of fish stocks after the collapse of the herring population in 1969. Since then, the fishing industry is closely monitored to prevent over-fishing

Like in other Nordic and predominantly protestant countries, mass education was given high priority in Norway. Compulsory schooling was already introduced in 1739 (Becker and Woessmann, 2010; Grytten, 2004; Solstad and Andrews, 2020). Ranestad (2020) finds that this increased the HC stock and provided Norway with a comparative advantage in the production of high-tech products. Though access to natural resources and HC were favorable for industrialization, a lack of cheap energy sources and domestic capital supply harmed economic development during the 19th century (Grytten, 2020; Lindmark and Minde, 2018; Semmingsen, 1960). Instead of expanding its manufacturing sector, Norway specialized in shipping and natural resource exports. This development was driven by geographic proximity to the UK, the first country undergoing industrialization, combined with a maritime trade tradition. The downside of this development towards trade dependency was high vulnerability to macroeconomic fluctuations. Since the UK was Norway's major trading partner during this period, its economic performance was a major determinant of Norwegian economic performance.

A major shift in the industrial structure was only observed in the early 1900s, when the construction of the first hydroelectric plants provided Norway with extremely cost-efficient and environmental friendly electricity (Da Silva et al., 2016; Grytten et al., 2020; Lindmark and Minde, 2018). The access to cheap energy sources provided Norway with a comparative advantage in energy-intensive industries and made the country attractive to foreign investments. In combination access to foreign

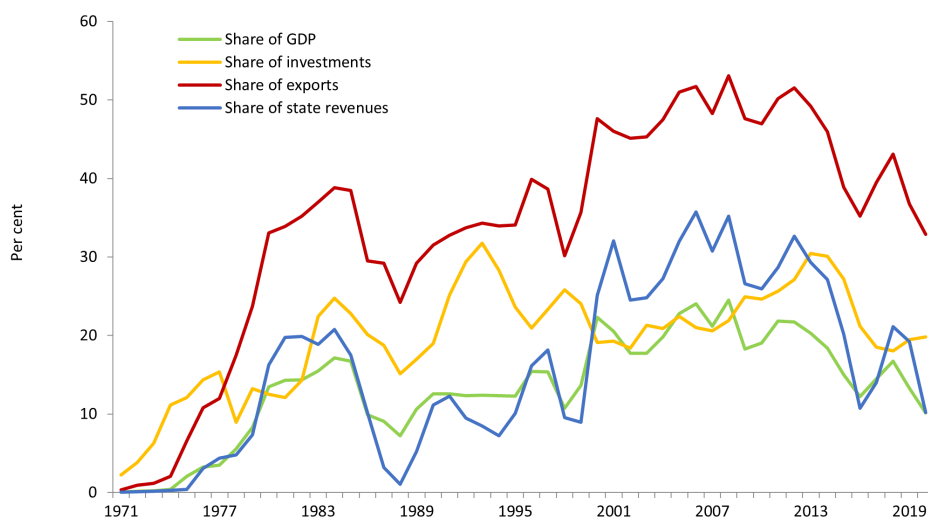
capital and the advantage in energy-intensive production promoted the establishment of pulp, paper, manufacturing, and the chemical industry (Grytten, 2020).

Semmingsen (1960) notes that economic conditions and technical change severely affected Norwegian demography between the second half of the 19th century and the great depression when Norway experienced a period of mass migration. More than 780,000 Norwegians, which correspond to nearly half of the population in 1865, left the country during this period, primarily to the US (Historisk Statistikk, 2021). In several cases, Migratory decisions were driven by the introduction of specific technologies. For example, the introduction of steamboats resulted in substantial rationalization in the marine industry during the 1880s, spurring mass migration among sailors. In other words, migration functioned as tool to release surplus labor. However, changes in US migration policy halted the migratory movement from 1930 onwards. This amplified the problem of mass unemployment since surplus labor was trapped in Norway (Grytten, 2020).

During WW2 Norway was occupied by Germany between 1940 and 1945. Though Norwegian GDP declined by 6% compared to 1939 over this period (Grytten, 2004), Norway was less severely affected by war destruction compared to continental Europe. Espeli (2013) accounts these considerably mild war losses to the unique nature of German occupation in Norway as most businesses and administrative authorities collaborated in with the occupying power. Furthermore, massive infrastructure projects helped to reduce unemployment and poverty. Nonetheless, significant parts of the merchant fleet were destroyed, and the country's population and economy were increasingly affected by rationing. Input shortage promoted the adaptation of less efficient technologies and subsistence farming, negatively affecting labor and overall productivity until 1950.

After WW2, Norway experienced a period of high growth which lasted until the 1980s (Grytten, 2004, 2020). One reason for successful economic development during the post war period is the adoption of Nordic Model, which was also endorsed by governments in Sweden and Denmark. In all three countries, large shares of the population were employed in the public sector and government policies facilitated wealth redistribution. Though the Nordic model did not promote rapid economic growth, it enabled the Scandinavian countries to maintain a highly egalitarian income distribution and social cohesion throughout their economic development process (Andersen et al., 2007). However, changes in macroeconomic conditions and globalization forced the Scandinavian economy to adjust the Nordic model and reduce the share of the public sector in economic activity.

Figure 1: Importance of the petroleum sector for the Norwegian economy



Source: Adapted from Norwegian Petroleum (2021).

According to Grytten (2020) and Sollund (2012), the emergence of the petroleum sector in 1971 marked a major shift in economic development and industrial structure. Today, the petroleum sector is the largest single contributor to state revenue, GDP, exports, and investment. Moreover, Mideksa (2013) finds that petroleum rents determine 20% of annual GDP per capita growth. In 2018, crude oil and natural gas extraction amounted to 86 million tons and 122 million m^3 , respectively (Norwegian Petroleum, 2021). According to Teigen (2018), Norway was 5th biggest oil extractor in per capita terms during the same year.

Figure 1 illustrates the importance of the petroleum sector in the Norwegian economy. Apart from government income, the petroleum industry accounts even for more than 15% of GDP and total investments. The share of petroleum products is especially high in total exports. In the period after 2000, they accounted for approximately 45% of the total export volume. In 2018, the petroleum sector generated 21.1% of total state revenue, which corresponds to 214 billion 2010 NOK (Norwegian Petroleum, 2021).

A major advantage of the access to petroleum rents income is its positive effect on government finances. According to World Bank (2021) data, Norway had the 6th highest net lending rate in relation to its GDP worldwide in 2019. It is therefore one of the few countries worldwide with positive net financial assets. Because of its stable financial position, the Norwegian government can engage in counter-cyclical government during financial crisis, compensating for lacks in private

investment. According to Grytten (2020), the Norwegian economy was for this reason less affected than other industrialized countries during the first oil crisis in 1973.

Despite the relevance of access to petroleum rents for high welfare levels today, the emergence of the petroleum sector resulted in severe economic and environmental consequences. Sollund (2012) denotes that the petroleum sector generates a significant fraction of Norway's carbon emissions. Moreover, fishery is negatively affected by environmental degradation and biodiversity losses caused by pollution from oil and natural gas extraction.

The emergence of the petroleum sector caused early deindustrialization in Norway. High profitability of investments in the petroleum sector as well as rising wages on the national level lowered profitability of investments in other industries (Grytten, 2020). Historical labor statistics reveal that employment in the manufacturing and mining industries declined both in absolute and relative terms from 24% to 18% between 1975 and 1985 (Historisk Statistikk, 2021). Moreover, petroleum exports exceeded manufacturing exports within a single decade.

What should be considered here, is that petroleum rents are highly sensitive to fluctuations in the crude oil price.¹ According to Eckbo (2009) and Hunnes and Grytten (2021), this became problematic when Norway underwent financial liberalization and deregulation during the early 1980s. Lower credit standard facilitated a substantial expansion of bank loans and created a housing and asset price bubble. Banks faced higher risk of non-performing loans and became more vulnerable to macroeconomic fluctuations. When the crude oil price suddenly dropped by 70% during the mid-1980s, international investors started to speculate against the Norwegian crown. In the late 1980s, financial markets collapsed in Norway and other Scandinavian countries. Similar to the 2009 *Global Financial crisis*, several commercial banks needed to be saved through government intervention to avoid a complete collapse of the financial sector. Though this was prevented, unemployment rates surged during the Scandinavian Banking crisis, returning to its pre-crisis levels of around 3% only in the late 1990s (SSB, 2021).

As illustrated in figure 1, the 1985-oil price drop caused a massive reduction in the share of petroleum rents in total state revenue from 20.7% in 1984 to merely 1% in 1987, leaving a substantial hole in government finances. To prevent fluctuations in governmental income due to oil price

¹Oil Price volatility has been higher than metallic minerals, such as iron, copper or tin (Arezki et al., 2014; Jacks, 2013; Keay, 2015).

changes in the future and avoid overspending, the Norwegian government founded a national fund to manage its oil revenues (Grytten, 2020; Norges Bank, 2021). Since its foundation in 1990, the *Government Pension Fund Global* accumulated a total value of 1.275 billion USD, making it the biggest of its kind. The fund comprises a wide range of investments in shares, government bonds and real estate outside of Norway. To prevent overspending, the government is only permitted to spend the real returns of the fund, which on average equals 3% of the funds value. Furthermore, it allows for counter-cyclical monetary policy, boosting the Norwegian economy during economic downturns. This has a further advantage, since it ensures access of future generations to petroleum revenues, even after the depletion of oil and natural gas reserves.

Nonetheless, critical voices point out that the Government Pension Fund Global contributes to unsustainable development on a global scale. Sollund (2012) finds that most of the fund's value is invested in companies contributing to environmental degradation and natural capital depletion. The first investment in a renewable energy project, a Dutch offshore wind farm, was only undertaken in 2021 (Milne, 2021).

3 Genuine Savings framework

This section provides an overview over the GS framework in existing literature as well as the modification and extensions applied in this study.

Though the first formal presentation of GS was conducted by Hamilton and Clemens (1999) in the late 1990s, the concept goes back to the work of Weitzman (1976) and Solow (1974, 1986), who addressed the importance of accounting for natural capital in their studies on future well-being and inter generational equity already in the mid-1970's. Their work is closely related to the *Hartwick rule* (Hartwick, 1977) and the concept of *weak sustainability*. According to Hartwick (1977), economic development is considered as weakly sustainable if well-being is non-declining over time. Assuming perfect substitutability across capital components, depletion of non-renewable natural resources must be compensated by investment into reproducible capital to ensure that future generations have at least the same consumption possibilities as people living today. The most extensive data set on GS estimates is provided by the World Bank (2021), providing data on GS in some cases back to the 1970s. Since these estimates and the World Bank methodology² serve as a baseline in several GS studies (Biasi et al., 2019; Qasim et al., 2020), this is also the case in this paper.

$$GS_t = NNS_t + EE_t - NRD_t - EC_t \quad (1)$$

GS in period t GS_t consists of four components: net national savings NNS_t , education expenditure EE_t , natural resource depletion NRD_t , as well as emission costs EC_t . As mentioned above, GS will turn negative if environmental degradation and NRD are not compensated by investment into reproducible capital. Reproducible capital refers in the GS framework to net national savings, which are calculated as the difference between gross national savings and the consumption of fixed capital.

