



The Perfect Wave

An Estimate of a Norwegian Petroleum Supercycle

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Acknowledgments

When we first started on our thesis, we wanted to work on a subject in the intersection between politics and economics. However, not on a subject that would only trigger the curiosity of a few, particularly interested, but one that would have a wider appeal. We are confident that we succeeded in finding such an up-to-date topic.

We also wanted to keep the form accessible for anyone, that is: so that even our grandparents could understand it. However, as our work has progressed, the latter has become increasingly difficult: The more knowledge we acquired, the more we realized that the broad and interesting subjects are not easily explained. For this, we apologize to our grandparents.

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Abstract

Over the last decades, the relationship between natural resource discoveries on macroeconomic development has been thoroughly debated. The importance of maintaining a sustainable development in mainland industries has made this a topic of interest for both economists and regulators. This master thesis aims to examine and quantitatively assess how the Norwegian economy has been affected by the evolution of its petroleum sector. We also relate our findings to earlier contributions on this topic from both theoretical and empirical literature.

We examine the effect of the petroleum industry on the Norwegian economy by conducting two comparative analyses. First, following a theoretical two-sector model, we compare the impact of booms and busts in oil prices on macroeconomic variables in two resource economies, Norway and Australia, and a non-resource economy, Sweden. Generally, we find that the predicted dynamics can be identified in the resource economies, but that these responses have changed through time. Notably, the introduction of a floating exchange rate has allowed the real effective exchange rate to respond to oil price fluctuations, thus shielding the remaining economy. Other institutional effects, such as the Norwegian fiscal rule, sovereign wealth fund and a well-defined monetary framework might also have contributed to this effect.

Second, we build a counterfactual scenario in which Norway did not discover petroleum. This is done by means of a synthetic control method, creating a synthetic Norway from 1972, using non-petroleum producing OECD countries. We find that Norwegian GDP per capita has been an average of 15.6 % larger than what it would have been in the absence of petroleum resources. Norwegian mainland industries have suffered an average loss in production of 12.4 % of mainland GDP relative to the counterfactual scenario. We hypothesize that the latter is owed to forfeited capital investment and real effective exchange rate effects. Furthermore, we find a petroleum-driven supercycle in the Norwegian GDP per capita, peaking already in 1998, suggesting that the contraction-phase is more mature than previously assumed. Although political priorities in favour of the petroleum industry have been beneficial, the generated revenue streams and returns on investment have crowded out parts of the mainland industries. This has implications for adjustments in the coming years, when the petroleum industry is phased out. We discuss briefly some scenarios for this adjustment process, and conclude.

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1 Introduction

1.1 Motivation and purpose

The extraction of petroleum resources from the depths of the North Sea has positioned Norway as the world's third-largest exporter of oil and natural gas,¹ accounting for 64 % of the country's export value over the last 30 years. The petroleum industry's contribution to national quarterly GDP has averaged roughly 27 % since 1978,² making it the largest component of Norwegian production in the period.

For several decades, economic literature has investigated a possible link between resource discoveries and development in the rest of the economy. Over-investment in a single sector, especially one extracting an exhaustible resource, has been found to have adverse effects on economies.³ This was also believed to be the case with the Netherlands in the decades following their 1959 discovery of natural gas. In 1977, *the Economist* warned that in the absence of a gradual adjustment to the post-gas era, the Dutch might “wake up one morning in the twenty-first century with a monumental hangover” (Kremers, 1986). The term Dutch disease has since been used to cover their subsequent period of painful restructuring.

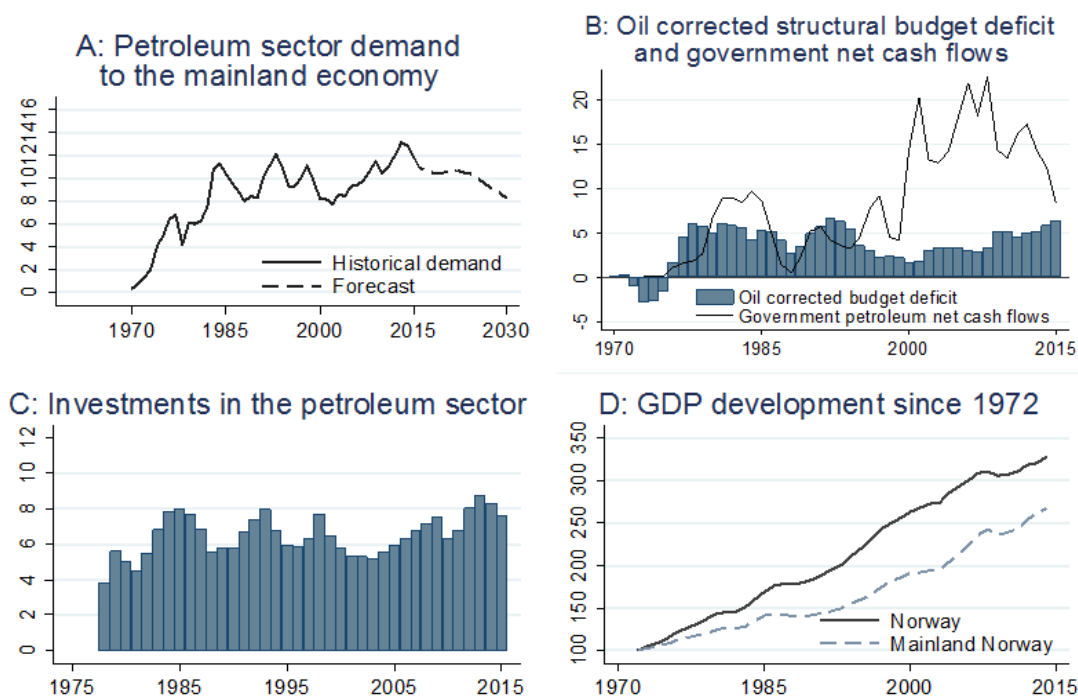
Although Norway had the opportunity to learn from the mistakes of the Dutch, there were still several indicators of Dutch disease symptoms in the Norwegian economy in the 1980s (Gjedrem, 2001). This was alleviated in the following decades, when the gradual accumulation of a sovereign wealth fund (formally known as the Norwegian Pension Fund Global) and a fiscal policy rule smoothed the budget impulse of the petroleum revenues. The sovereign wealth fund has played an important role in making Norway the special case of oil-producing countries, facilitating decades of economic growth and prosperity. Detached from the brutal volatility of oil-money inflows, Norwegian fiscal budgets have still been able to grow under the immense size of the world's largest sovereign wealth fund. But how big of a role has the petroleum sector really played in the economic growth of Norway?

¹ The ranking of oil exporting countries using 2014 data provided by U.S. Energy Information Administration (U.S. Energy Information Administration, 2015). The ranking of gas exporting countries is provided by British Petroleum's Statistical review of world energy (2015).

² The value of oil and natural gas extraction, including services, as share of total GDP is given from the national accounts (Statistics Norway, 2015).

³ See Frederick van der Ploeg (2011) for a thorough review.

**Figure 1: The petroleum industry at a glance:
Macroeconomic indicators, percentages of mainland GDP**



Note: Percentages of mainland GDP.
Source: Ministry of Finance (2015)

Differing views on the dominating effects a resource industry has on the rest of the economy have spurred an ongoing debate about whether the former contributes positively or negatively to the latter.⁴ While oil prices were soaring, these debates were mainly of academic interest. However, in light of the recent fall in oil prices, the issue has resurfaced in the minds of politicians and voters alike. Bringing the topic to the front pages, former Governor of Norges Bank, Svein Gjedrem, voiced concern over increasing public expenditures at the end of three “supercycles”⁵ in the Norwegian economy: Household debt and housing prices, the effect of the petroleum industry, and the budget impulse from the Norwegian Pension Fund Global (Gjedrem, 2015). Perhaps it is Norway that will wake up one morning in the not too distant future, with a monumental hangover.

⁴ See e.g. Corden & Neary, 1982; Neary & van Wijnbergen, 1986, for Dutch disease studies and Torvik, 2001; Garton, 2008; Bjørnland & Thorsrud, 2013, for studies on spillover effects.

⁵ A supercycle in this context is a pro-longed build-up and a following contraction that outlasts regular business cycles.

1.2 Research question

This thesis aims to investigate the following research question:

How big has the impact of the petroleum sector been on economic growth and welfare in Norway, and how may this affect future development? Do we find any evidence of an oil-driven supercycle in the Norwegian economy?

We attempt to address this question by comparing developments in different macroeconomic key variables in Norway to the developments in other countries, and by conducting a counterfactual analysis of Norway without oil.

1.3 Outline

The rest of this paper is structured as follows: In part 2, we account for the most important research conducted on the topic, as a basis for assessing whether our findings support previous work. This part covers Dutch disease-inspired theoretical literature and empirical studies of the effect of petroleum on the Norwegian economy. Part 3 introduces Steigum's two-sector model (The Norwegian Ministry of Finance, 1988), including cost of adjustment in the labour market. Following this model, part 4 seeks to establish an understanding of how the Norwegian economy has developed during oil price booms- and busts by comparing the macroeconomic responses in two resource economies, Norway and Australia, with a similar, non-resource economy, Sweden.

In part 5, we introduce a new method used for comparative studies, the synthetic control method, to examine the effect of the petroleum sector on the Norwegian economy. By applying macro data from similar, non-oil producing countries, we construct an artificial growth path from 1972 to 2015 for a counterfactual Norway without oil – also called the synthetic Norway. Part 6 investigates differences between the counterfactual and real Norwegian GDP, and address whether our findings support an oil-driven supercycle in the Norwegian economy. Using the discrepancies between non-petroleum and real Norwegian GDP, we seek to identify the unobserved petroleum effects on other industries, and comment on the relative performance of a counterfactual Norway during the 1987 bust and the financial crisis of 2008. Further, we discuss what our findings imply for the future development of Norwegian economy, in a period where the petroleum sector is gradually phased out, and present how expansionary monetary policy and labour market measures may affect the economy in a transitional phase. Finally, Part 7 concludes.

2 Literature review

Our focus is essentially related to the macroeconomic effects of extracting and exporting a valuable natural resource. We will devote most of our attention to the string of theoretical literature referred to as Dutch disease-literature, as it is the ruling paradigm for explaining the effects of a booming sector in a small, open economy as the Norwegian.⁶

Regarding empirical literature, we do not make an attempt to review a representative sample of global studies on resource boom effects. Instead, we focus on the extensive research on the effects of the petroleum industry on Norwegian economy conducted by Statistics Norway, the Norwegian Ministry of Finance and Norges Bank, amongst others. We refer to this research as the Norwegian tradition.

2.1 Theoretical literature

For the first part of the 20th century, natural resources were not a topic of particular interest in macroeconomics. Instead, researchers focused on price development and optimal production levels, such as Hotelling's rule for optimal depletion rates (1931). After the OPEC oil price hikes of 1973/1974, production in most Western economies suffered. An oft-cited study by James D. Hamilton showed that most recessions in the United States between 1948 and 1979 had been preceded by a spike in the price of crude oil (Hamilton, 1983). As a consequence, macroeconomists gained a new-found interest in the wider impacts of natural resources.

A theoretical framework of the Dutch disease hypothesis was presented by the Australian economist W. Max Corden and co-authors in a series of papers (Corden & Neary, 1982; Corden, 1984). Within the framework of a small, open economy producing two tradable goods and a single non-tradable good, the sectoral adjustment processes in an economy with a booming sector is explained. This approach has formed the basis for most other studies conducted in the field.

⁶ A related string of literature, referred to as 'resource curse' literature, explores the adverse outcomes in economic welfare for resource rich economies. Early contributions, founded on Dutch-disease theory, proclaimed a negative relationship between resource abundance and economic growth (e.g Sachs & Warner, 1995; 2001). Recent contributions, however, argue that economic and political institutions play a significant role in determining the welfare outcome of resource abundance (e.g. Mehlum, Moene, & Torvik, 2006; Robinson, Torvik, & Verdier, 2006). Although providing additional insight on related topics, such as the importance of a fiscal policy rule, we do not delve deeper into this literature as its focus lies beside that of this thesis. For a comprehensive survey of the resource curse literature, see van der Ploeg (2011).

2.1.1 The core Dutch disease-model

In their 1982 paper, Corden and Neary showed that the effect of a boom in one of the tradable sectors, after an initial adaptation to exploit the booming resource, would be increased demand for, and output of, non-tradeable goods. This is shown, in most cases, to result in an upward pressure on the real exchange rate, causing the tradable sector to contract. These dynamics are determined to originate from two distinct effects, namely the *resource movement effect* and the *spending effect*.

The mechanism of these effects can be illustrated with a resource-extracting economy, assuming no distortions in commodity or factor markets.⁷ A boom in resource prices raises the marginal product of the mobile factors employed in the extracting sector, and so draws resources out of the other two sectors. The higher real income resulting from the boom leads to an increase in demand for all goods. Prices on tradeable goods are determined on the international market, and so the increased demand is met through increased imports.⁸ Prices on non-tradeable goods rise relative to the price of other goods, i.e. causing a real appreciation, and thus lead to further adjustments in the sector composition, drawing resources to the service sector (Corden & Neary, 1982).⁹

As such, the resource movement effect tends to lower the output of services, whereas the spending effect tends to raise it. Manufacturing is unequivocally reduced through the direct de-industrialisation of the resource movement-effect, and indirectly as a consequence of real appreciation. The latter is a consequence both of reduced output in services due to the resource movement effect, and of increased demand for services due to the spending effect. Allowing other input factors than labour to move between sectors, Corden & Neary (1982) show that de-industrialization depends on the relative factor intensity between the three sectors. Attempts to empirically measure Dutch disease phenomena have since provided evidence that non-resource exports are crowded out during resource booms, e.g. Harding & Venables (2013).

⁷ This particular specification of the model holds labour as the only input factor allowed to move between sectors, and has later been referred to as the “core model” (Corden, 1984, Section I). A detailed specification is provided in Corden & Neary (1982).

⁸ Provided there are no trade barriers protecting manufacturers catering to the home market.

⁹ See also Eastwood & Venables (1982), van Wijnbergen (1984) and Neary & van Wijnbergen (1984) for elaborated early contributions in this area.

2.1.2 Rigidities

Studies building on this framework have since introduced rigidities, i.e. sticky wages and prices, using disequilibrium specifications (van Wijnbergen, 1984; Neary & van Wijnbergen, 1986). Under the assumption of fixed short-run labour-supply, it can be shown that a boom may lead to undesired outcomes such as transitional unemployment or repressed inflation,¹⁰ depending on the labour demand elasticities in each sector and the share of tradable goods in the index weights of CPI. As in the *core model*, the spending effect will result in a price increase for non-tradeable goods while tradeable prices, as given by the international market, remain constant. If tradable goods account for a sufficiently large share of the indexation of CPI, product price relative to inflation adjusted wages is expected to fall in the non-tradeable sector, while they will rise in the tradeable sector. This would result in a reduction of employment in the tradable sector while the non-tradeable sector will be willing to absorb all available labour, *ceteris paribus*.

In the presence of price rigidities, excess demand for non-tradeable products and lower real product wages will cause excess demand for labour. This will lead to a state of repressed inflation. Contrary, if the share of non-tradeable goods in the consumption basket is sufficiently high, CPI adjusted wages will keep product wages in the non-tradeable sector at par with the price increase for non-tradeable goods. As the product wage thus remains high (or unchanged), the labour market will not clear, resulting in classical unemployment: there is excess demand for non-tradeable goods due to price rigidities, but not enough labour demanded, in either sectors, at current wages. These conditions were shown to accord well with empirical observations made in oil exporting countries before and after the oil price hikes of 1977/78 (van Wijnbergen, 1984).