The second component that positively affects GS estimates is education expenditure, which accounts for HC investment. In the World Bank methodology education expenditure refers exclusively to public but not to private education expenditure (Biasi et al., 2019; Bolt et al., 2002).

Since NRD and pollution reduce the natural capital stock, both variables lower GS estimates. Bolt

²The World Bank methodology is summarized in Bolt et al. (2002)

et al. (2002) calculate NRD as the sum of subsoil depletion and deforestation. Emission costs account exclusively for CO_2 emission from fossil fuel burning and deforestation. For the period after 1990, the World Bank even include separate GS estimates accounting for particulate matter damage (Biasi et al., 2019; World Bank, 2021).

Despite the popularity of the World Bank framework, there exist several possibilities to further extend and improve the World Bank methodology. First, Biasi et al. (2019) and Blum et al. (2017) propose that the explanatory capacity of GS could be improved by the inclusion of additional natural capital components. Their findings suggest that NRD are underestimated when following the in World Bank methodology, since it does not account for several dimensions of natural capital including biodiversity losses, water pollution, and soil degradation. For this purpose, Arrow et al. (2012) and Greasley et al. (2017) include the current value of agricultural land, while Biasi et al. (2019) incorporate measures for soil degradation and water pollution.

Second, Arrow et al. (2012) and Biasi et al. (2019) find that the exclusion of other substances contributing to climate changes results in an underestimation of total emission costs. In connection to this, Blum et al. (2017) point out that there exist several different carbon prices. In their paper they use two alternative carbon prices of $\$131/tCO_2$ and $\$1,455/tCO_2$. The lower price refers to a scenario where global warming is limited to 2 degrees Celsius, while the higher price of $\$1,455/tCO_2$ assumes that no effective restrictions to prevent climate change are implemented. Both values significantly exceed the price of $\$28.62/tCO_2$ ³ utilized in the World Bank estimations (Bolt et al., 2002).

Third, traditional GS do not account for changes in population size (Greasley et al., 2014; Hanley et al., 2015; Qasim et al., 2020). Population growth implies, that total wealth must be shared by an increasing population. In this case, positive GS might be insufficient to ensure non-declining wealth per capita. This phenomenon is known as the *wealth dilution effect*. Greasley et al. (2014) find strong evidence for this in the UK prior to 1945.

Fourth, Biasi et al. (2019) and Pyzheva (2020) point out that GS estimated on the national level obscure unsustainable development on the regional level. This has severe implications for long-term development prospects in regions with high levels of NRD.

Finally, several long-term GS studies account for exogenous technological change since technolog-

³The World Bank uses a value of 20 1995 USD. This value is deflated to 28.62 2010 USD utilizing the US deflator.

ical change was a major driver of rising consumption possibilities in OECD countries over time (Blum et al., 2017; Greasley et al., 2014; Qasim et al., 2020).

$$GSTFP_t = GS_t + PVTFP_t \quad (2)$$

As presented in equation 2, $GSTFP_t$ are calculated as GS_t augmented by the present value of TFP growth $PVTFP_t$. Based on the framework developed by Pezzey et al. (2006) the present value of TFP growth is preferred here instead of the absolute value which is used for example in Arrow et al. (2012).

The present value of TFP growth $PVTFP_t$ it is calculated as the difference between GDP in period $t + z$ and period t , discounted by the long-term interest rate i over a time horizon z , which can take the value 20, 30, or 50 years.

$$PVTFP_t = \frac{GDP_{t+z} - GDP_t}{1 + i^z} \quad (3)$$

GDP_{t+z} equals GDP_t , multiplied by 1 plus trend TFP growth $T(TFP)_t$ raised to the power of z . Trend TFP growth is extracted by using a Kalman Filter.

$$GDP_{t+z} = GDP_t * (1 + T(TFP)_t)^z \quad (4)$$

While GS account for a wide set of capital components, estimates should be interpreted with caution. Pezzey (2004) finds that negative GS estimates are a good indicator for unsustainable development since consumption possibilities of future generations are reduced. However, a positive GS value does not necessarily imply non-declining well-being in the future. Consequently, GS is rather a one-sided sustainability indicator, useful for identifying periods of unsustainable development.

Another concern are the distribution of benefits from NRD across individuals and the concept of weak sustainability itself. Qasim and Grimes (2021) detect an unequal distribution of benefits from NRD, which has important implications for economic development prospects and income inequality. While NRD is beneficial for individuals with higher income and education levels, the well-being of the poor is abated. Dietz et al. (2007) find that most natural resource exporters

report negative GS. However, NRD is not the sole driver of negative GS values. Natural resource abundance reduces in most cases institutional quality, harming investment into physical and HC. This effects is commonly known as the *natural resource curse* (Ploeg, 2008).

Four main modification and extensions of the GS framework are applied in this article. First, GS estimates augmented by the present value of technological change $GSTFP_t$. Second, fishery rents are included in the GS framework because of the traditional importance of the fishery sector for the Norwegian economy. Third, in difference to the World Bank, natural resource rents can turn negative in this study. This is motivated by Hanley et al. (2015), who recognize that augmentation of renewable natural resources like forest and fish stocks can increase the natural capital stock. However, this is not applicable to non-renewable natural resources like minerals and fossil fuels. Finally, the main estimations in this study are based on the medium carbon price scenario of $\$131/tCO_2$. Since this exceeds the price used in the World Bank methodology, our estimates are expected to be lower compared to those provided by the World Bank (2021).

4 Data

In difference to most other countries Norwegian national accounts and collections of historical statistics provide detailed information back to the 19th century, facilitating historical analysis. Data to construct GS estimates is primarily sourced from Statistics Norway (SSB, 2021; SSB, 1965; Norges Bank, 2013). A complete overview over the general data sources and the data on natural resource rents is presented in tables 3 and 4 in the appendix.

4.1 Net National Savings

Since gross national savings are not provided by the SSB (2021) prior to 1978, NNS_t are calculated as the sum of gross fixed capital formation $GFCF_t$, net FDI inflows $NFDI_t$ and net exports NX_t , minus consumption of fixed capital CFC_t . Data on all NNS components is sourced from the SSB (SSB, 1965; SSB, 2021).

$$NNS_t = GFCF_t + NFDI_t + NX_t - CFC_t \quad (5)$$

4.2 Education Expenditure

Data on public education expenditure is provided by the SSB (Historisk Statistikk, 2021; Norges Bank, 2013; SSB, 2021). Values for the years 2013 and 2014 are linearly interpolated.

4.3 Natural Resource Rents

NRD_t is calculated as the sum of forestry $R(Fo)_t$, fishery $R(Fi)_t$, and mining rents $R(M)_t$.

$$NRD_t = R(Fo)_t + R(Fi)_t + R(M)_t \quad (6)$$

Estimation methods and data sources for the fishery, forestry, and mining sector are reported separately in this section. A complete reference table for natural resource rents is provided in table 4.

4.3.1 Forestry rents

Forestry rents $R(Fo)_t$ are calculated as the change in forest area FA between period t and $t - 1$ multiplied by the timber price $P(T)_t$, and forest density FD . Forest density is assumed to remain constant across time.

$$R(Fo)_t = [FA_t - FA_{t-1}] * FD * P(T)_t \quad (7)$$

Data on forest area and density is provided by the SSB (Historisk Statistikk, 2021; SSB, 2021) and the FAO (2000). Timber prices are based on Federico and Tena Junguito (2018), Blum et al. (2017), and Forest Research (2021). Similar to other studies, single observations are connected through linear interpolation (Blum et al., 2017).

4.3.2 Fishery rents

To calculate fishery rents in period t , labor costs in fishery $LC(Fi)_t$ are deducted from total revenues in fishery, sealing, and whaling $R(FSW)_t$.

$$R(Fi)_t = R(FSW)_t - LC(Fi)_t \quad (8)$$

Data on revenues and employment in the fishing, sealing, and whaling industry is sourced from the SSB (SSB, 2021; Historisk Statistikk, 2021). Since data on the number of fishermen is only available from 1875 onwards, it is assumed that the number of fishermen increased linearly between 1866 and 1874. Eitrheim et al. (2007) provides average wages in the primary sector for the 1899-2006 period. Prior to 1899, wages in fishery are assumed to be equal to wages in agriculture and forestry. From 2006 onwards, wages are reported as total wage costs in the fishing industry (SSB, 2021).

4.3.3 Mining rents

Mining rents are calculated as the difference between the sum of individual mineral and fossil fuel rents $\sum_i R_{i,t}$ and labor costs in the extractive industry $LC(M)_t$.

$$R(M)_t = \sum_i R_{i,t} - LC(M)_t \quad (9)$$

Revenues of an individual mineral or fossil fuel i $R_{i,t}$ are equal to the quantity extracted during period t $Q_{i,t}$ multiplied by the world market price $P_{i,t}$.

$$R_{i,t} = Q_{i,t} * P_{i,t} \quad (10)$$

Data on extracted quantities are provided by the SSB (Historisk Statistikk, 2021; SSB, 2021), Norwegian Petroleum (2021), and Clio Infra (2014). Furthermore, the SSB (Historisk Statistikk, 2021; Norges Bank, 2013), Eitrheim et al. (2007) and Norwegian Petroleum (2021) provide information on the number of employees and wages in the mining and oil sector. For the period after 2006 wage costs are based on changes in total wages. Detailed information on natural resource prices is included in table 4.

4.4 Emission Costs

Emission costs EC_t are calculated as the product of carbon emissions $CO_{2,t}$ and the carbon price $P(CO_2)_t$.

$$EC_t = CO_{2,t} * P(CO_2)_t \quad (11)$$

Carbon emission data is sourced from the historical emission data series PRIMAP (Gütschow et al., 2016) and the Global Carbon Atlas (2021). Carbon prices are based on Blum et al. (2017).