2.1.3. Learning by doing and re-entry problems

In the framework of Corden & Neary, a boom will always lead to a welfare gain for the economy, despite reduced output in the manufacturing sector. This follows from the expansion of the economy's production frontier under the assumption of full factor employment. The adjustment process described by Corden & Neary need not, however, lead to economic development along a sustainable path. While both production and consumption will be affected by the boom, re-

¹⁰ Repressed inflation is a recurrent theme in studies of central planning economies. It describes a situation in which inflationary pressures are building in economic variables, but is restrained by rigidities or public intervention (Charlesworth, 1956).

adapting to a post-boom period in which resource wealth is reduced could potentially result in *re-entry issues*. In addition to rigidities reducing welfare gains in the short and medium run, production in the long run might also depend, at least partly, on accumulated experience. If sectors in the economy are subject to such *learning by doing* (LBD) effects, a post-boom reversal of the dynamics predicted in the abovementioned models could result in a version of re-entry problems. With an adverse wealth shock reducing private consumption, sticky prices- and wages will induce a temporarily lower overall production level, amplified, and possibly prolonged, by LBD effects. This has resulted in calls for public intervention, most commonly in the form of industry subsidies to the tradable sector or by imposing trade barriers. Whether or not such interventions are justified is a recurrent theme in macroeconomic policy (i.e. van Wijnbergen, 1984; The Norwegian Ministry of Finance, 2015).

Initially, LBD effects were assumed to be most significant in the manufacturing sector, with apparent implications for Dutch disease-type dynamics.¹¹ However, using a model where LBD and spillover effects were allowed in all sectors, Ragnar Torvik found that “depending on the characteristics of the economy at hand, production and productivity in both the tradable and non-tradable sector can go either way” (Torvik, 2001). This approach has been applied in a recent empirical study, finding that in the case of Norway, productivity gains have been positive in both sectors (Bjørnland & Thorsrud, 2013).

The concern that gains from natural resource booms have strong asymmetrical effects, has since been a topic of discussion. Later studies in this field has moderated the view of Corden and Neary somewhat, introducing the term “two-speed economy” to explain the phenomenon where output and productivity growth rates differs between different sectors of the economy. In the case of Norway, employment in non-tradeable sectors such as construction and business services has increased by 30-40 % over the last decade, while employment in manufacturing has either fallen or stagnated. Regarding the expected future developments of the Norwegian economy, it has been disputed whether or not these effects will be sustainable in the long run (e.g. Garton, 2008; Bjørnland & Thorsrud, 2013). These will be discussed further in part 2.2, when reviewing

¹¹ Several studies explore combinations of Learning by doing with models of Dutch disease. See van Wijnbergen (1984) and Sachs & Warner (1995) for early contributions.

empirical research. Related topics are also labour training costs and other costs related to sectoral adjustment. We will elaborate on these issues in part 3.3.

2.1.4 Implications for policy

In the theoretical literature, the boom-phase dynamics of a resource boom are thoroughly covered. Less attention has been given to what happens when the resource revenue stops and the same dynamics will be put in reverse. In the presence of rigidities, these dynamics can be painful in the short to medium run, and could justify pre-emptive public intervention, such as expansionary fiscal policies in the short run, to smooth the adjustment process.¹² Although resource income is mainly working through the spending effect in Dutch disease theory, the loss of a source of national revenue has consequences for intertemporal consumption as well as sectoral adjustments. Consequently, in the long run, a potential role for public policy could therefore be to facilitate consumption smoothing across time. Examples of such strategies being applied have been seen in both Norway and Australia.¹³ If such a strategy is deployed during the boom-phase of a resource revenue stream, this could help to alleviate the pressures accrued by the spending effect. Further, as well as reducing the build-up in aggregate demand, it provides room for expansionary fiscal policy in future periods. As such, public saving of (parts of) the resource revenue could be seen to have multiple advantages (Corden, 2012; Thøgersen, 2015).

Regarding the resource movement effect, the need for public policy intervention is disputed. In order to extract the booming resource, a resource extracting sector needs to be built or upgraded, which consequently must lead to sectoral adjustments.¹⁴ Further, as revenues from a resource boom enter the economy, real appreciation, in terms of the prices on non-tradeable goods relative to tradeable goods, is inevitable (van Wijnbergen, 1984).

2.2 Empirical research

There has been done extensive empirical research mapping the impact of petroleum activity on the Norwegian macroeconomy. This is done either by creating counterfactual scenarios in

¹² See Steigum and Thøgersen (2003).

¹³ Although consumption smoothing has been a target for both the Norwegian Pension Fund Global and the Australian Future Fund, it certainly is not its only advantage (e.g. Corden, 2012; Thøgersen, 2015).

¹⁴ Cappelen, Offerdal & Strøm (1985) provide a detailed overview of the construction of a petroleum extracting industry in Norway, and its immediate influence on the economy.

complex econometric models, or by isolating effects in time-series data. In the following, we seek to build an understanding of the current research in what we refer to as the *Norwegian tradition*.

2.2.1 MODAG and KVARTS

Over the last 30 years, Statistics Norway have developed KVARTS and MODAG, two macroeconomic models used for extrapolations and policy analysis in the Norwegian economy in the short- and medium term. The models are mainly used by the Ministry of Finance and Statistics Norway. The main difference between the two models is that MODAG uses yearly data, whereas KVARTS uses quarterly data (Boug & Dyvi, 2008).

The models consist of around four thousand equations that explain relationships in the Norwegian economy, primarily based on terminology and defined relationships from the national accounts. MODAG is a disaggregated model differentiating between 45 products and 30 industries and uses input-output connections to place the products on different activities. Furthermore, it uses econometric equations to describe how different actors in the economy tend to behave, based on historical time series from national accounts, economic theory and econometric methods (ibid.).

As KVARTS and MODAG replicate the Norwegian business cycle when given the historic input data, altering input data allows the researchers to create a ‘best-estimate’ for what a counterfactual business cycle would look like in the face of any given change in input factors. The models’ complexity allows researchers to estimate sector specific effects, and also decompose the counterfactual business cycle. It also provides them with the ability to examine to what extent developments within a given industry have amplified the cyclical movements in the period.

The two models have been used in several analyses of the Norwegian economy, as well as in numerous Norwegian official reports. In a 1996 paper, Statistics Norway researchers Cappelen, Choudhury and Eika examine the extent to which the growth rate of the Norwegian economy was affected by the petroleum sector during the period 1973 – 1993. By setting petroleum related, direct effect-variables to zero between 1973 to 1993, keeping all other factors unchanged, and revising down the net external liabilities by the end of 1972 equal to accumulated gross investments in the petroleum sector, they estimate a counterfactual economy without oil. Their findings indicate that the petroleum sector had increased Norwegian GDP by 29 % and reduced

unemployment by 3.2 % in the 20 year period and that 1/3 of the deviations from trend for mainland GDP can be traced back to factor demand shocks in the oil industry. The study also finds that a “Norway without oil” would either have developed quite similarly to the European average, with different industry structures, “*less Dutch Disease, lower consumption and a smaller public sector*”, or it could even have had lower growth than in most European countries (Cappelen, Choudhoury, & Eika, 1996).

Eika, Prestmo & Tveter (2010) disaggregate the demand from the petroleum sector and study the components’ effect on the Norwegian economy using a counterfactual setup with KVARTS. They find that the total resource and input demand of the petroleum sector amounted to 18.5 % and 7 % of mainland GDP in 2009, respectively. Further, they claim a gradual downscaling of the total resource demand from the petroleum sector to 10 % towards 2019 would result in a yearly, negative demand impulse of 0.6-0.85 % of mainland GDP.

Cappelen, Eika and Prestmo (2013), study the vulnerability of the Norwegian economy to changes in oil prices and the petroleum sector. Their method is to create extrapolations of the Norwegian economy until 2040, with a baseline of gradually reduced demand from the petroleum sector to 50 % of 2015 levels by 2040. They also study the impacts of either a supply- or a demand side shock in oil prices, where the negative effects on mainland production are estimated to be 2 and 5 % respectively, with unemployment levels rising between 0.2 and 1.4 %.

In a follow-up study from 2014 elaborating on a supply-side shock, Cappelen, Eika and Prestmo make slight adjustments to the size and dynamics of the oil price decrease from their 2013 study. They compare their previous baseline example with a sharp price drop from 94 to 40 US dollars per barrel, before stabilizing at 60 US dollars. In the baseline scenario, they find that the average growth of mainland GDP will reach 1.2 % per year between 2012 and 2040, compared to 1.9 % during the last 25 years. In the scenario with lower oil prices, average growth in GDP will be 3.6 % lower in 2020 and 2.9 % lower by 2040. They also make predictions as to the real value of governmental net cash flows and unemployment, concluding that even in the scenario with reduced oil prices, the petroleum sector will still contribute significantly to government revenues (Cappelen, Eika, & Prestmo, 2014).

2.2.2 NEMO and SVAR

On deciding monetary policy, Norges Bank uses a combination of macroeconomic models. At the core lies the Norwegian Economy Model (NEMO), a New Keynesian quarterly dynamic stochastic general equilibrium model (DSGE) consisting of a home economy and a foreign economy. The purpose of the model is to estimate how the Norwegian mainland economy will move towards long-term equilibria in response to exogenous shocks and changes in the domestic interest rate. The petroleum sector is exogenous to the mainland economy, while investments in oil production are endogenous (Brubakk et al., 2006).

Isolating effects of petroleum activity on the Norwegian economy can also be done by using structural vector autoregressions (SVAR). The SVAR method uses information from a number of variables that have a high degree of correlation (for example GDP, inflation and unemployment) to estimate variables such as potential output and output gap, or identifying different shocks and their effects on economic indicators.¹⁵

The method consists of decomposing GDP into three components; a deterministic trend, permanent supply-side shocks and temporary demand-side shocks. By using restrictions taken from economic theory on long-term multipliers, different underlying structural shocks can be identified. Since the models often use few constraints on the relationships between variables, they are regarded as data driven with few data-revision issues (Bjørnland, Brubakk, & Jore, 2005).

Bjørnland (1998) uses SVAR to study the impact of an energy boom on manufacturing output in Norway and the United Kingdom. Looking for evidence of Dutch disease symptoms, she identifies demand-, supply- and oil price shocks to the output gap. Her findings indicate that there is little evidence of a Dutch disease in the United Kingdom, and no evidence in Norway – where the manufacturing output actually benefited, at least temporarily, from both an energy boom and higher oil prices. Real oil price shocks are found to be the largest contributor towards changes in manufacturing output.

¹⁵ See for example Bjørnland, Brubakk & Jore (2005) or Bjørnland (1998).

However, it is important to note that the impulse from the British petroleum sector to the remaining economy has been considerably smaller than in Norway.¹⁶ Thus, finding weak evidence of a Dutch disease in the UK would not be surprising. Furthermore, Bjørnland's findings on the Norwegian manufacturing output could be explained by an augmented two-sector model. With a non-tradable and a tradable industry, a persistent oil price shock would increase the activity level in the petroleum sector, and attract resources from the other sectors. Thus, resources would not only move from traditional industry because of higher demand for non-tradable goods, but also because more of the activity in the traditional, tradable industry is now directed towards the petroleum industry. Thus, we also get a structural change within the tradable sector, where the industry has become more "oil-dependent". To this effect, it looks like the traditional industries have benefitted from higher oil prices, when in fact the long-term consequences of a slowdown in the oil sector could be even more severe than first anticipated (Torvik, 2015).

Furthermore, Bjørnland finds that Norwegian prices act in accordance with Dutch disease theory, as energy booms increase prices through increased economic activity. However, with a real oil price shock, domestic prices fall temporarily as the exchange rate appreciates. Bjørnland claims these findings to indicate that the Norwegian economy is vulnerable to any changes in oil prices, because a fall in oil prices will affect mainland industries not only through reduced investment demand from the petroleum sector, but also through tightened fiscal policies with the reduction in government income.¹⁷

Using a similar model, Bjørnland and Thorsrud (2013) study the productivity spillover effects between a booming energy sector and non-oil sectors in Norway using a Bayesian Dynamic Factor Model (BDF), which allows for embedding a SVAR.¹⁸ This set-up allows the researchers to study spillover effects such as resource movement, spending effects and productivity spillovers

¹⁶ Oil and gas extractions accounted for 6 % and 20 % of GDP in UK and Norway respectively in 1993 (Bjørnland H. C., 1998).

¹⁷ The latter has become less important after the introduction of *Handlingsregelen* in 2001, as the budget impulse from the petroleum sector now depends on the size of the real return of Norwegian Pension Fund Global rather than the annual net cash flow (The Norwegian Ministry of Finance, 2015).

¹⁸ For a more detailed explanation, see (Bai & Wang, 2012).

between sectors when examining the impact of independent disturbances in the real oil price, global demand and domestic non-oil activity to the output-gap.

They find substantial spillover effects from the booming energy sector to the non-oil sectors. In particular, the energy sector stimulates investments, employment and wages as well as value added in most tradable and non-tradable sectors, especially in construction, business services and real estate services. They show that an increase in oil activity by 1 % caused by an energy sector boom would increase mainland GDP with 0.4 % and investment in the mainland sector with 0.7 % after 1-2 years. Moreover, energy booms explain around 30 % of the variation in these two variables, 20 % of the variation in mainland wages and less than 10 % of the variation in mainland employment (Bjørnland & Thorsrud, 2013).

Furthermore, they find that the windfall gains due to changes in the real oil price stimulates the economy primarily if the change is caused by global demand disruptions because of reduced cost competitiveness. A price increase in real oil prices caused by increased global demand would have twice as large an effect on mainland GDP and investment compared to an oil specific shock. In addition, gains caused by energy booms are not related to changes in energy prices, but rather the change in distribution of wealth due to spillovers, resource movement and spending effects. A possible explanation could be that oil specific shocks increase production costs, thus reducing the real spending effect. Even though they find no evidence of Dutch disease with a contraction of the manufacturing sector, they find that non-tradable goods grow at a much faster pace than tradable goods, indicating a two-speed economy. In addition, they find evidence for a spending effect in the public sector from increased oil prices, despite of the Norwegian fiscal rule.

As a final remark, they also point out that the contribution from the oil activity on the Norwegian economy has been negative or mildly positive since 2006/2007 indicating a decline in the productivity spillovers lately. This, combined with the recent years' decline in labour input per hours worked, they claim to be a major concern in the long run.¹⁹

¹⁹ Note that the Norwegian cost level has improved compared to our trading partners after the reduction in oil prices, and the depreciation of NOK from 2015.

3 Two-sector model

In order to achieve a more precise and relevant analysis, we examine studies expanding the initial works of Corden and Neary (1982; Corden, 1984). We follow the framework of a two-sector model for an open economy developed by Steigum (1988), comprising rigidities. Thereafter, we expand the analysis by introducing cost of adjustment in the labour market (Steigum, 1984). These models facilitate a detailed explanation of the Norwegian development and will be used to study responses in three economies during oil price booms and busts in part 4.

3.1 Formalizing a two-sector model

In the following section, we present the key relationships of the two-sector model.²⁰

Short-term equilibrium

The model consists of two sectors, j , where sector 1 is defined as the private, non-tradable (N) sector, and sector 2 is defined as the tradable (T) sector, excluding the petroleum industry and ocean transport. The gross product of each sector, Q_j , is given by:²¹

$$Q_j = L_j^{\alpha_j} K_j^{1-\alpha_j} H_j, \quad j = 1,2 \quad (1)$$

where L_j is employment, K_j is the real capital at the beginning of the period and H_j is capacity utilization.²² Employment and real capital are exogenous in the short term, whereas capacity utilization is endogenous and normalized to 1 in the long-term equilibrium. In each period, the sectors select H_j to maximize their profit function $\pi_j = p_j Q_j - w_j(H_j)L_j$ given L_j, K_j , product price p_j , a sales restriction for sector 1, $Q_j \leq Q$, and a quadratic wage equation, $W_j(H_j) \equiv w[b_{0j} + b_{1j}H_j + b_{2j}H_j^2]$. This yields:

$$H_j = \frac{(p_j - p_{sj})\bar{Q}_j - b_{1j}wL_j}{2b_{2j}wL_j}, \quad j = 1,2 \quad (p_{s2} = 0), \quad (2)$$

²⁰ For all formal proofs and supplementary references, we refer to The Norwegian Ministry of Finance (1988).