4.5 TFP

As presented in equation 2, $GSTFP_t$ is calculated based on GS augmented by the present value of TFP. GDP data is retrieved from Grytten (2004) and the OECD (2021). Bergeaud et al. (2020) provide data on TFP growth for the period from 1890 to 2019. $PVTFP_t$ are discounted with the long-term discount rate of 2.8% for the 1852-2003 period (Eitrheim et al., 2007).

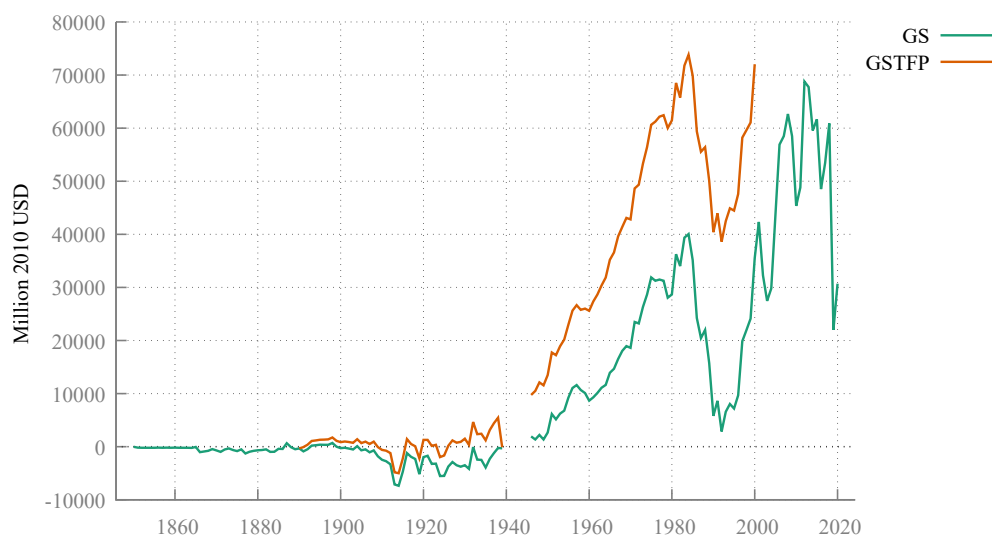
5 Results

In the first section estimation results of Norwegian GS and GSTFP are presented. The second section focusses on the contribution of single GS components to overall estimates.

5.1 GS and GSTFP

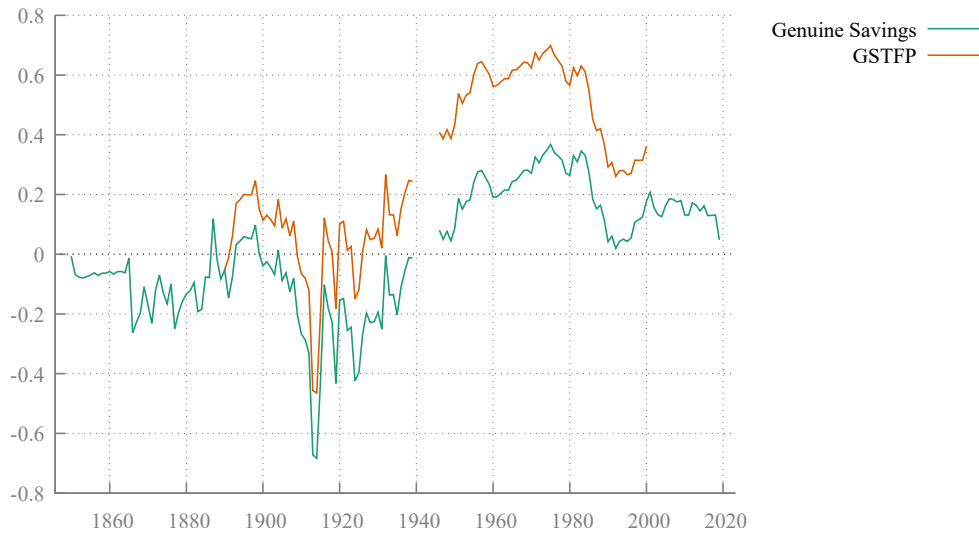
GS and GSTFP in absolute values and as a share of GDP are presented in figure 2 and 3. While Norwegian GS were negative during most years prior to WW2, they turned consistently positive after 1946. Since GSTFP also accounts for productivity gains, GSTFP values typically exceed GS estimates. However, during periods with very low GS values, GSTFP also turned negative. This applies especially to the 1910s and early 1920s.

Figure 2: GS and GSTFP, 1865-2018 (Million USD)



Norwegian GS reached a record of \$68.7 billion in 2012, corresponding to 17% of GDP. In relative terms the highest values were reported during the 1970s when GS and GSTFP amounted to 35% and 70% of GDP, respectively. This drop in the relative share can be accounted to a more than fourfold rise in GDP values since the 1970s. The minimum GS value both in absolute and relative terms was reported in 1914 when GS amounted to -\$7.4 billion which corresponds to -68% of GDP. Norwegian GS and GSTFP until 1939 are illustrated in figure 4. Except for a short period during the 1890s GS were nearly constantly negative until WW2, indicating an extended period of unsustainable development. Substantial fluctuations in GS since 1900 are closely related to economic

Figure 3: GS and GSTFP, 1865-2018 (%GDP)



and financial crises. For example, dips in GS estimates between 1917 and the early 1930s can be explained by disturbances of international trade during WW1, a financial crisis in the early 1920s, and the Great Depression (Grytten, 2020). As mentioned above, GSTFP do not indicate unsustainable development for most of the period until 1939. Only during the 1910s and early 1920s technological advances are insufficient to compensate for low GS levels.

Figure 4: GS and GSTFP, 1865-1939 (Million USD)

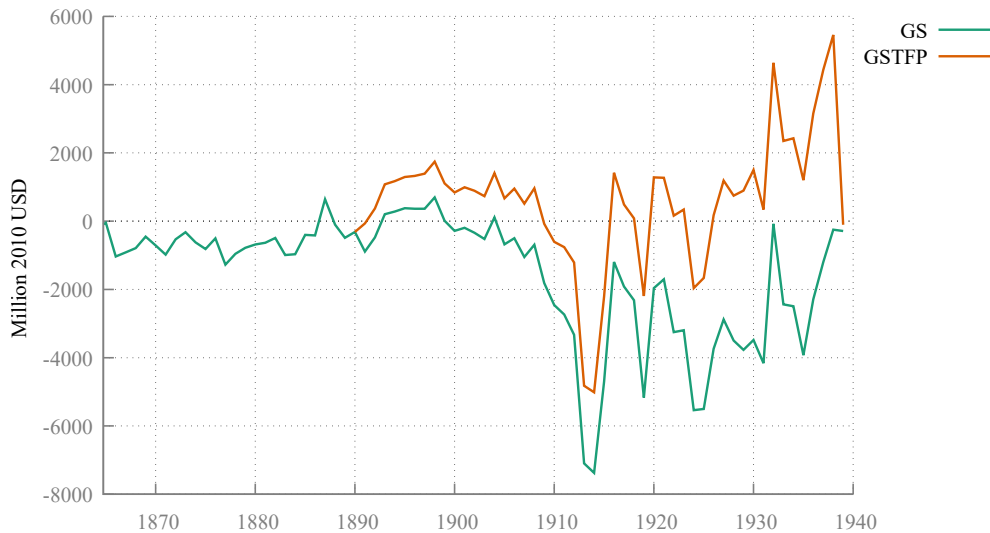
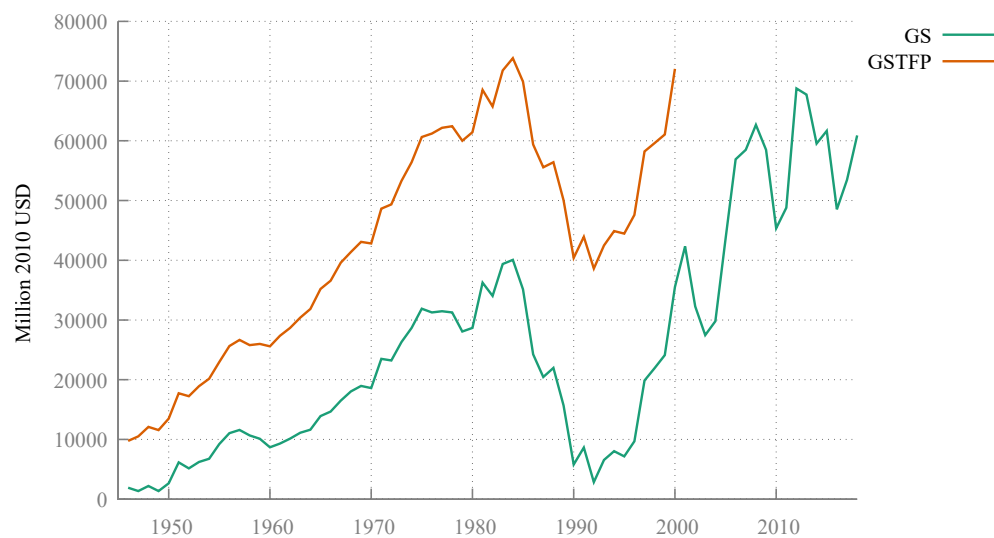


Figure 5 presents GS and GSTFP estimates for the period after WW2. Despite of several macroeconomic shocks, GS estimates remain positive throughout this period. In difference to most other

countries, Norway did not experience significant reductions in GDP and GS during first and second oil crisis. Grytten (2020) accounts this to increasing oil prices, which massively raised the Norwegian export surplus.

The biggest drop in GS occurred during the *Scandinavian Banking Crisis* in the late 1980s and early 1990s. Between 1984 and 1992, GS dropped by 93%, from \$40 billion to merely \$2.8 billion. After this crisis, GS also show large drops after the burst of the *dot-com bubble* and the *Global Financial Crisis* but relative reductions in GS did not exceed 35%. GSTFP indicate even stronger signs of sustainable development in Norway, exceeding GS estimates by a factor of two. This indicates further increases in well-being over the next decades.