²¹ We choose to normalize the well-known parameter of technology, A_j , to unity, as it is not necessary for our purposes.

²² Here, H_j is an index of the number of hours worked per employee. As noted in The Norwegian Ministry of Finance (1988), it implies the same capacity utilization for labour and real capital.

where \bar{Q}_j is the gross product at normal capacity utilization. The variable p_{s1} is the difference between the market price and sectoral shadow price, i.e. the short-term marginal cost. This will be positive if the sales restriction is binding, and zero if not.²³

Real, private, disposable income, Y_d , is given by:

$$Y_d = (p_1Q_1 + p_2Q_2 + p_3Q_3 + wL_g + Y^0 - T - reF)/p_c \quad (3)$$

Where Q_3 is the exogenous gross product of the petroleum- and ocean transport sector with the related price index p_3 .²⁴ L_g is exogenous employment in the public sector, Y^0 is the exogenous quantity of the remaining elements of GDP, T is net taxes (equalling, by assumption, public expenditure), r is the exogenous real interest rate on foreign debt and p_c is the consumer price index, defined as

$$p_c = p_1^\mu p_2^{1-\mu}. \quad (4)$$

with μ the constant budget share of non-tradable goods in private consumption.

Private consumption of goods is defined by equations:

$$C_1 = \mu \frac{p_c C}{p_1} \quad (5a)$$

$$C_2 = (1 - \mu) \frac{p_c C}{p_2} \quad (5b)$$

C_2 is private consumption of tradable goods, either produced in the T -sector or imported, and C is a Cobb-Douglas volume index for private consumption. Private consumption is determined through the consumption function:

$$C = \gamma C_{t-1} + (1 - \gamma) Y_d. \quad (0 \leq \gamma \leq 1) \quad (6)$$

²³ The short-term equilibrium may involve an excess supply in the N-sector and/or excess supply in the labour market.

²⁴ Note that after establishing a sovereign wealth fund and fiscal policy rule, petroleum revenues are no longer explicit in Y_d . Instead, the inventory of foreign debt F will, *ceteris paribus*, decrease with p_3Q_3 each period. Over time, this has resulted in a net positive international investment position and a positive contribution to private, disposable income equalling the expected return of the sovereign wealth fund. Spending effects occurring from high salaries accrued in the petroleum sector will result in an increase in Y^0 , while the fiscal policy rule will enable alterations in government budgets equalling a change in net taxes T . Thus, the direct impact of a change in oil price or quantity will be expressed indirectly through ΔF , ΔY^0 and ΔT .

The market price of non-tradable goods is flexible upwards, but sticky downwards,

$$p_1 = \bar{p}_1 + p_{d1}, \quad (7)$$

where \bar{p}_1 is an exogenous price floor in the short-term equilibrium and p_{d1} is the price supplement needed to clear the non-tradable market:

$$Q_1 = G_1 + I_1 + \mu \frac{p_c C}{p_1}. \quad (8)$$

and p_{d1} and p_{s1} are complementary variables so that:

$$P_{d1} \cdot P_{s1} = 0, \quad P_{d1} \geq 0, \quad P_{s1} \geq 0.$$

In (8), G_1 and I_1 are the exogenous public sector- and investment demand from the non-tradable sector. The allocation of exogenous demand from the T - and N -sector is determined through constant budget shares.

The other two prices of goods are determined by $p_2 = ep_2^*$ and $p_3 = ep_3^*$, where p_2^* and p_3^* are exogenously given prices on the world market, denoted in foreign currency. In addition, the wage level, w , is also exogenous in the short run. Demand for employment in the two sectors is determined through a gradual adjustment towards a long-term employment goal, L^* , in each sector.²⁵

The growth in total workforce (ΔL_j) is

$$\Delta L_j = \lambda_j (L_j^* - L_j) \quad (0 < \lambda < 1), \quad j = 1, 2 \quad (9)$$

where L_j is decided from a long-term maximization of sector profit with respect to employment L_j^* and capacity utilization H_j^* . The latter, given by a restriction of $L_j^* \leq L_j$ on the access to labour, an expected sales restriction and the exogenous capital stock, K_j . This yields

$$H_j^* = \frac{(1-\alpha_j) [(1-\alpha_j)^2 b_{1j}^2 + 4b_{0j}^f (2\alpha_j - 1) b_{2j}]^{\frac{1}{2}}}{2(2\alpha_j - 1) b_{2j}} \quad (10)$$

²⁵ The cost conditions causing this movement do not explicitly appear in the model.

$$L_j^* = K_j \left[\frac{R_j^f}{\alpha_j H_j^*} [b_{0j}^f + b_{1j} H_j^* + b_{2j} H_j^{*2}] \right]^{-\left[\frac{1}{1-\alpha_j}\right]}. \quad (11)$$

R_1^f and b_{0j}^f denotes the long-run expectation of the N -sector's real product wage, $\frac{w}{p_1 - p_{1s}}$, and $(b_{0j} + b_d)$ respectively, while R_2^f is expected real product wages in the tradable sector. Expectations are formed adaptively. If the sector does not expect sales restrictions or scarce labour access, L_j^* and H_j^* is decided from regular marginal conditions. An expectation of a sales restriction ($p_{s1} > 0$) leads to a lower L_j^* than usual, but does not affect H_j^* . Scarcity of labour is accounted for by b_d , representing a shadow supplement in the part of the wage that is independent of capacity utilization H . $b_d > 0$ induces a substitution effect so that H_j^* increases and L_j^* decreases, making the rationing mechanism efficient. With a short-term scarcity of labour, b_{0j}^f will increase, causing a reduction of L_1^* and L_2^* . In the short-term equilibrium, b_d equals the value that make the demand and supply of labour cancel out. Thus, b_d is complementary with the unemployment rate (U) beyond a certain minimum unemployment rate, in other words:

$$b_d \cdot U = 0, \quad b_d \geq 0, \quad U \geq 0. \quad (12)$$

U is the difference between supply and demand of labour, so that

$$U = (1 - \bar{u})\bar{L} - (L_1 + \Delta L_1) - (L_2 + \Delta L_2) - L_3 - L_g. \quad (13)$$

For all our examples, $U > 0$ and $b_d = 0$. \bar{L} is the exogenous labour supply, \bar{u} is the minimum unemployment rate at which labour scarcity occurs, L_3 and L_g is the exogenous employment in the petroleum- and the public sector respectively. In this model, the petroleum- and public sector choose their employment shares exogenously, before the labour market clears.

The current account deficit, measured in foreign currency, equals the increase in real external debt.

$$\Delta F = p_2^*(C_2 + I_2 + G_2 - Q_2) - p_3^*Q_3 + rF. \quad (14)$$

For simplicity, the gross product of sector 3 is defined as net exports. How public expenditures are financed, determines how the debt increase is distributed between private and public

sectors.²⁶ These equations, as well as the expectation equations, define the short-term equilibrium.

Medium term dynamics

The model dynamics, described through a sequence of short-term equilibria, arises from wage- and price changes over time (w and \bar{p}_1), inventory changes and adaptive expectations. To define the stationary equilibria, Steigum disregards growth in the real capital stock and labour supply, technological advances as well as growth trends in other exogenous variables.

In the former section, the changes in L_1, L_2 and F were described. The expected variables are determined through adaptive processes of the nature:

$$R_j^f = aR_{j,t-1}^f + (1 - a)R_j, \quad (15)$$

where R_j is the real product wage in sector j . Furthermore, the wage dynamics is assumed to follow an expected real wage target, W_T , so that

$$w_{t+1} = W_{T+1}p_c^f. \quad (16)$$

In the end of each period, t , W_{T+1} , and then w_{t+1} is set for the next period. The latter is determined by the expected consumer price index (CPI), p_c^f , for period $t + 1$. Furthermore, the CPI is determined by P_1^f and P_2^f that, in turn, depend on the adaptive inflation expectations and the expectations for future devaluations.²⁷ Equation (16) implies that if inflation becomes higher than expected, the realised real wage in period $t + 1$ is lower than W_{T+1} . However, this will be adjusted in the next wage negotiations.

²⁶ Steigum also base the model simulations on the assumption of taxes being equal to public expenditures. This implies that all external debt/liabilities are accumulated in the private sector.

²⁷ The equivalent in a floating exchange rate regime would be expectations of future changes to the exchange rate. In this case, we would both have the effect of real appreciation of currency as well as the central bank potentially raising the interest rate in an attempt to dampen inflationary pressure in the economy, indirectly affecting the relative changes in price-to wage ratios between the two sectors. How these effects would play out in the model are unclear, as the relative changes in prices would depend – among other things – on how a change in interest rates affects the long-run productivity in each sector and thus the Harrod-Balassa-Samuelson effect (e.g. Lothian & Taylor, 2008). In the following, we assume that the effect of a floating exchange rate regime would not significantly change the model predictions of Steigum (1988).

We assume that the development of W_T depends on the conditions in the labour market, measured by the unemployment rate u and b_d , where $u = U/L$.

$$W_{T+1} = [1 - c_1(u - u^*) + c_2 b_d] W_T \quad (17)$$

Here, u^* is the unemployment rate that stabilizes the development of real wages over time, consistent with the stationary equilibrium.²⁸

Regarding domestic price development, it is assumed that the price floor \bar{p}_1 is affected by expected domestic inflation, p^f , as well as the degree of demand pressure or excess supply in the market for non-tradable goods. The latter, measured by both p_{d1} and p_{s1} .

$$\bar{p}_{1,t+1} = (1 + p_1^f)[\bar{p}_1 - v_s p_{s1} + v_d p_{d1}], \quad (v_s > 0, v_d > 0) \quad (18)$$

Also here, alternative specifications could be plausible.²⁹ This model emphasizes that the equations are compatible with a stationary equilibrium or with permanent inflation, and that pressures and slacks in the respective markets have an impact on wage- and price development.

Stationary equilibrium

For each level of foreign debt, there exist a stationary equilibrium where, $u = u^*$, $p_{s1} = p_{d1} = 0$, $H_j^* = 1$, $\Delta L_j = 0$ and $\Delta F = 0$. This stationary equilibrium can be summarized in the following three equations, in three unknowns p_1 , L_1 and $y(= p_c C)$. Here, $p_2 = 1$, making p_1 the relative price of non-tradable goods.

$$p_1 \alpha_1 D_1 L_1^{\alpha_1 - 1} = \alpha_2 D_2 (L^0 - L_1)^{\alpha_2 - 1} \quad (19)$$

$$-\frac{\mu y}{p_1} + D_1 L_1^{\alpha_1} = +I_1 + G_1 \quad (20)$$

$$-(1 - \mu)y + D_2 (L^0 - L_1)^{\alpha_2} + p_3 Q_3 - rF - I_2 - G_2 = 0. \quad (21)$$

²⁸ As Steigum points out, this wage determination model is only one of many plausible alternatives. A perhaps preferable alternative when studying the Norwegian economy, could be the “main-course theory”, according to Aukrust (1977), following the Norwegian “frontfagsmodellen”.

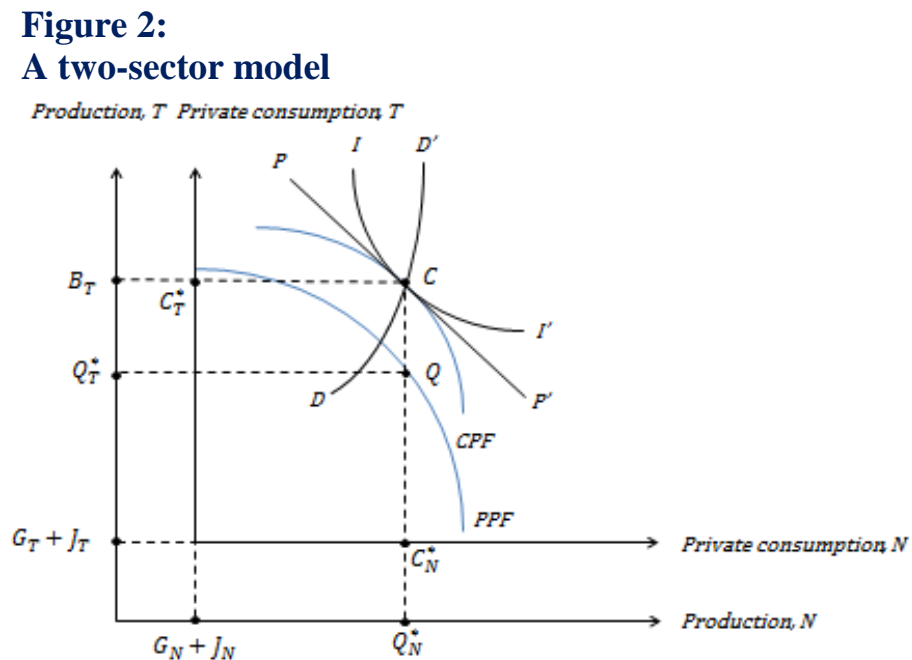
²⁹ As for example monopolistic competition

Where $D_j = K_j^{1-\alpha_j}$, ($j = 1,2$) and $L^0 = (1 - u^*)\bar{L} - L_3 - L_g$. Equation (19) expresses that the value of the marginal product of labour is the same across all sectors and equation (20) defines the market equilibrium in the non-tradable sector. The last equation requires long-term balance in the current account, given a constant foreign debt, F .

3.2 Movements towards stationary equilibria

Following the two-sector model formalized above, we will discuss movements towards new stationary equilibria caused by shocks in the petroleum wealth, defined as the net present value of the petroleum income. This shock is caused by either a fall or an increase in oil prices or oil quantity and would immediately transmit itself to the permanent income from the petroleum industry. Hereby denoting a negative shock as an adverse wealth shock and a positive shock as a favourable wealth shock, we will study the implications of these shocks by using the graphical model illustration from The Norwegian Ministry of Finance (1988).

In a stationary equilibrium, factor inputs and production in both sectors are efficient. The unemployment rate has reached a level consistent with a stable development in real wages over time, and the current account is in balance. For each level of foreign debt there exists such a steady state. In *Figure 2*, we illustrate this kind of stationary equilibrium. The outer axis system



measures the production of tradable (T) goods- and non-tradable (N) goods, while the inner system illustrates private consumption of these goods. The Production Possibility Frontier (PPF) demonstrates production at normal capacity utilization in both sectors. Labour availability for the two sectors is determined by the location of the PPF , as it illustrates the difference between total labour supply and employment in the public (G) and petroleum sector (J) as well as the natural unemployment rate. Thus, the lower the employment in the public sector and the lower the natural rate of unemployment, the further out lays the PPF . An increase in public employment would shift the PPF inwards, as there is less left for private consumption. In the short term, the unemployment rate is fixed, but companies can adjust the amount of hours worked.

To illustrate the Consumption Possibility Frontier (CPF), the permanent petroleum income minus real interest costs is added on top of the PPF . The consumption point C , is a stationary market equilibrium with a balanced current account. At this point, imports' share of demand is equal to the vertical distance between C and Q . The relative prices of N and T -goods is equal to the slope of the tangent line PP' through C , and the equilibrium wage level in the two sectors is equivalent to the sectoral marginal products in Q . Depending on the long-term size of the foreign exchange income, the DD' curve illustrates all possible stationary consumption bundles. Thus, it accounts for relative price alterations between N and T -goods. The II' -curve is the indifference curve for all private consumers, representing their preferences with respect to consumption of T -and N -goods.