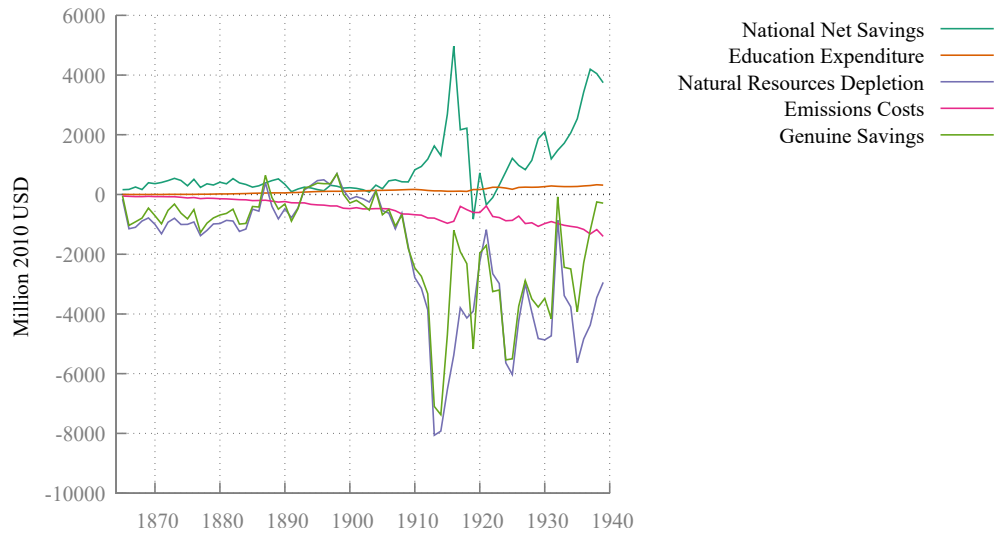
Figure 5: GS and GSTFP, 1946-2018 (Million USD)



5.2 GS components

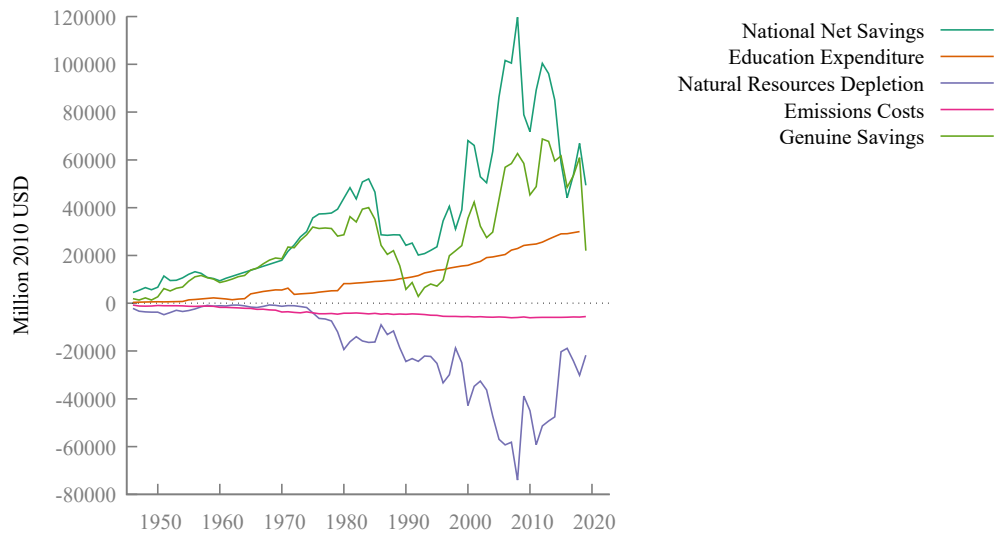
This section investigates the contribution of different GS components to overall estimates. Figure 6 illustrates trends in GS components in the period leading up to WW2. Components reducing GS are presented as negative numbers. Norway failed to follow the Hartwick rule during this period since NNS and education expenditure are insufficient to compensate for NRD and emission costs. Before WW2, NRD was the most important determinant of GS, determining 60% of its total value. Moreover, emission costs rise rapidly to \$1.4 billion in 1939, which corresponds to 50% of NRD in 1939.

Figure 6: GS Components, 1865-1939 (Million USD)



A major switch in GS determinants occurs around WW2, illustrated in figure 7. GS stayed positive for the entire postwar period, despite of a substantial increase in NRD due to oil extraction from 1971 onwards. The main reasons for this are high NNS levels and rising HC investment. Moreover, NRD and emission costs declined over recent years.

Figure 7: GS Components, 1946-2018 (Million USD)



Interesting in this context is also the volatility of GS components. NRD and NNS are highly volatile over the entire observation period. Since both components are to a large extent determined by changes in the oil price, this results in large simultaneous swings in both components. In difference

to this, education expenditure and emission costs estimates are far more stable over time. While education expenditure increased over the entire observation period, emission costs are slightly declining after 2010. Increasing and stable HC investment even during economic downturns prevented negative GS values after 1946. While NNS decreased to less than half its pre-crisis value during the *Scandinavian Banking Crisis*, education expenditure increased by more than \$4 billion. In this way, HC investment compensated reductions in physical capital investment sufficiently such that the Hartwick rule was still fulfilled.

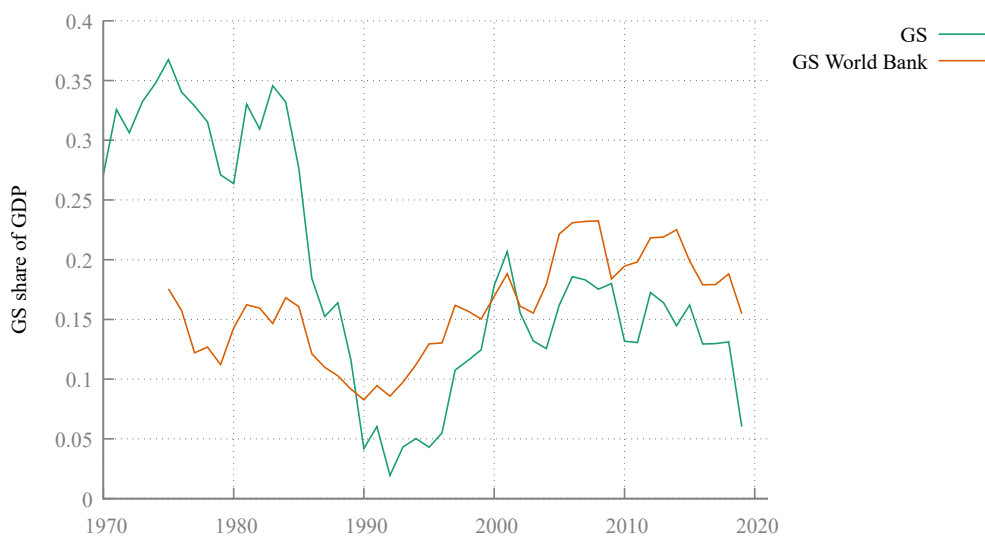
6 Discussion

This section compares our estimates to World Bank estimates as well as Swedish and Dutch GS. Furthermore, it discusses particular aspects of the Norwegian economy, shortcoming of the GS framework, and provides some advice for policy makers.

6.1 Comparison to World Bank estimates

In figure 8, our estimates are compared to World Bank (2021) figures as a share of GDP. While our estimates exceed those provided by the World Bank by 14 percentage points on average before 1990, this trend is reversed during recent years. Deviations in GS estimates can be accounted to differences in evaluation methods of single GS components. Figures comparing individual GS components to World Bank data are included in figure 12 in the appendix.

Figure 8: Comparison to World Bank data, 1970-2018 (% GDP)



Education expenditure is not a major driver of deviations in GS levels. Volatility of World Bank estimates is only slightly higher compared to our estimations. However, significant differences can be detected when comparing NNS, NRD, and emission costs.

NNS are the main driver of the deviations in GS until the mid-1990s. Before 1995, our estimates are about twice as high compared to World Bank. After this NNS converge until they become nearly identical after 2005.

NRD is the second factor that significantly contributes to differences in absolute GS values. Though

both data sets show similar trends, estimates in our study exceed World Bank figures for the entire period from 1970 to 2018. What should be noted here is that these differences are not driven by the inclusion of fishery rents. Instead, they can be accounted to differences in the valuation methods. As illustrated in figure 13, the ratio of NRD including and excluding fishery rents converges to one after 1971. The reason behind this is a shift in the determinants of different primary sector for total NRD. While NRD in- and excluding fishery rents differs by 80% during the 1960s, these differences diminish to 1% during the 1990s. Mining rents determine already 81% of NRD in 1975, surpassing 95% by 1979.

Another important driver of discrepancies in GS levels is the carbon price used to evaluate emission costs. Differences in emission costs if carbon emissions are valued at different carbon prices are illustrated in figure 14. The preferred price of $\$131/tCO_2$ is more than four times higher than the price used in the World Bank methodology. Differences in absolute values are even more significant if the higher carbon price of $\$1455/tCO_2$ is used to calculate emission costs. In this case emission costs exceed World Bank estimates by a factor of 50.

To check whether deviations in emission costs are rather driven by carbon prices or in differences in emission data, World Bank estimates are re-valuated at a value of $\$131/tCO_2$. While the results presented in figure 12 reveal that differences in carbon prices are the main driver of variations in emission costs, there even exist significant variations in carbon emission data. These are most significant around 1970, when emission costs in our study are approximately twice as high. However, this trend is reversed over the observation period. Since 2000 carbon emissions are higher for most years in the World Bank data set.

6.2 Particular aspects of the Norwegian economy

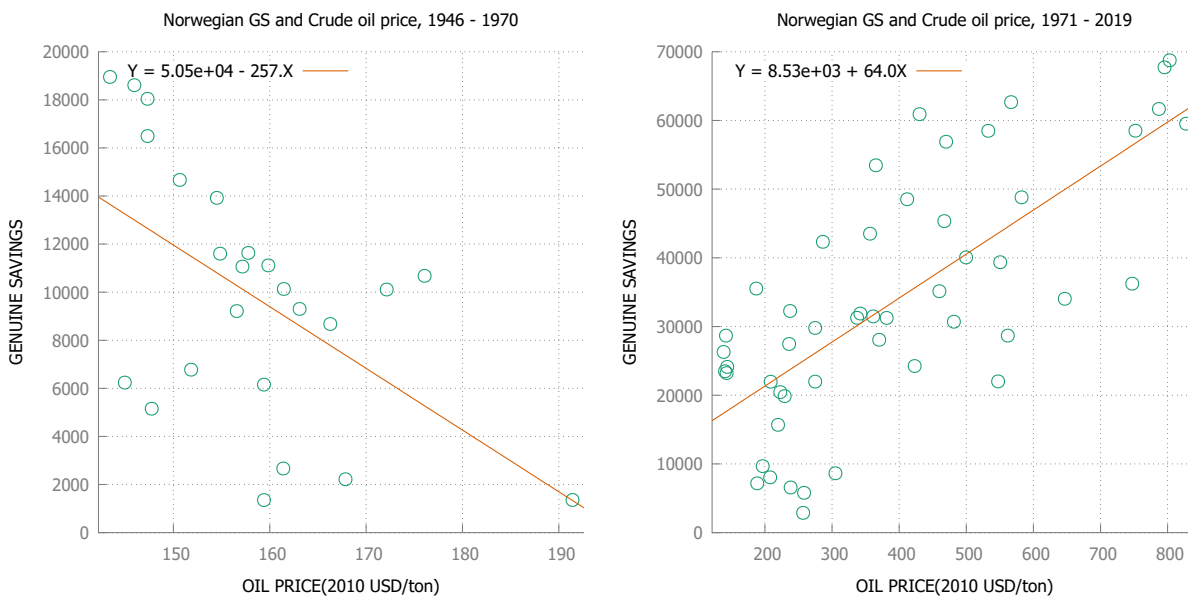
This subsection discusses the mass migration out of Norway during the second half of the 19th century and the oil dependency, which have both significant implications for GS accounting.