Given no change in real investments and real public consumption, private consumption will increase with a favourable wealth shock, either from higher oil prices or through increased production from new energy resource discoveries.³⁰ As private disposable income increases, the CPF moves out. When demand increases for all goods and services, the price of N -goods rises in order to clear the market, thus steepening the slope of the PP' -line. Because of the oil price

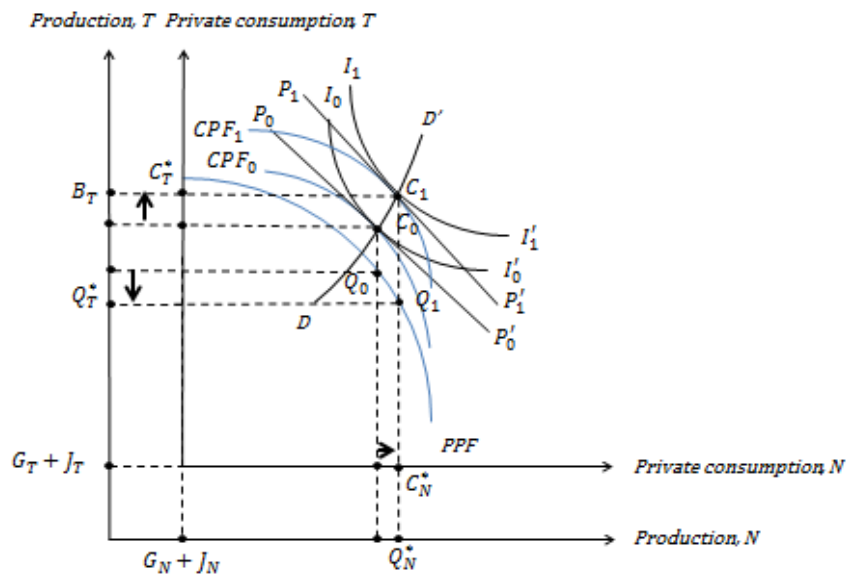
³⁰ As the petroleum sector is assumed to be capital intensive, we disregard the fact that a new resource discovery could demand additional employment from other sectors, moving the PPF inwards. The opposite would, however, be an important factor when the petroleum sector is downscaled, and eventually, phased out.

increase and the fact that the price for domestic goods increases more than those of foreign goods, we experience an appreciation in the real effective exchange rate (REER).³¹

Moving north-east on the DD' -curve and south-east on the PPF , we now produce more in the non-tradable sector, and less in the tradable sector as the marginal product of labour has increased in the former. The increased demand for T -goods combined with reduced production in the tradable sector results in an increase of imports. Any changes in the trade balance will depend on the relative size of the increase in petroleum revenues relative to the value increase of imports.

As domestic prices have increased, wages are also adjusted in the medium run, increasing relative to prices in the T -sector. With a falling marginal product of labour in the T -sector, labour is relatively more profitable in the N -sector, causing a reduction of employment in the former in favour of the latter. However, the sign of the real wage adjustment depends on several structural features in the economy. As in The Norwegian Ministry of Finance (1988), we assume that the non-tradable sector is more labour intensive than the tradable sector in Norway. Thus, we expect

**Figure 3:
Oil price hike**



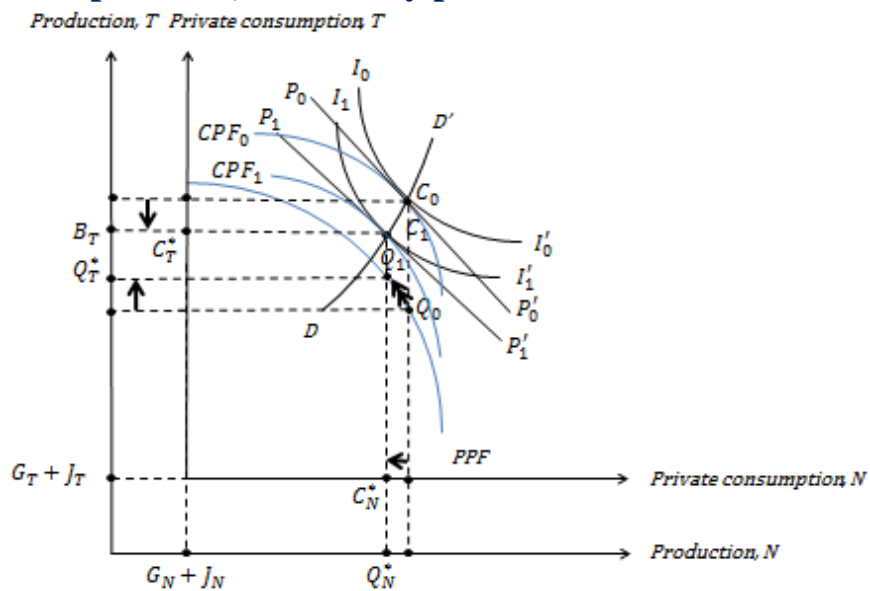
³¹ REER is a measure of the relative price of domestic tradeable goods in terms of foreign tradeable goods. See appendix A.1 for a further introduction to this measure.

the real wage to be positively related to a favourable wealth shock.³² This implies an increase in the real wage equilibrium of the labour market, still consistent with full employment and balance in the current account.

If a favourable wealth shock should increase public (or energy sector) employment, this would push the *PPF* inwards and thus reduce private consumption. The reduction in labour supply would have the largest effect in the labour intensive non-tradable sector making the relative price of *N*-goods to increase. As labour is scarce, real wages increase.

With an adverse shock in the petroleum wealth,³³ private disposable income falls, causing an inwards shift of the *CPF*, reducing private demand for all goods. Given a significantly large adverse wealth shock, the price of non-tradable goods falls to its price floor, or not at all if the initial price equals the price floor. In either case, the price would not decrease enough to clear the market, and the non-tradable sector produces an excess supply, at least in the short run. In the

Figure 4:
Oil price fall, with sticky prices



³² However, as Steigum (1988) point out, the share of non-tradable goods in the private consumption basket is larger than the share of tradable goods. Nevertheless, as employment in the non-tradable sector is more than three times the size of employment in the tradable sector, we assume a positive net relationship between foreign exchange income and real wages.

³³ Again, assuming that the negative shock does not markedly increase the labour supply for the rest of the private economy.

next period, the non-tradeable sector will reduce capacity by reducing the number of hours worked.

As the price of domestic goods fall relative to foreign goods, demand for tradable goods will fall relatively more. Thus, imports decrease while the demand for domestically produced T -goods increases. To clear the market, the tradable sector must increase production. Further, the change in relative prices of domestic and foreign goods causes a depreciation of the REER. Again, any changes in the trade balance will depend on the ability to substitute away from imported goods and the size of the petroleum shock.

Opposite to the favorable wealth shock, the new equilibrium will lay south-west on the DD' -curve. In the medium run, the price floor will be adjusted downwards, so that the market clears. Furthermore, wages are also adjusted. As the marginal product of employment in the T -sector becomes relatively higher than in the N -sector, employment is reduced in the latter and real wages are expected to decrease. Thus, a new stationary equilibrium is reached, although after somewhat more time due to sticky prices.

3.3 Cost of adjustment

Another way to explain the effect of rigidities in the economy is through Steigum's (1984) description of the cost of adjustment. He postulates that new workers entering a high-productivity industry will require some sort of training from skilled workers in order to acquire the expertise necessary to become productive. Thus, a training cost will follow structural changes in the economy, including the cost of training new workers as well as the cost of temporarily withdrawing skilled labour from production. This additional adjustment cost causes the transformational process to be more gradual and time-consuming. In addition, there will be an interval of stationary equilibria where the marginal training cost exceeds the productivity gains of an additional unit of labour, creating a state of hysteresis (Steigum, 1984).³⁴

Steigum's model implies that we would not only observe frictional unemployment as the process of moving to a new job takes time, but also structural unemployment, caused by a mismatch between supply and demand for labour in different sectors as new employment requires training,

³⁴ These issues are also studied by Kemp and Wan (1974).

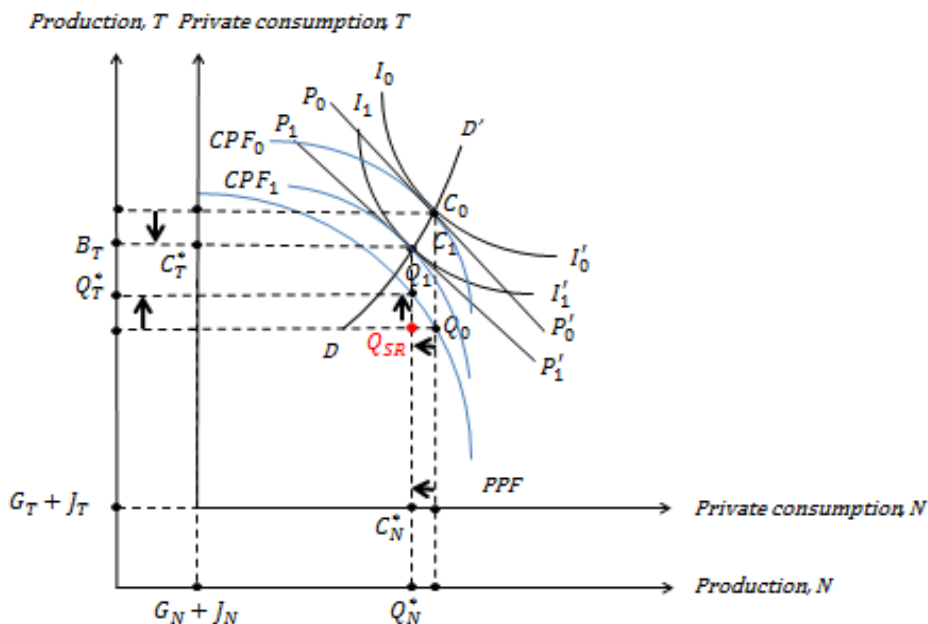
and because of price- and wage rigidities. Considering two types of knowledge, firm-specific and industry specific,³⁵ there would also be two types of structural unemployment caused by the training cost, depending on the type of knowledge required for training. With firm-specific knowledge, the firms have incentives to pay for the training, as this would increase labour productivity. In this case, structural unemployment arises when the marginal cost of training is larger than the productivity gains from employment, leading to insufficient structural change. With industry specific knowledge, each firm has less incentive to pay for the training as the employee can apply this knowledge at competing companies. In this case, unemployment could also arise from parts of the labour force spending time in retraining institutions not organised by the companies, or if the training cost for each individual is sufficiently high for them to prefer waiting for better times in their initial industry.

Adding this to the framework of Steigum (1988) for an adverse wealth shock, we would expect a slow-down of the transformational process described above, resulting in a prolonged period of reduced production. In *Figure 5*, the reduced employment in the non-tradable sector is showed as a leftward shift along the old production level of the manufacturing sector. Training costs will lead to increased structural unemployment, with the new medium term production level located inside the *PPF* (denoted Q_{SR}). This illustrates a loss in production capacity for both sectors, and reduced wealth compared to the potential production level.

Vice versa, the structural process of moving labour from the tradable sector to the non-tradable sector would also increase structural unemployment, keeping production inside *PPF* for some time. However, as the non-tradable sector is dominated by services, it is often not regarded as a high-productivity sector (as opposed to the tradable sector). Thus, the expected effects of possible training costs would be relatively lower during oil price booms than in busts.

³⁵ See Becker (1993).

Figure 5:
Oil price fall, with sticky prices and cost of adjustment



3.4 Key takeaways

Using this model as a framework, we will compare real variable changes with the model's anticipated effects following favourable- and adverse wealth shocks.³⁶ During oil price booms, we will expect a general wealth increase through a higher growth rate of real GDP and a positive output gap. Furthermore, we expect an appreciation of REER as non-tradeable prices rises, and increased imports as foreign tradeable goods become relatively less expensive. In terms of sectoral employment, we use manufacturing employment as a proxy for the tradable sector and different service sectors as a proxy for the non-tradeable sector. Here, we expect to observe reduced growth in manufacturing employment and the opposite for service sectors, combined with rising real wages. However, these transitions are expected to take some time and may lead to a period of lower productivity or temporarily higher unemployment.³⁷

³⁶ However, note that the model assumes no change in real investments and real government consumption. As these indicators fluctuate in our sample, we must include their effect when analyzing the developments of different key indicators.

³⁷ Although, as noted earlier, we expect a larger increase in unemployment during oil price busts than in booms.

When studying adverse wealth shocks through oil price busts, we expect to see a general reduction in wealth through reduced growth rates of real GDP and widening the output gap. As the price of domestic goods falls relative to foreign goods, REER is assumed to depreciate, followed by a reduction in imports and fall in value of the petroleum exports. If the oil driven bust period lasts for some time, we expect to observe a reduction in employment in service sectors and increased employment in the manufacturing sector. Furthermore, we expect the real wage growth to stagnate or decrease. Because of adjustment costs, we also expect an increase in the unemployment rate in the short to medium run, until the transformational phase is complete, and we again reach a new stationary equilibrium.

4 Comparative analysis

The last 40 years have seen some of the largest commodity price fluctuations in history.³⁸ Fortunate timing has allowed Norway to profit from the booms in petroleum prices, while other economies have suffered. As postulated by Steigum's (1988) model, these booms (and busts) are expected to have real implications for the allocation of resources between sectors in the economy. In addition to studying the Norwegian economy, we choose to study the development in Sweden and Australia. The former is a Scandinavian, stable democracy similar to Norway along many economic and institutional dimensions, making it a natural benchmark for our attempt to disentangle effects from the petroleum industry. The latter has experienced a resource boom in its mining industry that is of a comparable nature to the oil price boom, and is thus expected to show some of the same developments as the Norwegian economy. By comparing the responses and adjustments in these economies, we hope to identify the most important oil-driven developments in Norway. That is: we need to understand the build-up during the oil price boom in order to make predictions about its reversal. After an initial presentation of the growth rates of our three comparison economies, we will compare the underlying macro variables during periods of commodity price booms and busts with changes proposed in Steigum's model.

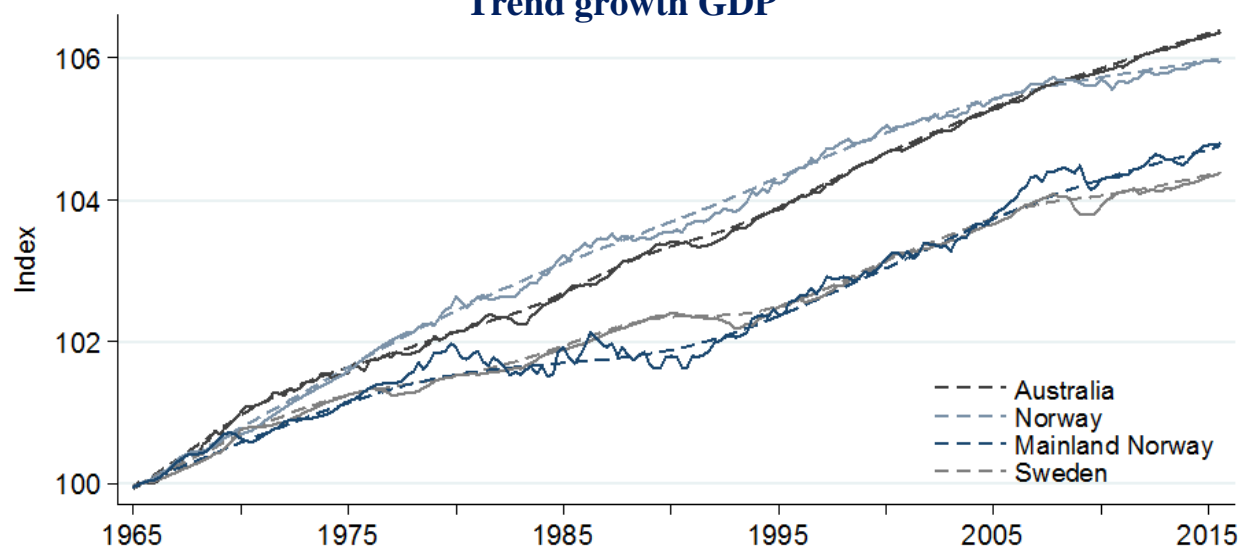
4.1 Overall economic development

Studying the general economic development in Norway, Australia and Sweden the last fifty years, they seem to be developing along two different paths. The resource driven economies of Australia and Norway have an overall higher yearly GDP trend growth rate (as calculated by means of the HP-filter) throughout the period, compared to that of Sweden and mainland Norway.³⁹ From the 1980s until 2006, we find an increasing difference in the pace of the trend growth of the total Norwegian- and Australian economy, compared to the trend growth of mainland Norway and Sweden. However, in the last ten years of the sample, there are signs of convergence.

³⁸ See Cuddington and Jerret (2008) for a review.

³⁹ Following Statistics Norway, the term "mainland Norway" covers the Norwegian economy minus offshore industries, defined as petroleum activity and ocean transport.

**Figure 6:
Trend growth GDP**



Note: Seasonally adjusted data. Logs of GDP. Index 1965 avg. = 100
Sources: National accounts and OECD.

Similar across all four time series, is a high trend growth in the post-World War II economic expansion. During the 1970's, the yearly average trend growth of both the Swedish and the Australian economy decreased by a percentage point, while the Norwegian total economy sustained its growth rate from the previous decade, consistent with the build-up period in the petroleum sector.⁴⁰ The economic turbulence of the 1980s caused divergent growth paths and the detachment of the Norwegian total economy to the mainland economy is especially visible. In this period, the Scandinavian banking crisis is a visible factor in both mainland Norway and Sweden. However, a high oil price and an expanding petroleum sector induced a positive impact on the total Norwegian economy, trend growth rate averaging 2 percentage points higher than that of the mainland economy between 1980 and 1992. From 1992 the difference in trend growth between the total and mainland economy gradually decreased, and since 1997, trend growth of the mainland economy has been higher than that of the total economy.

Over the entire period, the Swedish and Norwegian mainland economies have seemingly been exposed to the same shocks – the Norwegian discovery of petroleum being an exception. Apart

⁴⁰ It is common to divide Norwegian petroleum history into three periods; a search and exploration period from 1963/1964 until 1970, a build-up period from 1971-1980 and a production and development period starting in 1981 (see e.g. Bjerkholt et al. 1985; 1990).

from occasional periods of higher growth, a general observation is that it is not until the post financial crisis-era of 2009-2015 that the average yearly growth rate of mainland Norway catches up with the Swedish. In that context, the Swedish economy seems to have outperformed mainland Norway overall.

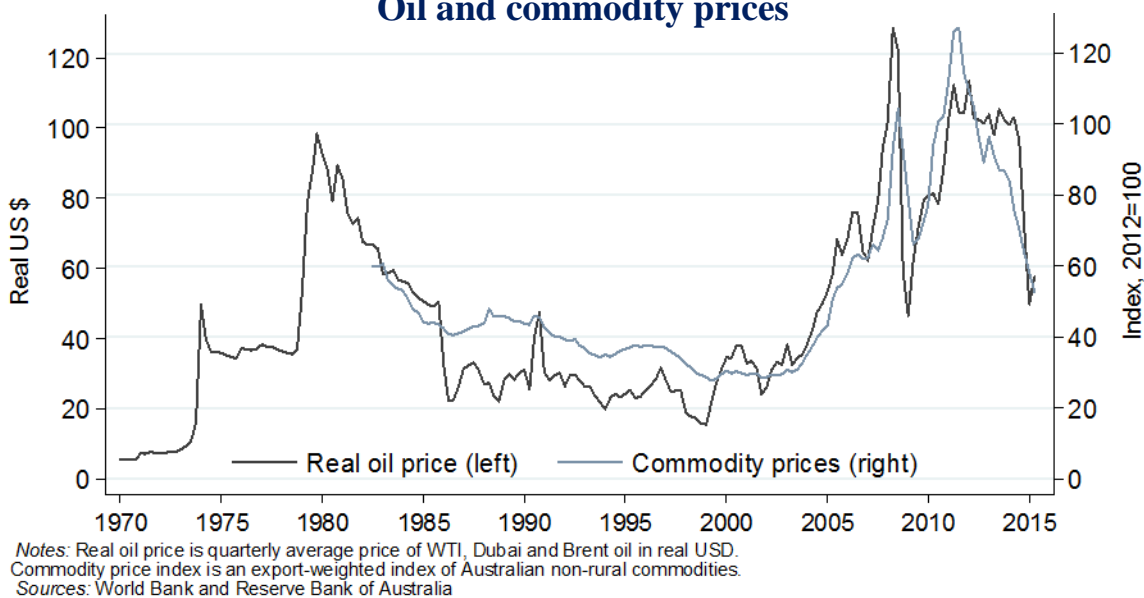
The Australian economy has, similar to Norway, experienced a resource boom over the last 15 years, as output prices of the mining industry have doubled twice since 2001.⁴¹ Both countries have experienced a significant improvement of their terms of trade, and seen a decrease in average unemployment rates over the last ten years. Overall, the Australian economy has had the strongest performance of the three countries. After the financial crisis, we see an indication of a slowdown in the total Norwegian economy compared to the Australian.

4.2 Analysis of different oil price booms- and busts

As Figure 7 illustrates, Norwegian and Australian oil- and commodity prices have fluctuated considerably during the last 15 to 30 years. Using the insights from Steigung's model of rigidities and cost of adjustment (1984; 1988), we will analyse different periods of positive and negative oil- and commodity price shocks, and the responses we observe in key indicators to evaluate the model fit. For the Australian economy, we will study the commodity price boom of 2003 until 2011, as well as the subsequent bust period from 2011. Using Sweden as a natural benchmark, we will examine the macroeconomic impacts of the oil price boom of 1999 until 2008 in the Norwegian economy. Furthermore, we follow the same procedure when studying the oil price drops of 1986 and 1997. The former caused by the OPEC collapse, the latter caused by reduced Asian growth and at-capacity OPEC inventories. Where relevant, we will elaborate on special characteristics in the key indicators. All relevant plots are listed in Appendix A.

⁴¹ Driven by high demand from growing Asian economies, this commodity price boom has been the topic of several Australian studies over the period (e.g. Battellino, 2010; Downes, Hanslow, & Tulip, 2014; Garton, 2008; Plumb, Kent, & Bishop, 2012).

**Figure 7:
Oil and commodity prices**



Unsurprisingly, these periods differ from the stylized states defined in the model, and could thus not be used as proof of the model's predictive accuracy. First, fluctuations in real investments and government consumption interfere with the predicted dynamics as they are exogenous to the model while still affecting the real economy. Second, the medium and long-term dynamics predicted in the model need time to develop. If the economy is exposed to new variable shocks before all effects of the previous shock have fully developed, interpretation will be distorted. One example is the oil price drop of 1997, lasting only to 1999 before being relieved by a positive oil price shock. In addition, it is impossible to identify any causal effects of the energy price changes, as we are unable to observe the true counterfactual scenario. For example, the commodity price boom of 2003 until 2011 spanned over both boom and bust phases of the Australian business cycle. However, a business cycle bust in a commodity price boom would not mean that Steigum's model (1988) does not show relevant dynamics, as the commodity price boom could have dampened the contraction of the business cycle. Thus, we merely hope to learn how different variables seem to have developed during different oil- and commodity price booms and busts, and whether or not these observations are in accordance with the model.

The 1999-2008 oil price boom

Using *Table 1*, we start with the prolonged oil price boom of 1999 to 2008. Because of the length of this period, it seems plausible that the Norwegian economy has seen some of the structural changes postulated by our framework. Furthermore, the effect of possible training costs could also be applicable, although less significant than during oil price busts. During the eight year period from 1999 until 2008, the real price of oil rose with a staggering 600 % from about 16 USD to 122 USD. In this period, Norwegian REER appreciated with 13 % as prices for Norwegian goods were rising in accordance with what the model predicts. This differs from the Swedish economy, where the REER depreciated in accordance with the expected effects of an oil-importing economy.

From 1999 until 2008, Norwegian import volumes increased by 75 %, compared to an export volume increase of 10 %, resulting in a growth in non-oil trade deficit of 46 % – as would be expected from the framework. In the decade following 1999, the oil price boom drove Norway's total export prices to more than double those of imports, relative to 1981 levels. Thus, despite the

Table 1:
Commodity price boom

	Model predictions	Oil boom (1999q1 - 2008q3)				Mining boom (2003q1 - 2011q4)	
		Norway		Sweden		Australia	
		Total	Max Y/Y change	Total	Max Y/Y change	Total	Max Y/Y change
ΔOil/Com price	+	684,0 %	122,0 %			313,2 %	61,8 %
ΔREER	+	12,9 %	10,7 %	-4,6 %	-9,6 %	53,8 %	29,1 %
ΔU (perc. p)	+	-0,24	-1,51	-2,61	-1,83	-0,87	1,50
ΔTrade balance	-	-45,9 %		163,8 %		38,2 %	
ΔGDP	+	37,6 %	8,4 %	34,4 %	6,1 %	29,3 %	5,1 %
Output gap	Start	1,4 %		0,2 %		-0,1 %	
	End	4,7 %		1,5 %		-0,2 %	

Notes: All numbers are change within the specified period in percentages, except unemployment which is the percentage point change. Total change column is percentage change from first to last quarter in the period, max Y/Y growth is the maximum 4 quarter change in the period. Real oil price is quarterly average price of Brent, WTI and Dubai oil-prices in constant US dollars. REER is the trade-weighted real effective exchange rate. Trade balance is export value less import value of non-commodity goods in the economy. GDP is growth in real GDP from national accounts, mainland growth is provided for Norway. Output gap are results from HP-filtering, with $\lambda = 1600$ for Australia and Sweden, $\lambda = 40\ 000$ for Norway.

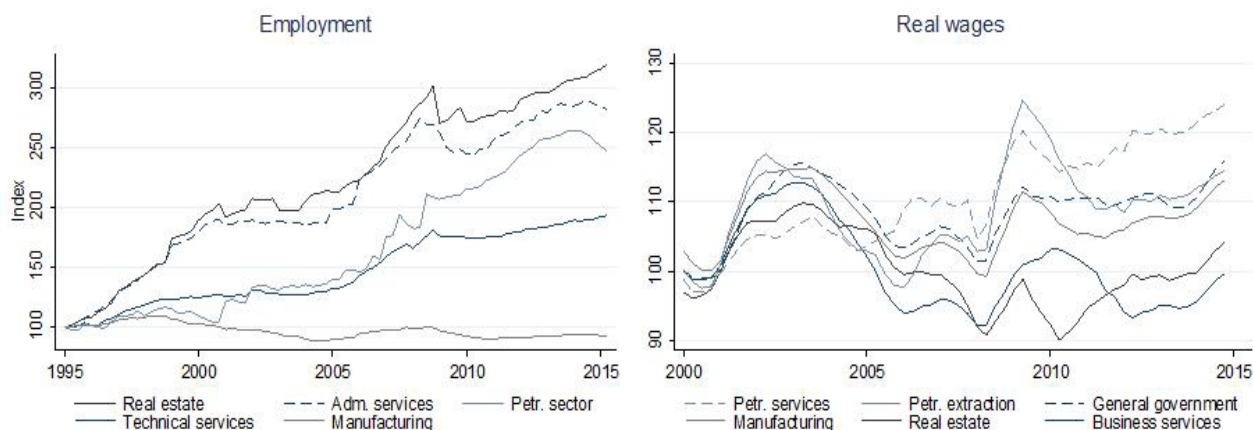
large growth in import volume, Norwegian total trade balance increased with 579 % over the period, compared to the Swedish increase of 191 %.

There also seems to be a positive effect in the main macro variables, with higher year on year growth in GDP in the oil price boom periods, both compared to Swedish growth and Norwegian growth in the oil price bust periods in *Table 1*. Overall, the unemployment rate seems to have decreased through the oil price boom, although both the Swedish and Norwegian unemployment seem to follow the same cycle. Unemployment in both countries increase from 1999 until 2005, before being reduced towards 2008 (in 2005 the unemployment rates were 4 % and 8 % in Norway and Sweden. By 2008 they had fallen to 2 % and 6 %, respectively). Therefore, it seems unlikely that the increase in unemployment through 2005 is caused purely by cost of adjustment from moving labour from the tradable to the non-tradable sector.

This long-lasting oil price boom is also characterised by other features of the general Norwegian economy. First, with the establishment of a sovereign wealth fund in 2001, the direct income effects from petroleum revenues would be expected to be reduced. Second, while the output gap of the mainland economy was negative until 2005, it was followed by a boom period with build-ups of several bubbles in different financial assets, leading up to the financial crisis of 2008. Third, the prolonged period of high oil prices lead to a tremendous growth in oil investments. The latter two factors is expected to impact real GDP, output gap and unemployment, thus making it hard to analyse the oil price increase's effect on unemployment and general wealth.

When it comes to the changes in real wages and sectoral employment, we have studied the development of support services such as business services, technical services, real estate and petroleum related services. Furthermore, we use manufacturing as a proxy for tradable services. Employment in these service sectors increased substantially compared to the manufacturing sector between 1999 and 2008. More interestingly, the largest growing sector has been petroleum related services, whose employment numbers has grown by more than 600 % since 1995. The increased demand for such services also put an upward pressure on real hourly wages, growing by 24 % over the last 15 years, compared to a sector-wide average of 15 %. Since 2000 to 2008, both wages and employment growth was most comprehensive in petroleum related services, supporting the predictions of Steigum's model (1988). As a comparison, the service sectors in Sweden have grown by less than 6 % the last 20 years.

**Figure 8:
Norwegian labour market**



Notes: Employment is log-growth, index 1995q1 = 100. Real hourly wages, 4 quarters moving averages. Rebased, 2001q1 = 100. Petr. sector employment contains both petroleum services and petroleum extraction. Sources: Statistics Norway

As pointed out by Bjørnland and Thorsrud (2013), business related- and real estate services are the sectors that are most influenced by the development in the petroleum sector. The employment patterns reveal that the recent increase in petroleum prices also benefited sectors outside of the industry itself, especially those with a supporting function. In comparison, employment in the manufacturing sector has been at a stand-still, providing some support for a *two-speed economy*-hypothesis. However, employment in the Swedish manufacturing sector shows the same pattern, making it plausible that this development is driven by a general trend rather than the oil price shock.⁴²

Competitiveness of Norwegian export industries

This framework does not explicitly highlight the effect of oil price changes to the Norwegian non-petroleum export industries. Since 2001, when an official inflation target was adopted by Norges Bank, there has been a clear co-movement between the REER and real oil price, causing a real appreciation of the NOK when the price of its main export commodity increases. Although the central bank's inflation targeting has kept inflation in place, the real appreciation enforces the unfavourable position of other export industries in the face of an oil price hike, reducing demand for all other Norwegian exports along with their international competitiveness, *ceteris paribus*.

⁴² An interesting observation is the fact that the real hourly wage growth in Sweden has been higher than the Norwegian in several industries over the last 15 to 20 years. This could however originate from an exceptionally low activity level in the Swedish economy around 1995, the base year of the index. The Swedish unemployment rate and the output gap were 10 % and - 4 % respectively in 1994.