According to Greasley et al. (2017), mass migration might weaken education expenditure as a measure of the HC stock. In traditional GS accounting the HC investment is exclusively measured based on public education expenditure. This might be problematic in case of large-scale migratory movements, since public education expenditure does not account for gains or losses in HC through migration. While this leads to an underestimation of HC accumulation in countries receiving

migrants, it results in HC depletion in sending regions. The effect on the human capital stock depends in this case strongly on the selection of migrants from the total populations. In case that mainly young adults who just completed their education, this might result in substantial HC losses. As shown in figure 6 education expenditure was a minor component of GS during the pre-WW2 period. Nonetheless, HC accumulation might in this case still be overestimated if measured as public education expenditure.

As mentioned above, the Norwegian economy has benefited to a high extent from tax and export income from the petroleum sector, which can be used for counter cyclical fiscal policy (Grytten, 2020; Hunnes and Grytten, 2021). An important instrument in connection to this is the Government Pension Fund Global, introduced in section 2.2, which allows the government to spread income from the petroleum over time. In combination with high income from oil exports, this facilitated a substantial rise in NNS, exceeding even the tremendous increase in NRD.

Figure 9: Correlation between Norwegian GS and the Crude oil price, 1946-1970 and 1971-2018



Nonetheless, overall economic performance, government finances and GS became highly sensitive to changes in the crude oil price (Grytten, 2020; Hunnes and Grytten, 2021). Figure 9 illustrates the correlation between Norwegian GS and the crude oil price between 1946 and 1970 on the left and for the period from 1971 and 2018 on the right. As in most non-oil exporting countries, Norwegian economic performance and GS was negatively correlated with the oil price, during the earlier

period (Blum et al., 2017; Maeda, 2008). This relationship was reversed after Norway became an oil exporter in 1971. Today, an increase in the oil price is strongly associated with high GS. However, since there exist significant fluctuations in the oil price, Norwegian GS became far more volatile since the 1970s (Arezki et al., 2014; Jacks, 2013; Keay, 2015). This can be seen by greater dispersion of single observations during the later period.

6.3 International Comparison

In this section, Norwegian GS per capita are compared to Swedish and Dutch estimates. GS per capita is the preferred measure here since it accounts for differences in population size across countries. Sweden is selected because of its geographic proximity as well as similarities in climatic conditions and natural resources abundance. Moreover, the countries are closely connected throughout history and share similar institutions (Acar, 2017).

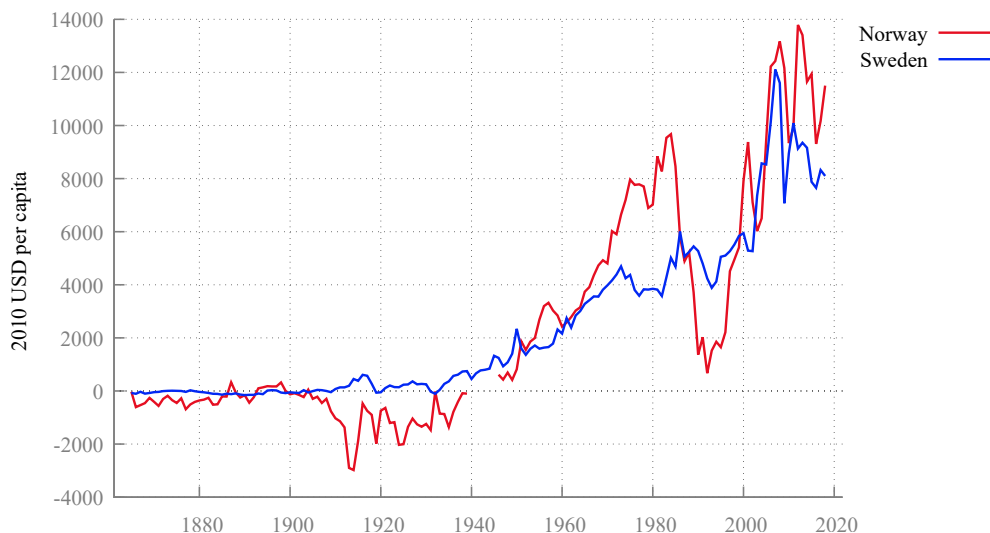
The comparison of the Netherlands and Norway is based on the great importance of the petroleum sector in both countries. Since the discovery of the Groningen field in 1959, natural gas extraction severely affected Dutch energy policy and economic development (Van Hulten, 2009). Both countries were industrialized prior to the discovery of oil resources and are considered as small open economies (Grytten, 2020). These similarities make it interesting to compare the effects of sudden shock in energy depletion on GS estimates in developed countries.

6.3.1 Sweden

Swedish GS estimates for the period from 1850 until 2000 are provided by Lindmark and Acar (2013). After 2000, data is sourced from the World Bank (2021). Emission costs are adjusted to the medium carbon price of $\$131/tCO_2$. Population data for the entire period is provided by the SCB (2021).

Norwegian and Swedish GS per capita are compared in figure 10. Similar to Norway, Sweden experienced unsustainable development throughout the second half of the 19th century. Lindmark and Acar (2013) account this to high levels of NRD in the forestry and mining sector. Nonetheless, Swedish GS per capita turned positive around 1910, three decades earlier compared to Norway. This was facilitated by increased investment in HC and physical capital, compensating for NRD. After WW2, GS per capita converged to similar levels until the 1970s. Until the outbreak of the

Figure 10: Norwegian and Swedish GS per capita, 1865-2018 (2010 USD)



Scandinavian banking crisis, Norwegian GS per capita exceed Swedish estimates by about 50%. However, Norwegian economic performance and GS became extremely vulnerable to fluctuations in the crude oil price. Swedish GS per capita levels stayed basically constant during the Scandinavian banking crisis, while Norwegian GS per capita dropped by 93% compared to their pre-crisis level. Norwegian caught up to Swedish GS per capita only in 2000. In 2018, Norway and Sweden reported GS per capita estimates of \$11,502 and \$8,101, respectively.

Table 1: Norwegian and Swedish GS per capita components in 2018 (2010 USD)

	Norway	Sweden
NNS	12,636	5,379
EE	5,659	3,420
NRD	5,696	57
EC	1,097	640
GS	11,502	8,101

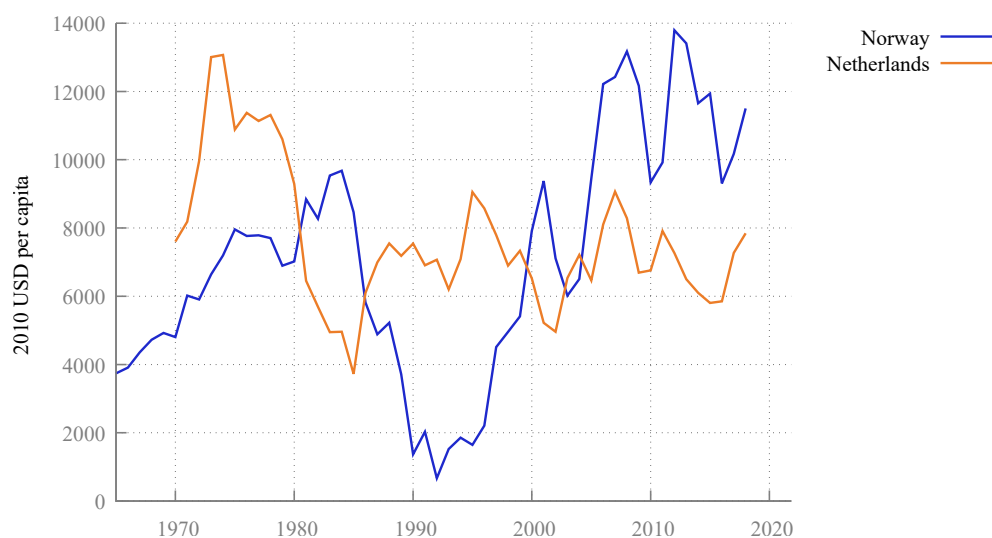
Comparing GS per capita components explains differences in GS per capita levels. These are reported in table 1. GS per capita levels in Norway are about 42% higher compared to those in Sweden. NNS and education expenditure in Norway which are about twice as high compared to Sweden. Nonetheless, the positive effect of HC and physical capital investment on Norwegian GS estimates is ameliorated by significantly higher NRD and emission costs. While emission costs are approximately twice as high, Norwegian NRD exceeds Swedish levels by a factor of 100.

Consequently, a significant fraction of Norway's additional HC and physical capital investment does not contribute to future improvements in well-being, since it is needed to compensate for NRD.

6.3.2 Netherlands

Dutch GS estimates are currently only available from the World Bank (2021) between 1970 and 2019. Like the Swedish GS estimates, emission costs are re-valuated at $\$131/tCO_2$. Population data is sourced from the Dutch Statistical Office (CBS, 2021b). The idea is to present only a short comparison in this paper. A further comparison of the commodity shock will be conducted as soon as long run Dutch GS estimates become available.

Figure 11: Norwegian and Dutch GS per capita, 1965-2018 (2010 USD)



Norwegian and Dutch GS per capita are compared in figure 11 for the period between 1970 and 2018. Dutch GS per capita exceeded Norwegian estimates for nearly the entire period before 2000. Norwegian GS per capita are only significantly higher during the second oil crisis in the early 1980s. Furthermore, Dutch GS per capita are in general less volatile. Since 1990, GS per capita in the Netherlands is remaining stable at approximately \$7000, while Norwegian estimated were highly volatile. Only since 2005, Norwegian GS per capita constantly exceed Dutch figures, by approximately 30%.

One major driver of differences between the two countries, exports of petroleum products account

for a far greater share of Norwegian compared to Dutch exports. In Norway about 40% of the total export volume is composed of petroleum products, while it is merely 10% in the Netherlands (Norwegian Petroleum, 2021; World Bank, 2021). This explains why Dutch GS are less volatile since they are to a lower extent determined by a single commodity (Arezki et al., 2014; Jacks, 2013; Keay, 2015).

Table 2: Norwegian and Dutch GS per capita components in 2018 (2010 USD)

	Norway	Netherlands
NNS	12,636	7,077
EE	5,659	2,137
NRD	5,696	155
EC	1,097	1,598
GS	11,502	7,462

Differences in GS per capita components are presented in table 2. Similar to Sweden, the Netherlands have far lower NNS and education expenditure compared to Norway. Differences in HC investment are especially large. Dutch education expenditure amounts to less than 40% of HC investment in Norway. Furthermore, emission costs are 45% higher in the Netherlands. This can be accounted to a high share of fossil fuels in energy consumption amounting to 90% in 2019 (IEA, 2021). In comparison, Norway derived only half its total energy from fossil fuels in 2012 Lindmark et al. (2018). Like in the case of Sweden, NRD in the Norway significantly exceeds values in the Netherlands. Though NRD per capita in the Netherlands is nearly three times higher compared to Sweden, Norwegian NRD still exceeds the Netherlands by a factor of 37.

A caveat when comparing Dutch and Norwegian GS estimates is the lack of historical GS data for the Netherlands. Dutch GS estimates for the period between 1900 and 2020 is currently still under construction. As soon as it becomes available, a long-term comparison between the two countries will be conducted to analyze how GS estimates of industrialized countries are affected by sudden shocks in energy depletion.

6.4 Shortcomings of the GS framework

Since the development of the GS framework, the valuation of different GS components has been subject to discussion in academia. This section covers the most important controversies.

Public education expenditure is widely considered as an insufficient measure of the human capital stock. Greasley et al. (2014) point out that this measure is not representative for the total HC stock before WW2. At this time, individuals spent extremely little time in school and accumulated most HC on the workplace. As an alternative, the authors propose discounted lifetime earnings as a HC measure. Nonetheless the use of lifetime earnings is hindered by data availability.

Closely connected to this is the omission of private education expenditure. In large parts of the developed world but even in some industrialized countries, insufficient public education investment is compensated by investments into private education (Tooley and Dixon, 2005; Wolf and Zohlnhöfer, 2009). To address this problem, Biasi et al. (2019) account for both public and private education expenditure when estimating the Italian HC stock. Though the share of private education in Norway increased over recent years, merely 4.6% of all pupils attended private schools in 2020 (SSB, 2021). Therefore, public education expenditure is considered a good estimator of total education investment in Norway.

Greasley et al. (2014) point out that there exists a risk of double counting in case that both TFP growth and public education expenditure are included in GS estimates. They suggest that long term R&D investment could serve as a more accurate indicator for technological change. However, due to a lack of data the use of R&D investment as an indicator for technological change is not feasible when constructing long run GSTFP data series.

As mentioned above, the GS framework omits several dimensions of natural capital. Hanley et al. (2015) and Blum et al. (2017) observe that GS merely accounts for quantifiable resources, disregarding biodiversity losses, local pollutants, and reductions in ecosystem services. This results in a massive undervaluation of the natural capital stock and NRD. Inclusion of additional natural capital components would improve GS as a sustainability indicator. Moreover, Hanley et al. (2015) point out that the assumptions of perfect substitutability across capital components does not hold if ecosystems are irreversibly destroyed. To address this problem, they propose the introduction of a NRD restriction, ensuring the preservation of a crucial natural resource stock.

Finally, GS could be improved by accounting for local pollutants such as sulfur and nitrogen (Greasley et al., 2014). Prior to the 20th century, these were of greater concern to the environment and human well-being since global carbon emissions were low and there were no signs of climate change. However, limited data availability prevents once more the inclusion of local pollutants in

long term analysis.

6.5 Policy advice

Though Norway achieved high levels of GS and well-being over the second half of the 20th century, there exists potential for further improvements. Increases in GS can be achieved either by increasing physical and HC investment or by reducing NRD and emission costs. As demonstrated in subsection 6.3 education expenditure and NNS in Norway are already very high in an international comparison. For this reason, the reduction of NRD and emission costs appears as a more likely candidate for further improvements in GS.

The major cause of NRD is petroleum and NG extraction. Several arguments mentioned in the paper support a reduction in oil and natural gas extraction extraction. A delay in drillings would directly reduce NRD since extraction of non-renewable resources would be lowered. Moreover, it would reduce fluctuations in exports, government income and GS, resulting from the high volatility and natural gas prices. Finally, carbon emissions and environmental impacts which negatively affecting the maritime environment and fish stocks would be reduced (Schwach, 2013). However, what must also be considered here is that a reduction in oil rents would simultaneously lower NNS, the biggest driver of Norwegian GS.

Bang and Lahn (2020) raise awareness to the fact that resource policy and climate policy are not well aligned in Norway but rather working in opposite directions. In the past promotion of resource extraction has been favored over climatic and environmental concerns. This is even closely connected to the allocation of investments in the Government Pension Fund Global. As mentioned in section 2 investments highly concentrated in extractive as well as carbon intensive industries, which are contributing to global warming and environmental degradation (Milne, 2021). To ensure long term sustainable development and mitigate risks from climate warming, investments should be balanced towards renewable energies and other projects promoting a sustainable transition of the world economy.

Though emission costs are the smallest relative component of GS estimates they increased significantly over the observation period. Carbon emission increased from basically zero in 1865, to 46 Mt in 2010. During recent years carbon emissions declined slightly to 42 Mt. According to (Lindmark et al., 2018), this massive increase in carbon emissions can be accounted to rising energy

consumption from approximately 60 PJ in 1865 to 780 PJ in 2010 as well as the significant share of fossil fuels in Norway's energy mix. As mentioned above, hydroelectric generation accounts for most of electric energy in Norway. This exerts a positive effect on GS estimates in Norway since lower carbon intensity reduces emission costs. However, electricity accounts only for half of Norwegian total energy consumption, while non-renewables cover 45% of Norwegian energy needs. The main reason for this is that reliance on fossil fuels remains high in transportation, mining, and the industrial sector.

What should be acknowledged here is that Norway is actively trying to lower carbon emissions especially in transportation, accounting for 35% of total carbon emissions alone (SSB, 2021). CBS (2021a) reports that Norway became the first country worldwide selling more fully electric vehicles than hybrid or fossil fueled powered cars in 2020. Until 2025 the country aims to completely abandon the sale of fossil fuel powered cars.

7 Conclusion

The main contribution of this paper lies in the first long-run estimation of Norwegian GS. Due to the great importance of fishery in Norway, our estimates for NRD account not solely for deforestation and mining but even for depletion of fish stocks. Furthermore, the methodological framework differs slightly from the World Bank methodology since it allows for augmentation of renewable natural resources and includes a measure for technological change.

According to our findings Norway experienced unsustainable development prior to WW2 driven by substantial NRD. Since 1946, GS remained positive throughout financial crisis and despite of oil and natural gas extraction. This was facilitated by high levels of NNS and significant increases in HC investment, which raised well-being in Norway above levels in Sweden and the Netherlands. However, dependency on the petroleum sector made the Norwegian economy extremely vulnerable to shocks in oil and natural prices, which is reflected in immense fluctuations in GS.

An important instrument to spread income from oil rents over time and reduce fluctuations in government budget is the Government Pension Fund Global. Nonetheless, this fund has been criticized to assist unsustainable development since most investments are undertaken in extractive industries.

To ensure sustainable development in the future, Norwegian GS should be stabilized and possibly increased even further. In addition to this, Norway should attempt to balance its economy away from oil dependency and reduce the share of investments in extractive industries in the Government Pension Fund Global.

Future analysis could focus on comparisons of Norwegian GS to additional countries and over extended periods. Of special interest are its Scandinavian neighbors aside of Sweden and other industrialized countries experiencing shocks in NRD.

Bibliography

- Acar, S. (2017). *The curse of natural resources: a developmental analysis in a comparative context*. Springer.
- Andersen, T. M., B. Holmstrom, S. Honkapohja, S. Korkman, H. T. Soderstrom, and J. Vartiainen (2007). *The Nordic Model: Embracing Globalization and Sharing Risks*.
- Arezki, R., P. Loungani, R. Van der Ploeg, and A. J. Venables (2014). Understanding international commodity price fluctuations.
- Arrow, K. J., P. Dasgupta, L. H. Goulder, K. J. Mumford, and K. Oleson (2012). Sustainability and the measurement of wealth. *Environment and development economics* 17(3), 317–353.
- Bang, G. and B. Lahn (2020). From oil as welfare to oil as risk? norwegian petroleum resource governance and climate policy. *Climate Policy* 20(8), 997–1009.
- Becker, S. O. and L. Woessmann (2010). The effect of protestantism on education before the industrialization: Evidence from 1816 prussia. *Economics Letters* 107(2), 224–228.
- Bergeaud, A., G. Cette, and R. Lecat (2020). Long-term productivity database. Available at longtermproductivity.com.
- Biasi, P., S. Ferrini, S. Borghesi, B. Rocchi, and M. Di Matteo (2019). Enriching the Italian Genuine Saving with water and soil depletion: National trends and regional differences. *Ecological Indicators* 107, 1–28.
- Blum, M., C. Ducoing, and E. McLaughlin (2017). A sustainable century? *National wealth: what is missing, why it matters*, 89–113.
- Bolt, K., M. Matete, and M. Clements (2002). Manual for Calculating Adjusted Net Savings. (September), 1–23.
- Bértola, L. and M. Rey (2018). The Montevideo-Oxford Latin American Economic History Database (MOxLAD): Origins, Contents and Sources. *Economic History of Developing Regions* 33(3), 209–224.
- CBS (2021a). Electric cars rise to record 54% market share in norway in 2020. Available at reuters.com.