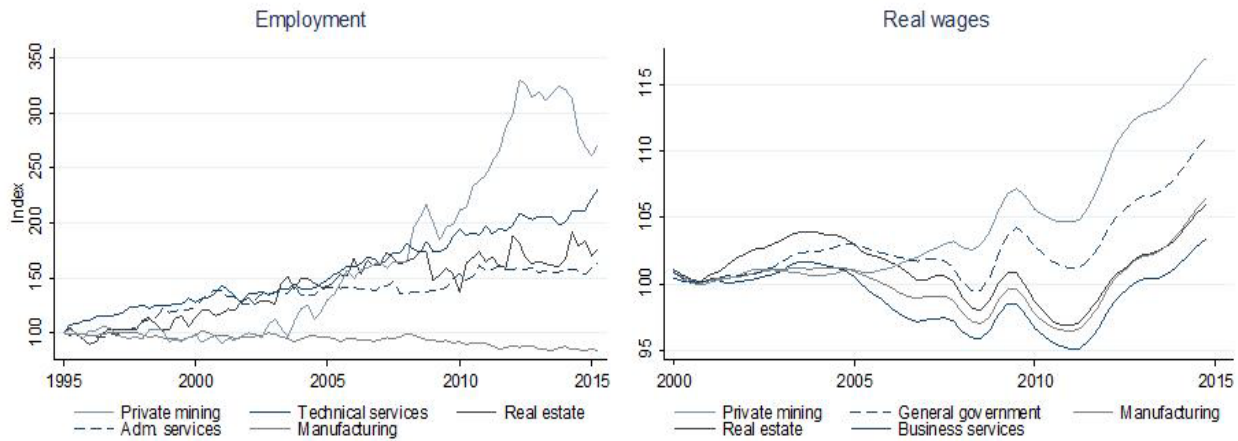
On the contrary, the recent oil price drop has, over the course of a year, reduced REER to the levels of 2000/2001. Reversing the reduction of international competitiveness the non-oil export industries have seen over the last 13 years, this is assumed to affect export industries positively also in the coming years. Similarly, relatively low import prices over the previous decades may also have affected the import share of inputs in Norwegian production, as well as making foreign services preferable to domestic. These structural challenges could thus dampen the positive effects for the export industry from a depreciating Norwegian currency.

The 2003-2011 commodity price boom

Australia experienced a commodity price boom between 2003 and 2011 similar to the Norwegian oil price boom. In this period, Australian commodity prices rose by 313 %, the Australian REER appreciated with 54 % and non-commodity imports grew by 84.7 % – in accordance with the model's prediction. Even though the value of Australian exports increased markedly in this period, and the commodity share of exports increased at an average of 51 % per year between 2000 and 2010, the deficit in the total trade balance persisted. One explanation could be that the volume component of imports outweighs the increased favourable terms of trade owed to high export prices. However, in 2011, the Australian trade balance was positive for the first time as in commodity prices and the volume of mining exports increased significantly.

We also see a slightly higher year-on-year growth in the Australian real GDP compared to the commodity bust period studied later. Consequently, unemployment decreased somewhat through the period, from a level of 6 % in 2003 to 4.2 % in 2008, before increasing again to 5 % by 2011. However, these variables are highly consistent with the movement of the business cycle, obscuring the connection with sectoral adjustments. Furthermore, the mining sector's share of the total Australian economy is considerably lower than the petroleum sector's share of the Norwegian economy, thus applying a much smaller impulse to the Australian economy. Illustrating this, despite an increase in mining investments as a share of GDP from 2 % to 8 % between 2000 and 2013, the impact on business cycle fluctuations have been estimated to be about 2 %. Another factor explaining the latter could be that the increase in the gross product from the mining sector has been more than outweighed by a downscaling of the manufacturing sector (Downes, Hanslow, & Tulip, 2014).

**Figure 9:
Australian labour market**



Notes: Employment is log-growth, index 1995q1 = 100. Real hourly wages, 4 quarters moving averages. Rebased, 2001q1 = 100
Sources: Australian Bureau of Statistics and Macrobond

The Australian labour market shows some of the same tendencies as the Norwegian market. As predicted by the model, employment in business related services and real estate has grown substantially compared to manufacturing, which has seen a slight decrease since 2000. From 2003 to the peak of commodity prices in 2013, mining employment increased by approximately 225 %. Furthermore, it was the fastest growing sector (in terms of employment) as well as the sector with the highest growth in real hourly wages during the commodity price boom from 2003 to 2011. The negative development in the real hourly wage growth of all industries from 2003 to 2011 also seems to indicate that the commodity price boom was not a dominating factor in the overall industry wage setting.

1986-1990 Oil price bust

The price of crude oil rose considerably during the 1970s, tripling in 1973-1974 (OPEC 1) and doubling again in 1979-1980 (OPEC 2), peaking at 98.4 USD per barrel by 1979q4 (Gately, Adelman, & Griffin, 1986). This resulted in a drastic improvement of profitability for the growing Norwegian petroleum industry, with annual government net cash flow rising from 21.8 to 92.8 billion NOK (at 2016 prices) between 1979 and 1984.⁴³ However, in the first half of 1986, the real price of crude oil fell from 50 USD to 20 USD per barrel (2012 prices). Although output levels from the petroleum sector kept growing as new fields were opened, it was not

⁴³ A significant contribution to this increase was through a growing production capacity, with output levels growing by some 70 % in the period (The Norwegian Ministry of Finance, 2015).

sufficient to counteract the falling oil prices, reducing net cash flow by 59.2 % between 1985 and 1986. The impact of the oil price bust on a series of macroeconomic variables is presented in the left-most panel of *Table 2*.

As postulated by Steigum (1988), an adverse wealth shock should, in the short run, lead to reduced demand for all goods, a depreciation of the real effective exchange rate and reduced

Table 2:
Commodity price bust

		Model Predictions	Bust phase (1985q2 - 1990q3)		Bust phase (1997q1 - 1999q1)	
			Total	Max Y/Y change	Total	Max Y/Y change
Norway	ΔOil/Com price	-	-19,7 %	-54,6 %	-45,2 %	-37,4 %
	ΔREER	-	0,4 %	-5,1 %	-7,4 %	-5,3 %
	ΔU (perc. p)	+	1,24	2,28	-1,37	-0,99
	ΔTrade balance	+	51,7 %	-	-69,3 %	-
	ΔGDP		5,2 %	8,6 %	11,5 %	9,9 %
	Output gap					
		Start	3,9 %		-0,1 %	
		End	-1,9 %		1,4 %	
Sweden	ΔOil/Com price	-	-19,7 %	-54,6 %	-45,2 %	-37,4 %
	ΔREER	-	8,4 %	3,4 %	-5,5 %	-8,7 %
	ΔU (perc. p)	+	-1,61	-0,93	-3,55	-2,18
	ΔTrade balance	+	-103,8 %	-	17,8 %	-
	ΔGDP		9,9 %	4,2 %	9,9 %	5,0 %
	Output gap					
		Start	-0,9 %		-1,2 %	
		End	1,2 %		0,2 %	
			Bust phase (2011q4 - 2015q2)			
Australia	ΔOil/Com price	-	-53,9 %	-30,6 %		
	ΔREER	-	-7,9 %	-11,5 %		
	ΔU (perc. p)	+	0,80	0,53		
	ΔTrade balance	+	-110,7 %	-		
	ΔGDP		9,3 %	4,8 %		
	Output gap					
		Start	0,0 %			
		End	-0,3 %			

Notes: All numbers are change within the specified period in percentages, except unemployment which is the percentage point change. Total change column is percentage change from first to last quarter in the period, max Y/Y growth is the maximum 4 quarter change in the period. Real oil price is quarterly average price of Brent, WTI and Dubai oil-prices in constant US dollars. REER is the trade-weighted real effective exchange rate. Trade balance is export value less import value of non-commodity goods in the economy. GDP is growth in real GDP from national accounts, mainland growth is provided for Norway. Output gap are results from HP-filtering, with $\lambda = 1600$ for Australia and Sweden, $\lambda = 40\ 000$ for Norway.

imports. The latter effect is clearly visible in our data: between 1985q2 and 1990q3, the deficit in Norwegian non-petroleum trade balance is reduced by 51.7 %, indicating a substantial reduction in imports relative to exports. As our real effective exchange rate variable comprises relative prices of tradeable goods and domestic inflation, relative price changes between non-tradeable and tradeable goods within each country are only visible through the Balassa-Samuelson effect.⁴⁴ When the Norwegian government intervened by devaluating the NOK in 1986 to boost competitiveness, private consumption did not respond, leading to imported inflation.⁴⁵ Consequently, the real effective exchange rate rose by 2.6 % from 1985 to 1986, covering any relative price changes between non-tradeable and tradeable goods. This leaves us unable to reject the predictability of the model regarding this response. However, Steigum (1984; 1988) predicts that such price differences should lead to sectoral adjustments, with transitional unemployment rising in response to lower marginal product of labour. This is supported by the data, as registered unemployment rose to 5.3 % by 1990q1, an increase of 3.2 percentage points from 1986q3.

In the 15-quarter period leading up to the 1986 oil price drop, the Norwegian mainland economy had an annualized growth rate of 5.25 % per year (3.86 % for Sweden). In the following 15-quarter period, from 1986q1 to 1990q1, the Norwegian mainland economy *contracted* by 3 % in real terms. Still, caution must be taken when interpreting these variable changes as a consequence of the oil price bust alone, as the period coincides with one of the largest financial downturns in Scandinavian economic history. In terms of Steigum's framework (1988), whether reduced demand comes in the form of reduced access to credit, lower petroleum prices or both, the response in the abovementioned variables would be of the same sign. Albeit not being the only factor, the fall in oil prices contributed to this development through other channels than income, as petroleum investments fell from 9 % of GDP to 4 % by 1987.⁴⁶

Looking to Sweden, the composition of their tradeable sector, with a strong foundation in heavy industries such as mining, steelworks and shipbuilding, made them sensitive to the business cycle

⁴⁴ See e.g. Rogoff (1996).

⁴⁵ Although the NOK fell by 22.4 % to the USD between 1986q2 and 1988q2, the intervention failed to reduce inflationary pressure and was considered a failure. This was a contributing factor to Norway abandoning the fixed exchange rate system in 1992 (Hodne & Grytten, 2002)

⁴⁶ Demand impulses from the petroleum sector, and lack thereof, has been estimated to have amplified the business cycles of mainland Norway between 1973 and 1993 by about a third (Cappelen, Choudhoury, & Eika, 1996).

and to crises. The global downturn following the 1973-1974 oil price hike caused a lasting crisis in the sector that was not reversed until the mid-1980s (Schön, 2012). While Norway was heading into recession, the Swedish economy responded positively to the fall in oil prices, where unemployment rates fell by 1.6 % and compound real GDP growth totalled 11 % in the period. The financial crisis eventually caught up with Sweden in the early 1990s, as their economy contracted by 5 % over 15 quarters from 1990q1, with unemployment reaching 10 % as a consequence of women entering the working force, downscaling of the primary- and industrial sector as well as the industrial sector becoming more capital intensive (Schön, 2012). In addition, employment in public services had risen drastically during the 1970s and 1980s as it was an explicit political goal to keep unemployment low. Public employment was subject to reform and reversal.

1997-1999 Oil price bust

From 1997q4 through 1998q4, the price of crude oil fell from 25 USD to 15.7 USD per barrel, as economic growth in east-Asia stagnated. The petroleum sector had kept growing through a period of otherwise slow economic growth in Norwegian economy, with petroleum income equalling 25 % of mainland GDP in the first quarter of 1997. The drop in oil prices saw petroleum net cash flows cut in half over the next two years. Although this oil price bust proved to be short-lived, the expectations at the time were those of continued low oil prices as Asian demand schedules were downscaled (Statoil, 2000). Steigum's model (1988), assuming a fixed exchange rate, does not accommodate for all the dynamics in a regime of floating exchange rates. Still, some of the short and medium term responses observed in the period accord with what the model postulates. With the NOK floating freely, the real effective exchange rate depreciated with the falling oil prices (REER fell by 7.4 % between 1997q1 and 1999q1). As predicted, imports also fell substantially, reducing the deficit in non-petroleum trade balance by 39.5 % between 1998q3 and 2001q3. In the fall of 1997, Norway was at the top of a business cycle. Thus, the dynamics of a business cycle slowdown combined with an adverse wealth shock made unemployment rise steadily from 1999q1, as the economy entered a recession.

This was also the case with the oil price bust of 1986. The Swedish economy seemed to benefit slightly from falling oil prices, making their business cycle lag the Norwegian by 5-8 quarters. Still in recovery from the 1990s recession, the Swedish economy saw unemployment rates fall

from 12.3 % to 5.9 % between 1997q1 and 2001q1, with economic growth averaging 4.3 % per year. A growth in exports contributed to an upswing, eroding their trade balance deficit which was turned to a surplus in the mid-1990s, and kept growing throughout the 2000s. Compared with the response in the Norwegian economy, Swedish growth did not slow down until 2001, indicating that some of the abovementioned effects for Norway were indeed driven by the oil price drop.

2011-2015 commodity price bust

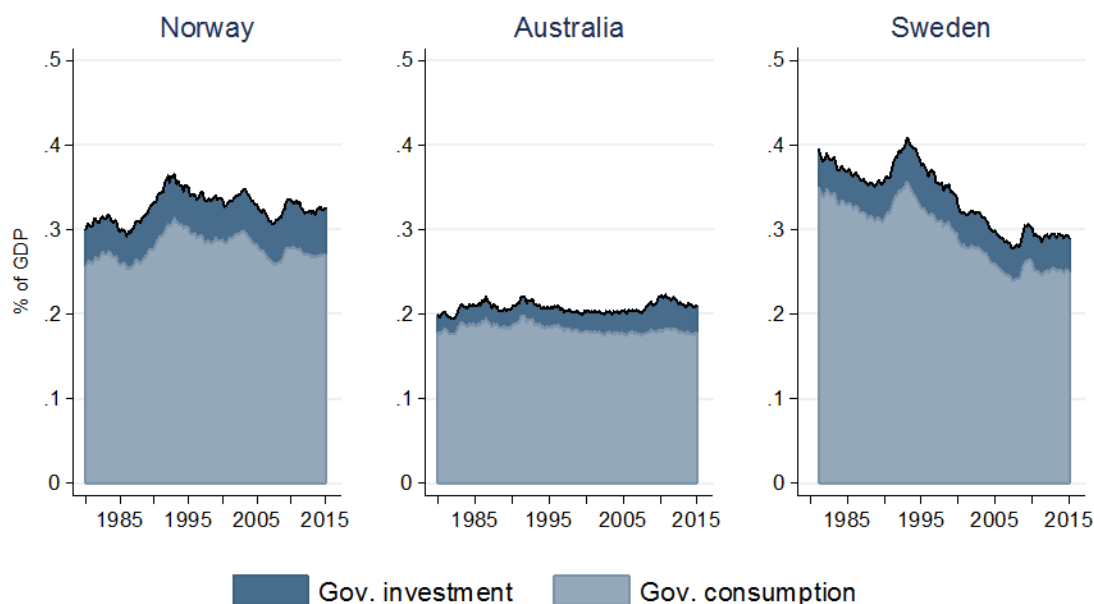
The boom in commodity prices which lead to the mining-boom in Australia has since been relieved by a substantial commodity price bust. From its peak in 2011q3 to 2015q2, the export-weighted commodity price index fell by 58.5 %. This price drop has been alleviated by increasing output levels at the completion of pre-planned investments, with the mining share of GDP growing from 7 to 8.5 % since 2011. As described in part 3, this would translate to $\Delta p_3 \ll 0$; $\Delta Q_3 \gg 0$, with the latter effect dominating the former. Consequently, the fall in commodity prices has resulted in ambiguous variable changes. As for the real effective exchange rate, the price drop has resulted in a depreciation of 7.9 % over the period, as expected from the model. Despite that the net effect on national income has been positive unemployment has risen by a full percentage point over the period, reaching 6 % in the first half of 2015. Still, the effect on the trade balance for non-commodities has been negative. Both non-commodity exports and -imports have been reduced over the period, but while exports have been reduced by 10 %, imports have only fallen by 1 % (United Nations, 2015). The former can be seen in light of several studies warning of a traditional Dutch Disease effect in Australia, brought on by the boom-era effects described above.⁴⁷

⁴⁷ See e.g. Corden (2012) and Downes, Hanslow, & Tulip (2014).

Public spending

As Steigum's framework assumes no change in public consumption and real public investments, we study the public sector separately. Public spending⁴⁸ as a share of GDP in mainland Norway and Sweden is on an overall higher level than in Australia, as would be expected from the Scandinavian welfare model. The spending levels during the last 35 years follow the business cycle of the different countries countercyclically. Although both Sweden and Norway had large public sector expansions in the 1960's- and 70's only the Swedish variables show signs of a downscaling. Furthermore, despite the fact that the Norwegian government spending level is not as high as the Swedish in the beginning of the time series, the Norwegian level has remained constant during this period. As such, it might seem that the resource boom in Norway has reduced the need for reforming public expenditures.