- CBS (2021b). Statistics netherlands. Available at [cbs.nl](https://www.cbs.nl).
- Clio Infra (2014). Clio infra: Reconstructing global inequality. Available at forestresearch.gov.uk.
- Da Silva, R., I. De Marchi Neto, and S. Silva Seifert (2016). Electricity supply security and the future role of renewable energy sources in Brazil. *Renewable and Sustainable Energy Reviews* 59, 328–341.
- Dietz, S., E. Neumayer, and I. De Soysa (2007). Corruption, the resource curse and genuine saving. *Environment and Development Economics* 12(1), 33–53.
- Ducoing, C., J. Peres-Cajías, M. Badia-Miró, A. K. Bergquist, C. Contreras, K. Ranestad, and S. Torregrosa (2018). Natural resources curse in the long run? Bolivia, Chile and Peru in the Nordic countries' mirror. *Sustainability (Switzerland)* 10(4).
- Eckbo, B. E. (2009). Banking system bailout-scandinavian style. *Cesifo DICE Report* 7(3), 9–12.
- EIA (2021). U.s. energy information administration. Available at [eia.gov](https://www.eia.gov).
- Eitheim, Ø., O. H. Grytten, and J. T. Klovland (2007). Historical Monetary Statistics for Norway - some cross checks of the new data. *NORGES BANK OCCASIONAL PAPERS* 38, 385–434.
- Espeli, H. (2013). Economic Consequences of the German Occupation of Norway, 1940-1945. *Scandinavian Journal of History* 38(4), 502–524.
- FAO (2000). Global forest resources assessment 2000. Available at [fao.org](https://www.fao.org).
- Federal Reserve Bulletin (1919). United states equivalents of london price of silver per ounce. Available at [fraser.stlouisfed.org](https://www.fraser.stlouisfed.org).
- Federico, G. and A. Tena Junguito (2018). Federico-Tena World Trade Historical Database : International Commodity Prices. Available at edatos.consorciomadrono.es.
- Forest Research (2021). Timber Price Indices. Available at clio-infra.eu/.
- Global Carbon Atlas (2021). Co2 emissions. Available at globalcarbonatlas.org.
- Greasley, D., N. Hanley, J. Kunnas, E. McLaughlin, L. Oxley, and P. Warde (2014). Testing genuine savings as a forward-looking indicator of future well-being over the (very) long-run. *Journal of Environmental Economics and Management* 67(2), 171–188.

- Greasley, D., E. McLaughlin, N. Hanley, and L. Oxley (2017). Australia: a land of missed opportunities? *Environment and Development Economics*, 1–25.
- Grytten, O. H. (2004). *The gross domestic product for Norway 1830–2003*, Volume 35. Oslo: Norges Bank.
- Grytten, O. H. (2020). The wealth of a nation: Norway's road to prosperity. *NHH Dept. of Economics Discussion Paper* (17).
- Grytten, O. H., M. Lindmark, and K. Bjørn Minde (2020). The wealth of nations and sustainable development: energy intensity and the environmental Kuznets curve. *Environmental Economics* 11(1), 110–123.
- Gullestad, P., A. Aglen, Å. Bjordal, and G. Blom (2014). Changing attitudes 1970–2012: evolution of the Norwegian management framework to prevent overfishing and to secure long-term sustainability. *Encyclopedia of Environment and Society* 71, 173–182.
- Gütschow, J., L. Jeffery, R. Gieseke, and R. Gebel (2017). The primap-hist national historical emissions time series (1850-2014)(v1. 1, updated february 2017). Available at essd.copernicus.org.
- Hamilton, K. and M. Clemens (1999). Genuine Savings Rates in Developing Countries. *The World Bank Economic Review* 13(2), 333–356.
- Hanley, N., L. Dupuy, and E. McLaughlin (2015). Genuine savings and sustainability. *Journal of Economic Surveys* 29(4), 779–806.
- Hartwick, J. M. (1977). Intergenerational equity and the investing of rents from exhaustible resources. *The American Economic Review* 67(5), 972–974.
- Historisk Statistikk (2021). *SSB - Historical Statistics*.
- Hunnes, J. A. and O. H. Grytten (2021). Public policy, resource rent and ethics: The case of the Norwegian petroleum industry. *NHH Dept. of Economics Discussion Paper* (12).
- IEA (2021). International energy agency. Available at iea.org.
- IMF (2021). Primary commodity price system. Available at data.imf.org.

- Jacks, D. S. (2013). From boom to bust: A typology of real commodity prices in the long run. Technical report, National Bureau of Economic Research.
- Keay, I. (2015). Immunity from the resource curse? the long run impact of commodity price volatility: evidence from Canada, 1900–2005. *Clometrica* 9(3), 333–358.
- Klugman, J., F. Rodríguez, and H. J. Choi (2011). The HDI 2010: New controversies, old critiques. *Journal of Economic Inequality* 9(2), 249–288.
- Lindmark, M. and S. Acar (2013). Sustainability in the making? A historical estimate of Swedish sustainable and unsustainable development 1850-2000. *Ecological Economics* 86, 176–187.
- Lindmark, M. and K. B. Minde (2018). Et energiregnskap for Fastlands-Norge 1835-2012. *Heimen* 55(02), 157–177.
- Lindmark, M., H. Nguyen Thu, and J. Stage (2018). Weak support for weak sustainability: Genuine savings and long-term wellbeing in Sweden, 1850–2000. *Ecological Economics* 145(April 2017), 339–345.
- Maeda, A. (2008). On the oil price-gdp relationship. *Japanese Economy* 35(1), 99–127.
- Mideksa, T. K. (2013). The economic impact of natural resources. *Journal of Environmental Economics and Management* 65(2), 277–289.
- Milne, R. (2021). Norway's oil fund makes first investment in renewable energy. Available at ft.com.
- National Archives (2021). Records of the u.s. bureau of mines. Available at archives.gov.
- National Mining Association (2021). Statistics: Historical gold prices – 1833 to present. Available at nma.org.
- Norges Bank (2013). Statistical yearbook. Available at www.ssb.no/a/histstat/aarbok/.
- Norges Bank (2021). Government pension fund global. Available at nbim.no.
- Norwegian Petroleum (2021). Alt du trenger å vite om norsk petroleumsvirksomhet. Available at norskpetroleum.no.
- OECD (2021). Oecd statistics. Available at stats.oecd.org.

- OFX (2021). Exchange rates. Available at ofx.com.
- Pezzey, J. C. (2004). One-sided sustainability tests with amenities, and changes in technology, trade and population. *Journal of Environmental Economics and Management* 48(1), 613–631.
- Pezzey, J. C., N. Hanley, K. Turner, and D. Tinch (2006). Comparing augmented sustainability measures for scotland: Is there a mismatch? *Ecological Economics* 57(1), 60–74.
- Ploeg, F. (2008). *Why Do Many Resource-rich Countries Have Negative Genuine Saving?: Anticipation of Better Times Or Rapacious Rent Seeking*. Centre for Economic Policy Research.
- Pyzheva, Y. I. (2020). Sustainable development of single-industry towns in siberia and the russian far east: What is the price of regional economic growth?
- Qasim, M. and A. Grimes (2021). Sustainability and wellbeing: The dynamic relationship between subjective wellbeing and sustainability indicators. *Environment and Development Economics*, 1–19.
- Qasim, M., L. Oxley, and E. McLaughlin (2020). Genuine savings as a test of New Zealand weak sustainability. *Environment, Development and Sustainability* 22(1), 89–127.
- Ranestad, K. (2020). Multinational mining companies, employment and knowledge transfer: Chile and norway from ca. 1870 to 1940. *Business History* 62(2), 197–221.
- SCB (2021). Statistics sweden. Available at scb.se.
- Schwach, V. (2013). The sea around Norway: Science, resource management, and environmental concerns, 1860-1970. *Environmental History* 18(1), 101–110.
- Semningsen, I. (1960). Norwegian emigration in the nineteenth century. *Scandinavian Economic History Review* 8(2), 150–160.
- Sollund, R. (2012). Oil production, climate change and species decline: The case of Norway. *Climate change from a criminological perspective*, 135–147.
- Solow, R. M. (1974). Intergenerational equity and exhaustible resources. *The review of economic studies* 41, 29–45.

- Solow, R. M. (1986). On the intergenerational allocation of natural resources. *The Scandinavian Journal of Economics*, 141–149.
- Solstad, K. J. and T. Andrews (2020). From rural to urban to rural to global: 300 years of compulsory schooling in rural Norway. *Journal of Rural Studies* 74, 294–303.
- SSB (1965). *Nasjonalregnskap 1865-1960*. Oslo: Statistisk Sentralbyrå.
- SSB (2021). Official statistics since 1876. Available at ssb.no.
- Stern, N. and J. E. Stiglitz (2021). The social cost of carbon, risk, distribution, market failures: An alternative approach. Technical report, National Bureau of Economic Research.
- Teigen, L. P. (2018). Norway's green delusions. Available at foreignpolicy.com.
- Tooley, J. and P. Dixon (2005). Private education is good for the poor—a study of private schools serving the poor in low-income countries.
- UN (2020). *Human Development Report 2020 -The Next Frontier: Human Development and the Anthropocene, Briefing note for Uganda*.
- Urrutia-Montoya, M., C. E. Posada, A. Pontón, and Ó. G. Martínez-Amaya (2000). Comercio exterior y actividad económica de Colombia en el siglo XX: exportaciones totales y tradicionales. *Borradores de Economía*; No. 163.
- U.S. Geological Survey (2021). U.S. geological survey. Available at usgs.org.
- Van Hulst, F. (2009). Brief history of petroleum exploration in the Netherlands. *Energie Beheer Nederland B.V., Netherlands* (October).
- Weitzman, M. L. (1976). On the welfare significance of national product in a dynamic economy. *The quarterly journal of economics* 90(1), 156–162.
- Wolf, F. and R. Zohlnhöfer (2009). Investing in human capital? the determinants of private education expenditure in 26 OECD countries. *Journal of European Social Policy* 19(3), 230–244.
- World Bank (2021). World development indicators. Available at worldbank.org.