**Figure 10:
Government spending**



Notes: Transfers not included. Percent of GDP. Seasonally adjusted. Mainland GDP for Norway.
Sources: Statistics Sweden, Statistics Norway, Australian Bureau of Statistics and Macrobond.

⁴⁸ We use the term public spending to cover public spending excluding transfers (i.e. including general government consumption and government investment, gross fixed capital formation).

5 Synthetic control method

5.1 Motivation

In order to better understand the impact of oil and gas resources on economic growth in the Norwegian economy, it would be valuable to compare its performance with that of a counterfactual economy where the oil and gas resources had been left untouched. Until recently, this has not been possible without large scale macroeconomic models.

Traditional comparative case studies are limited by two factors that affect empirical inference. First, there is a degree of ambiguity in how the units of comparison are selected, as the control group may be chosen on the basis of subjective measures.⁴⁹ Second, there is uncertainty about the control group's ability to represent a counterfactual outcome. If the control group is not sufficiently similar to the group of interest, then any difference in outcomes in the two groups could merely reflect differences in their characteristics. This uncertainty would not be reflected in the standard errors of traditional inferential techniques (Abadie, Diamond, & Hainmueller, 2015).

Empirical studies on natural resources and long-term economic growth, often using time-series, are troubled with endogeneity; countries that utilize their resources in an efficient manner grow richer and further utilize their resources more efficiently in the future. This problem is also inherent in the complex models of contemporary macroeconomics, such as the MODAG and KVARTS models of Statistics Norway.⁵⁰ Here, relationships between businesses and consumers are modelled and calibrated with those found in empirical research, but even these linkages are built on *ex post* adaptations to an economic environment in which the event already has occurred. In fact, the very strength of these models, i.e. that they are adapted to provide estimates as close as possible to the observed reality given historical data and economic theory, cause them to provide biased estimates of counterfactual developments.⁵¹

⁴⁹ In part 4, Australia and Sweden were selected for comparison due to their similarities with Norway.

⁵⁰ Such models are meticulous of nature, making calibrations a tedious affair. The MODAG/KVARTS models of Statistics Norway are constructed of more than 4000 equations, calibrated by empirical studies and economic theory.

⁵¹ Despite their strengths, DSGE models routinely fail to predict major events, as evidenced by the financial crisis of 2008/09. Critics argue they do not contain enough relevant information, and that they are founded on largely imperfect economic theory (Hendry, 2004).

Consequently, counterfactual analyses conducted in such systems are unreliable, unless the modelled interlinkages in the economy can be assumed to have developed independently of the event the researcher wish to study. Further, if the event of interest can be expected to have caused any structural changes, which certainly has been the case with petroleum resource discoveries in the North Sea, the reliability of these counterfactual estimates are reduced further.

The same can be said of the other method applied in the Norwegian tradition: the SVAR method of which Bjørnland (1998) and Bjørnland and Thorsrud (2013) are examples. Results from these methods are sensitive to model specification, as pointed out by Bjørnland (1998). If the restrictions imposed on the variables do not fit the true economic relationships, the results might be misleading. One example of which is that demand shocks are assumed to affect only the output gap, and not potential output. In the words of Bjørnland: “[T]he complexity of ways that energy shocks can influence the economy motivates the use of a less theoretical model” (Bjørnland H. C., 1998).

A recently developed method for comparative case studies, the synthetic control method (SCM), provides an alternative. Originally intended to bridge the gap between quantitative and qualitative approaches in political science, its qualities have also proved promising for applications in both economic policy and macroeconomics. The method was first presented and developed by Abadie and Gardaezabal in 2003, gaining attention with the *American Economic Review* study called “The Economic Cost of Conflict: A Case Study of the Basque Country”. In this paper, Alberto Abadie and Javier Gardeazabal estimate the cost of terrorism in the Basque Country by constructing a counterfactual real per capita GDP series from the early 1970s until late 1990s. Later, Abadie, Diamond and Hainmueller (2010) elaborated on the model’s formal properties, studying the effects of California’s Proposition 99, a large-scale tobacco control program implemented in 1988. In a third article, recently published in the *American Journal of Political Science*, they use SCM to examine the economic impact of the German reunification on West Germany’s economy (Abadie et al., 2015).

The principle behind SCM is that when the units for analysis are a few aggregate entities, a combination of units would prove better as a comparison than any single unit alone (Abadie et al., 2010). Because it makes the contribution from each comparison unit explicit, in contrast to regression analysis techniques, it allows researchers to combine quantitative and

qualitative techniques to analyse the differences and resemblances between the synthetic control group and the studied case (Abadie et al., 2015). Furthermore, contrary to traditional comparable analysis, it uses a data-driven algorithm to select comparison countries from a pool of candidates, but it does not depend on the researcher being able to predict the form and direction of interactions between economic variables. The model builds on the presumption that countries that are similar in observable qualities should, in the absence of large, structural shocks, develop along similar paths. If this condition is met, differences between the growth paths of Norway and its synthetic control estimate can be attributed to the difference between them, i.e. the petroleum industry.

5.2 Methodological approach

The synthetic control method uses a data-driven algorithm to create a counterfactual observation unit which we can compare to the actual performance of the unit of interest. We wish to estimate Norwegian GDP per capita in the absence of oil and gas revenues.

The synthetic control, or the *treated unit* (borrowing the expression from the medical sciences), is created as a weighted average of a set of untreated comparison units. SCM does so by using data from pre-treatment periods to minimize the difference between the treated and untreated units for observable characteristics that are predictors of the outcome we wish to study. In our case, these observed characteristics are macroeconomic indicators known from theory to predict economic growth. Since the donor pool is intended to replicate the outcome variable, GDP per capita, in the absence of a treatment, it is important that the donor pool is restricted to countries where firstly, GDP per capita is driven by the same structural processes as in Norway. Secondly, GDP per capita of the comparison unit must not have been subject to structural shocks during the period of study, and thirdly, GDP per capita is not driven by extraction of oil and natural gas. Consequently, we use a sample of non-oil producing OECD countries as our donor pool.

Formally, let Y_{jt} be GDP per capita in country j at time t . In a sample of $J + 1$ units, the treated unit is denoted $j = 1$ and the potential comparison units, $j = 2$ to $j = J + 1$ constitute the donor pool. All units are observed at time periods $t = 1, \dots, T$, out of which there are pre- and post-intervention periods denoted T_0 and T_1 respectively, so that $T = T_0 + T_1$. The treated unit is exposed to the event of interest during the periods $T_0 + 1, \dots, T$, but not during the pre-treatment period, $1, \dots, T_0$.

The synthetic control can be represented by a $(J \times 1)$ vector of weights $W = (w_2, \dots, w_{J+1})'$, with $0 \leq w_j \leq 1$ for $j = 2, \dots, J$ and $w_2 + \dots + w_{J+1} = 1$. This means that each particular value of the vector W represents a potential synthetic control, i.e. a weighted average of comparison countries. Following Mill's Method of Difference, Abadie et al. (2015) propose selecting W as to best resemble the characteristics of the treated unit in the pre-treatment period. We select k characteristics X that are predictors of the outcome of interest Y . Let X_1 be a $(k \times 1)$ vector comprising values of these characteristics for the treated unit, and X_0 be the $(k \times J)$ matrix containing the values of the same variables from the donor pool. The method then subjects the donor pool's predictor variables in the pre-treatment period to a dual optimization process that minimizes:

$$\sum_{m=1}^k v_m (X_{1m} - X_{0m}W)^2, \quad (1)$$

by selecting values for W and v_m . Here, X_{1m} is the value of the m -th characteristic for the treated unit and v_m is a weight reflecting the relative importance assigned to the m -th variable when measuring the inconsistency between X_1 and X_0W .⁵² Thus, W^* is chosen as the value of W that minimizes vector $X_1 - (X_0W)$, which gives the difference between the pre-event characteristics of the treated unit and the synthetic control.

Following the notation from above, let Y_1 be a $(T_1 \times 1)$ vector containing the post-event values of GDP per capita for the treated unit. Similarly, let Y_0 be a $(T_1 \times J)$ matrix, where the j th-column collect the post-event values of the outcome for unit $j + 1$. Then the estimator of the treatment effect from the synthetic control is given by the difference between the post-event outcomes of the treated unit, affected by the event, and the synthetic control not exposed to the event, $Y_1 - (Y_0W^*)$. This gives:

$$Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \quad (2)$$

⁵² The process of setting the value for the V-vector, containing weights v_m , can be done in several ways. Previously, both cross-validation and normative theory have been utilized (Abadie et al., 2010; 2015). We use a nested optimization procedure provided by Hainmueller, Abadie & Diamond (2015) to choose the weights v_m , by searching among all diagonal positive semidefinite V-matrices and sets of W-weights for the best fitting convex combination of the control units. This data-driven approach determines the weights v_m so that W^* equal the value of W that minimizes equation (1). These weights are normalized to sum to one.

Abadie et al. (2010) show that, under standard conditions, the fit of (2) is measurable in the pre-treatment period. If there are no important omitted predictor variables, and the number of pre-treatment periods is sufficiently large, a reliable synthetic match will be created such that $Y_{1t} - Y_{0t}W^*$ is close to zero when $1 \leq t \leq T_0$. In the post-treatment period, the sign and size of $Y_1 - (Y_0W^*)$ allow us to make inference about the direction and magnitude of the treatment effect.

5.3 Advantages and limitations

Due to its versatility and simple form, SCM allows researchers to answer questions previously withheld from statistical analysis. It is applicable in scenarios where regression-based methods are prohibited by small sample sizes, few treated units or both. In addition, as demonstrated by Abadie et al. (2010; 2015), SCM also has several advantages in situations where regression could be a feasible approach as it avoids extrapolation issues, cognitive biases, endogeneity and omitted variable bias.

When applied to macroeconomic or economic policy studies, it has the advantage of not resting on modelled interactions between predictors and outcome variables. Contrary to the complex macroeconomic models of, for example, modern day central banks, SCM utilizes the real-life performance of donor pool economies to predict a feasible development pattern.

However, while significantly reducing model specification error, it does not allow for analysis of different counterfactual scenarios, but limits the studies to a world in which the treatment never occurred. In addition, due to the model's specification, it will fail to provide suitable results in cases where the treated unit has extreme values for the outcome variable.

Our sample period begins in 1951 for both practical and empirical reasons. Following Abadie et al., a long pre-treatment period is required to reduce bias in the weights. In addition, our large post-treatment period (43 years) should also warrant a large pre-treatment period. However, using data from years in the immediate vicinity of WWII was deemed unlikely to provide additional value, as the post-war years saw countries recovering at different rates. The accuracy of historical data is disputable, and time-series are frequently subject to revisions, making measurement error bias a concern. As we are unable to avoid these issues, we assume that post-war effects on macroindicators from 1951 are largely similar across countries in our sample and that

measurement errors are randomly distributed across observations. We are not able to test these assumptions directly, but are assured through validation techniques.

For our estimates of the counterfactual to be accurate, the outcomes in GDP per capita in the untreated units must be unaffected by the Norwegian discovery of oil and gas. Norway's total oil and gas production accounted for less than 4 % of the annual world production at its peak between 1996 and 2002.⁵³ Although that translated to 23 % of European oil production in the period, its minor share of production of a globally traded commodity did not grant price-setting powers. As such, any direct (dis)advantages for other economies would have to be caused by proximity to the resource. Lead-time for oil's effect on an aggregated variable such as GDP per capita in the non-treated units is arguable, and likely to be diminishable. Furthermore, supply harbours and refineries catering the Norwegian petroleum sector are mostly situated in Norway, limiting any foreign demand impulses significantly.⁵⁴

Norway is also engaged in bilateral trade with most of the countries in the sample. Consequently, high growth in the Norwegian economy could affect the comparison economies through the trade channel. The increase in Norwegian imports shown in part 4 has provided a bigger export market for our trade partners, which leaves us unable to state that Norway's economic growth is fully exogenous to the untreated units' GDP. However, Norway's moderate size, a median of 1.5 % of the total population and 1.75 % of GDP in the sample, would indicate that any such effects on comparison countries' aggregate GDP can be expected to be minuscule.

As explained previously, the matching variables in X_0 and X_1 are meant to be predictors of post-event outcomes, as they are not affected by the event. However, the method has been criticized for being limited by heterogeneity in the effects of observed and unobserved factors that affect the outcome variable. Abadie et al. (2010) argue that with a large number of pre-event periods, the matching on the pre-event outcomes helps control for unobserved factors as well as the heterogeneity problem on the outcome of interest. They claim that as only the units that are alike in both observable and unobservable determinantes of the outcome variable, as well as in the

⁵³ Oil production as a share of world production peaked in 1996 at 4,6 % of total world production, according to British Petroleum (2015).

⁵⁴ One exception is the offshore cluster in Aberdeen. However, as the United Kingdom is a petroleum exporting country, they are not included in our donor pool.

effect of those determinantes on the outcome of interest, should create similar trajectories of the outcome variable over long periods of time. Thus, once established that the treated unit and the synthetic control unit behave similarly over an extended period of time, in the period before the event, a difference in the outcome variable could be interpreted as caused by the event of interest (Abadie et al., 2015). Whether our pre-treatment period is sufficiently large for these conditions to be met, is a matter of judgement. Consequently, we apply a range of established validation techniques to verify our findings.

5.4 Data and sample

We use quarterly country-level data for the period 1951 to 2015. The petroleum resources on the Norwegian continental shelf were discovered in December 1969, but production was not scaled for profit until 1975. Previous studies have suggested 1972 to be the first year in which the petroleum sector had a measurable impact on Norwegian GDP, due to increased investments and domestic demand. Thus, we set 1972q1 as our treatment period, giving us a pre-intervention period of 84 quarters.⁵⁵

The synthetic Norway is constructed using a weighted average of potential control countries from the donor pool. Our donor pool consists of 10 non-petroleum producing OECD member countries: Austria, Belgium, Denmark, Finland, France, Italy, Japan, New Zealand, Sweden and Switzerland.⁵⁶

Our outcome variable, Y_{jt} , is the real per capita GDP in country j at time t . GDP is Purchasing Power Parity (PPP)-adjusted and measured in 1990 U.S. dollars (USD). For the pre-treatment characteristics X_1 and X_0 , we use a standard set of economic growth predictors: inflation rate, investment rate, a human capital index, labour compensation as a share of GDP, a labour

⁵⁵ Setting the treatment period to 1969, 1975 or any period in between does not change our results substantially.

⁵⁶ The donor pool originates from a list of all 23 OECD member countries in 1972 (including New Zealand who officially joined in May 1973). Following Abadie et al. (2015), Luxembourg and Iceland have been excluded because of their small size and peculiarities in their economies, and Turkey because of a post-intervention GDP per capita far below the sample average. Further, we excluded Australia, Canada, the Netherlands, the United States and the United Kingdom as they have significant petroleum production in the observed periods. Finally, we exclude Germany, Greece, Ireland, Spain and Portugal due to significant structural changes in the posttreatment period: Ireland because of its “Celtic Tiger” expansion in the 1990s; Germany because of its reunification in 1990; Greece, Spain and Portugal for their structural breaks in the 1970s and for their poor performance after the 2008/09 financial crisis. Of the latter countries, Ireland is the only country to be attributed a non-zero weight if added to the donor pool. However, the qualitative results are not substantially different.

productivity measure, an index of the country’s openness to trade, government consumption as a share of GDP and the unemployment rate. We experimented with additional growth predictors, but including these did not change our results substantially. A list of all variables used in the analysis is provided in appendix B.1, along with their sources.