Appendix

Table 3: GS Components

Variable	Year	Reference
NNS	1865-1961	SSB (1965)
	1962-1969	Linear interpolation
	1970-2020	SSB (2021)
Education Expenditure	1863-1992	Historisk Statistikk (2021)
	1993-2012	Norges Bank (2013)
	2013-2014	Linear interpolation
	2015-2018	SSB (2021)
CO_2 emission	1850-1960	Gütschow et al. (2017)
	1960-2019	Global Carbon Atlas (2021)
TFP	1890-2019	Bergeaud et al. (2020)
GDP	1850-2003	Grytten (2004)
	2004-2019	OECD (2021)
Population	1850-2003	Grytten (2004)
	2004-2020	SSB (2021)
GDP deflator	1850-2003	Grytten (2004)
	2004-2019	SSB (2021)
Inflation	1850-2006	Eitrheim et al. (2007)
	2007-2020	SSB (2021)
Exchange rate	1915-2013	Clio Infra (2014)
	1941-1945	Grytten (2004)
	2014-2020	OFX (2021)
Long term interest rate	1852-2003	Eitrheim et al. (2007)

Table 4: Natural resources

	Variable	Year	Reference
Mining Quantities	Natural Gas	1971-2020	Norwegian Petroleum (2021)
	Crude Petroleum	1971-2020	Norwegian Petroleum (2021)
	All	1851-1992	Historisk Statistikk (2021)
		1993-2011	Clio Infra (2014)
2011-2020		SSB (2021)	
Mineral and Energy Prices	Coal	1850-1900	Federico and Tena Junguito (2018)
		1900-1971	National Archives (2021)
		1972-2019	EIA (2021)
	Copper	1850-1900	Federico and Tena Junguito (2018)
		1900-2010	Bértola and Rey (2018)
	Crude Petroleum	1900-2010	Bértola and Rey (2018)
	Gold	1850-1907	National Mining Association (2021)
		1908-2000	Urrutia-Montoya et al. (2000)
		2001-2010	World Bank (2021)
	Iron ore	1850-1900	Federico and Tena Junguito (2018)
		1900-2010	U.S. Geological Survey (2021)
	Lead	1850-1900	Federico and Tena Junguito (2018)
		1900-2010	Bértola and Rey (2018)
	Natural Gas	1922-2010	EIA (2021)
	Silver	1873-1900	Federal Reserve Bulletin (1919)
		1900-2010	Bértola and Rey (2018)
	Tin	1850-1900	Federico and Tena Junguito (2018)
		1900-2010	Bértola and Rey (2018)
Zinc	1850-1900	Federico and Tena Junguito (2018)	
	1900-2010	Bértola and Rey (2018)	
All	2011-2019	IMF (2021)	
Mining Labor costs	Employees mining	1850-1992	Historisk Statistikk (2021)
		1993-2012	Norges Bank (2013)
	Employees oil sector	1972-2018	Norwegian Petroleum (2021)
	Average wage	1850-2006	Eitrheim et al. (2007)
2007-2019		SSB (2021)	
Fishery	Quantity	1866-1990	Historisk Statistikk (2021)
		1990-2018	SSB (2021)
	Fishermen	1866-1874	Linear growth
		1875-1990	Historisk Statistikk (2021)
		1945-2019	SSB (2021)
	Wage	1850-2006	Eitrheim et al. (2007)
2007-2019		SSB (2021)	
Forestry	Woodland Area	1907-1967	Norges Bank (2013)
		2000	FAO (2000)
		2019	SSB (2021)
	Timber price	1850-1900	Federico and Tena Junguito (2018)
		1900-2010	Blum et al. (2017)
		2010-2019	Forest Research (2021)
Forest density		FAO (2000)	

Figure 12: Comparison to World Bank Components, 1970-2018 (Million 2010 USD)

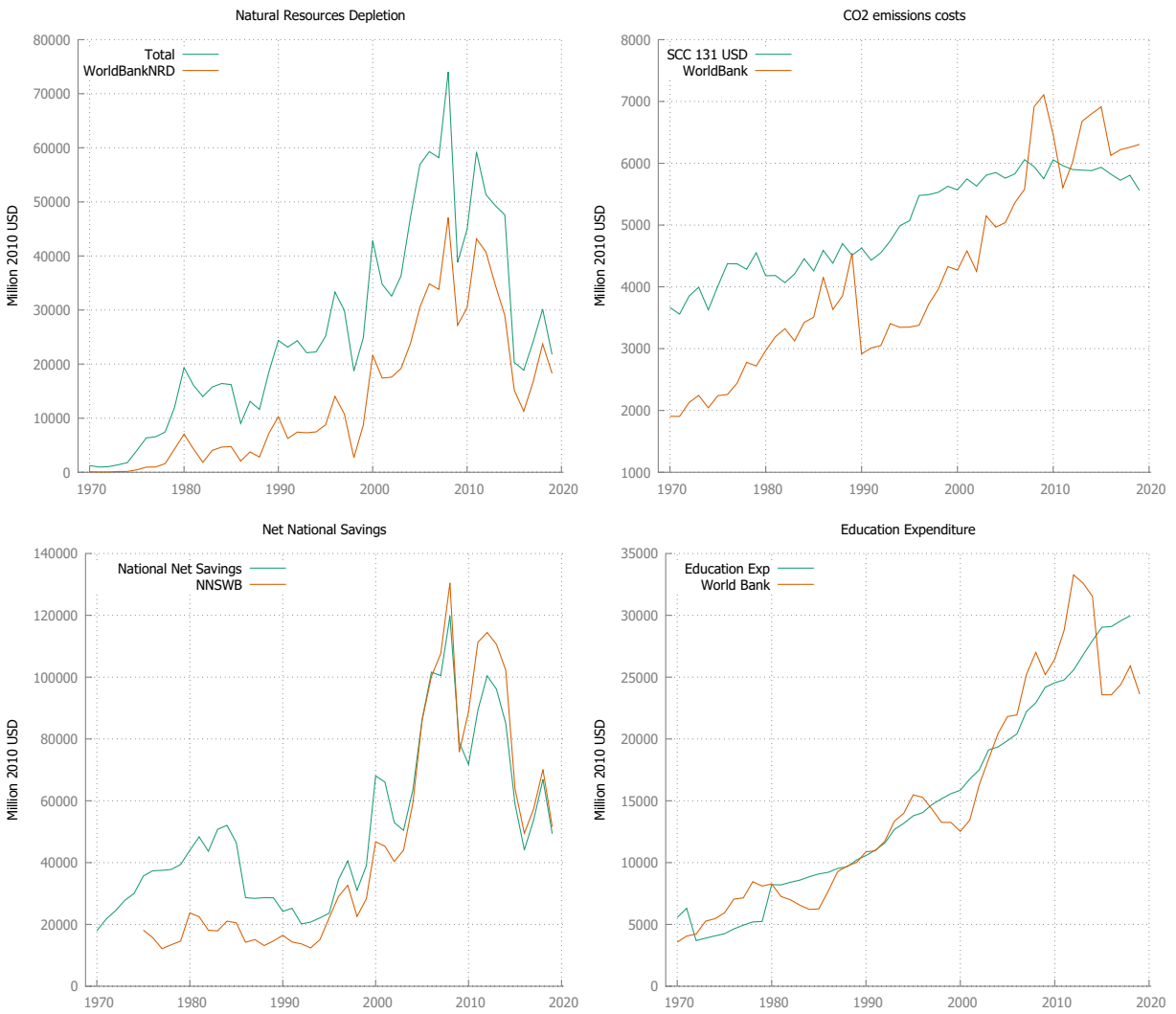


Figure 13: NRD including and excluding Fishery Rents, 1865-2018

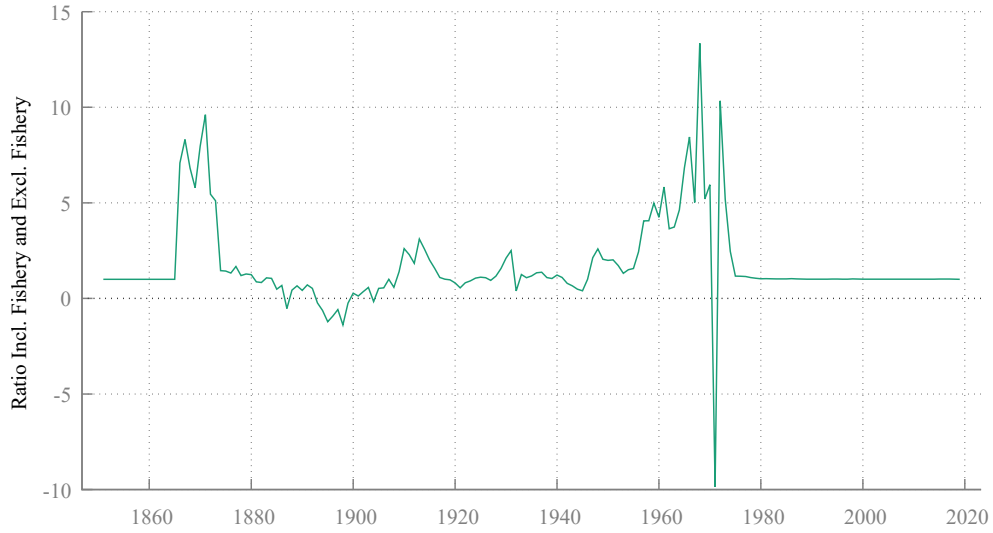
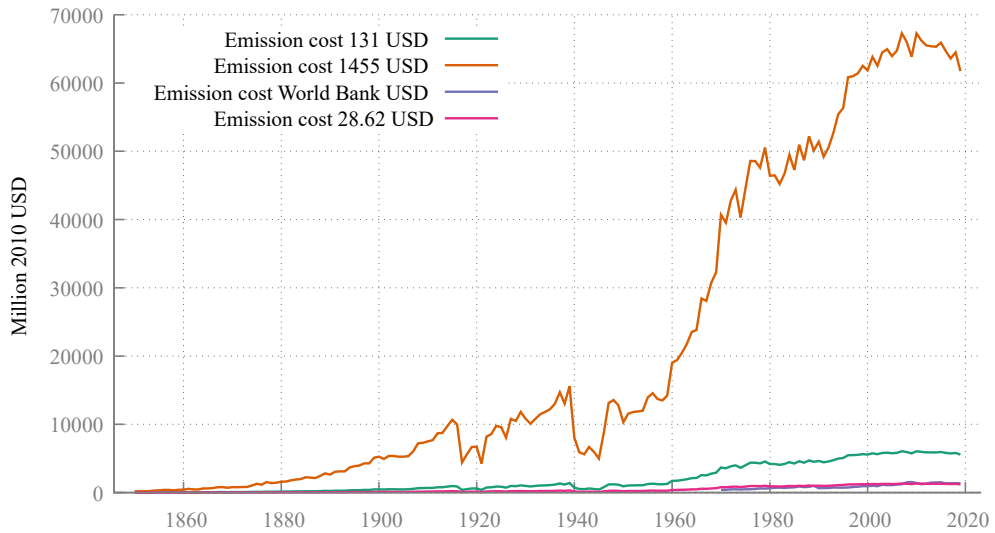


Figure 14: Emission Costs, 1850-2018 (Million 2010 USD)



Aims and Scopes

The Working Paper Series LUSEM Sustainability Research (LSR WPS) brings together research and policy discussions from a range of disciplinary approaches to improve social, environmental and economic sustainability and the reaching of Agenda 2030. The LSR WPS encourages manuscripts combining interdisciplinary perspectives with roots in business administration, economics, economic history, informatics and business law. In the quest of promoting a global sustainable development, the LSR WPS rests on the belief that successful transformations towards more sustainable organizations call for research and policy discussions including novel methodologies and theoretical approaches.

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