Since historic, quarterly observations are scarce for most other variables than GDP, we use annual observations for the characteristics X_1 and X_0 , while we use quarterly observations for GDP per capita. Following equation (1), the covariates are averaged across the pre-intervention period, meaning that using yearly observation frequencies in a quarterly panel does not impact the results.

5.5 Constructing a synthetic Norway

Using the technique described above, we construct a synthetic Norway without oil, with weights selected to best replicate the real development for Norway in the pre-treatment period. The resulting weights v_m for the characteristics are (in order from highest to lowest) the labour productivity measure (0.359), trade openness (0.324), unemployment rate (0.224), human capital (0.042), inflation (0.031), investment rate (0.030) and government consumption (0.001).

Table 3 compares the pre-treatment values for Norway, our synthetic Norway and a population weighted average of the donor pool. As is evident, the synthetic control is overall a closer match

**Table 3:
Economic growth predictor means before oil discovery**

	Norway	Synthetic Norway	OECD avg.	Weight
GDP per capita, USD 1990 PPPs	7736.19	7731.74	6465.73	-
Investment rate	0.053	0.044	0.074	0.03
Human capital index	2.510	2.365	2.190	0.04
Labour productivity	9.100	9.290	7.029	0.35
Inflation	0.050	0.037	0.044	0.03
Trade openness	0.706	0.621	0.243	0.32
Government consumption, share of GDP	0.180	0.149	0.174	0.00
Unemployment rate	0.020	0.030	0.026	0.22

Notes: All variables are averages over the pre-treatment period for our sample (1951q1 to 1971q4). OECD Sample is the population-weighted average of observations from our sample of OECD countries, excluding Norway. Note that the OECD average GDP per capita is reduced somewhat because of Japan’s low GDP in the pre-intervention period.

to Norway than the OECD average. The synthetic Norway is very close to the real Norway both in terms of pre-oil per capita GDP, investment rate, human capital index, labour productivity and trade openness. It performs slightly worse in unemployment, which is unsurprising as Norway has the lowest unemployment of the sample making it difficult to replicate without extrapolating. Inflation and government consumption is a poorer fit than the sample average.

Table 4 shows the weights given to each of the donor countries. Our synthetic Norway is a weighted average of Belgium, Finland, New Zealand and Sweden, in decreasing order.⁵⁷ All other countries have been assigned zero weights. This gives us the synthetic GDP per capita plotted in panel B of *Figure 11*.

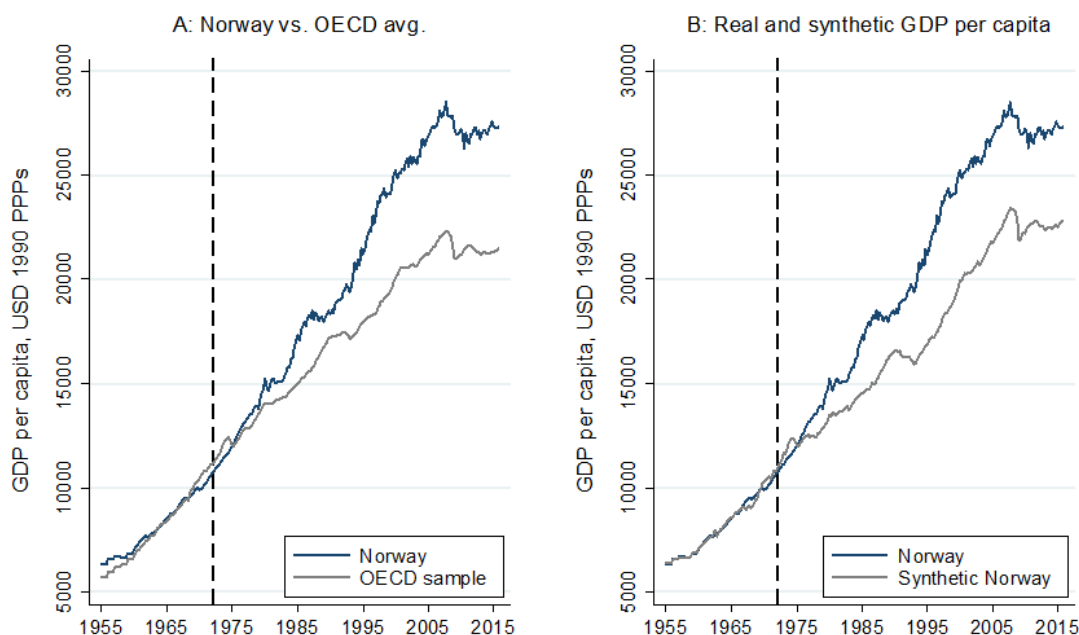
Comparing it to the OECD average from panel A, we can be assured that it seems to be a reasonable fit. While the OECD average shows a high growth rate through the 1970s and 1980s, followed by a somewhat slower growth rate through the 1990s, the synthetic Norway has a somewhat slower build-up, and an evident recession in the early 1990s. Although studies have argued that this crisis was amplified by the oil price drop in 1986, the recession hit our Scandinavian neighbours with a similar magnitude, indicating that it might be a Nordic phenomenon rather than an oil-driven one. Consequently, we would expect it to appear also in the counterfactual without oil – which it does.

Table 4:
Synthetic Control Weights

Country	Synthetic Control Weight
Austria	0
Belgium	0.508
Denmark	0
Finland	0.300
France	0
Italy	0
Japan	0
New Zealand	0.163
Sweden	0.029
Switzerland	0

⁵⁷ Note that if Ireland is included in the donor pool, Sweden is attributed the highest weight of all donor countries (0.503). A result where Sweden, rather than Belgium, has the highest weight is intuitively compelling. However, as Ireland is excluded due to its “Celtic Tiger” growth, our estimates of synthetic Norway are not substantially different.

**Figure 11:
GDP per capita: Norway, synthetic Norway and OECD**



Notes: OECD sample is population-weighted per capita GDP for our donor pool of 10 non-oil producing OECD countries. Synthetic Norway is generated using the procedure in part 5.

5.6 Inference in synthetic control

Although standard procedures for validating causal inference in statistical analysis is made difficult due to the small sample sizes and non-randomized data, a set of validation techniques for use in SCM has been developed, termed “placebo studies”. These are based on the premise that a particular synthetic control estimate would be undermined if similar effects were obtained in cases where the intervention did not occur. Results from placebo studies on our estimates of Norwegian GDP per capita without oil will be presented in part 5.7 Placebo studies.

For instance, if we achieve a significant treatment effect by moving the treatment to an arbitrary point in time, it would strongly discourage that our results are in fact caused by the treatment. This is called an *in-time placebo*. Similarly, we can reassign the treatment to other members of the donor pool (*in-space placebo*). If this results in treatment effects of a similar or greater magnitude than that of the unit directly exposed to the treatment, it would indicate that the observed effect is not driven by the treatment we have prescribed. Following part 5.2 Methodological approach, a well-fitted synthetic control would result in a small pre-treatment effect and a large post-treatment effect. By comparing the relative size of pre- and post-treatment

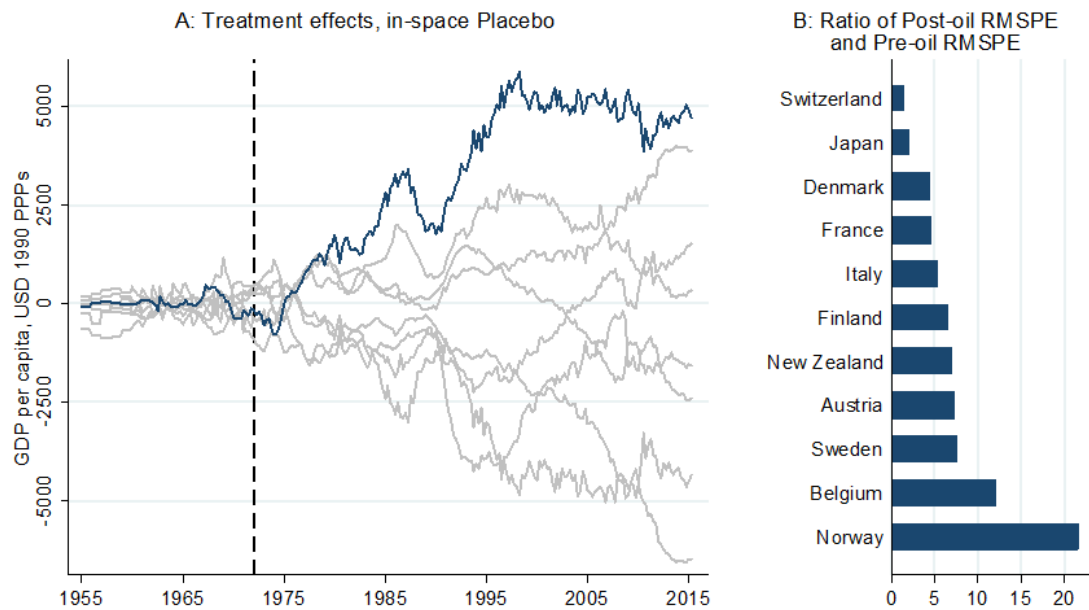
synthetic control effects from the in-space placebo study, we get an indication of the treatment effect.

We also test the robustness of our results with regard to the comparison units in the donor pool. By replicating the study while iteratively leaving out a comparison unit, we can verify that our synthetic Norway is not driven by a singular observation. Finally, we apply the same synthetic model approach to two countries, Australia and the United Kingdom, that have been exposed to the same treatment as Norway. This is done to study whether these countries show similar response to the treatment period as Norway.

5.7 Placebo studies

To evaluate the credibility of our results, we conduct a series of placebo tests. First, we test to see if the treatment effect, i.e. the difference between real and synthetic per capita GDP, is similar in magnitude and direction when applied to the countries in our donor pool. As is evident in the left panel of *Figure 12*, Norway (blue line) outperforms all donor countries over the entire period,

Figure 12: In-space placebo test

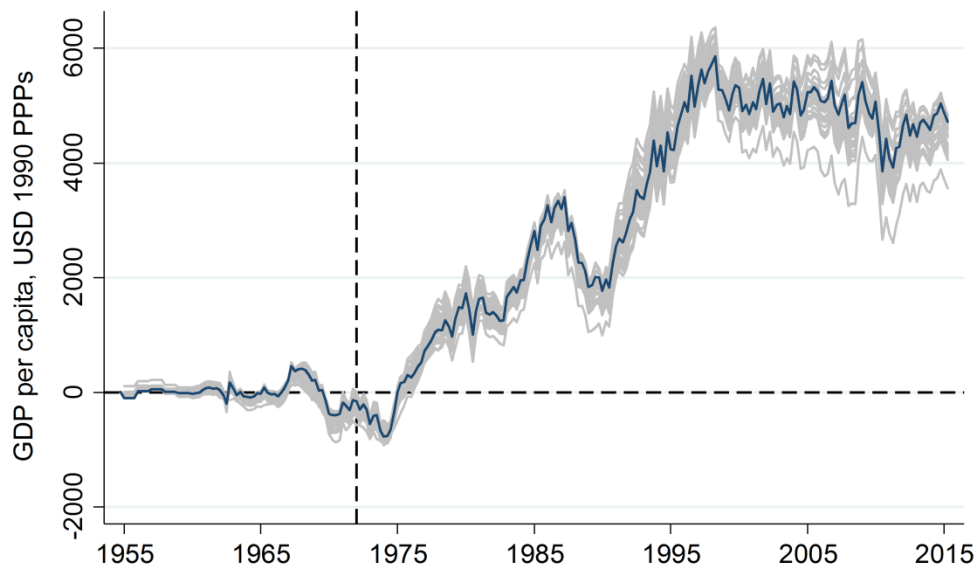


Notes: Panel A is treatment effect in GDP per capita for in-space placebos, iteratively testing for a treatment occurring in 1972 for each donor country. The blue line is Norway. Panel B displays the ratio between pre-treatment and post-treatment RMSPE for each country. Calculated as: $RMSPE\text{-ratio} = RMSPE_{post} / RMSPE_{pre}$. Switzerland, Japan and New Zealand are left out of panel A due a to lack of fit in the pre-treatment period.

with a positive treatment effect throughout.⁵⁸ This is also shown in the right-hand panel, where countries are ranked based on the ratio between post- and pre-treatment root mean squared prediction error (RMSPE).⁵⁹ A higher RMSPE-ratio indicates a better fit in the pre-treatment period, and a larger post-treatment difference. Norway has the highest RMSPE-ratio (21.6), almost double that of second-ranked Belgium (12).

As discussed in part 5.6 Inference in synthetic control, the treatment effect should not be substantially different if we move it in time to a period either before or after the discovery of oil. We control this by replicating the same procedure as our initial synthetic control, but setting the treatment period to a period before the oil discovery: 1964q4. Iteratively, we repeat the

**Figure 13:
In-time Placebo**



Notes: Treatment effect in GDP per capita for in-time placebos, iteratively testing for a treatment occurring in a different time-period than 1972q1. Grey lines are treatment effects for a treatment in each quarter between 1966 and 1978. The blue line is for 1972q1.

⁵⁸ Japan, Switzerland and New Zealand were not included in the plot, due to poor performance in the pre-treatment period.

⁵⁹ RMSPE measures a lack of fit between real and synthetic GDP per capita. Pre-treatment RMSPE for Norway is defined as:

$$RMSPE = \left(\frac{1}{T_0} \sum_{t=1}^{T_0} \left(Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \right)^2 \right)^{\frac{1}{2}}$$

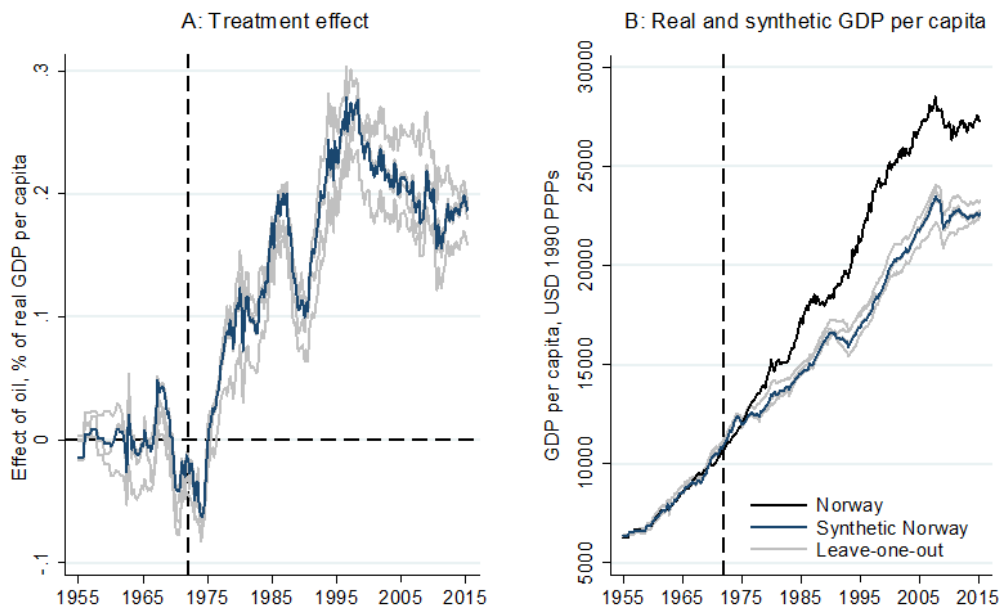
RMSPE is calculated analogously for post-treatment periods, and other countries.

procedure, moving the treatment period one quarter for each iteration. This allows us to compare the treatment effects to see if the results are really driven by the discovery of oil, rather than a lack of fit. In *Figure 13*, the blue line is that for a treatment period in 1972q1 as before, and the grey lines indicate treatment effects for each of the 60 quarters between 1964q4 and 1979q4. As we allow the pre-treatment period to be extended, the weights assigned to countries and variables change somewhat – although they do not alter the treatment effect substantially. We see that the full distribution of treatment periods show a positive treatment effect for the same time periods, with both the recession of the early 1990s and the peak-oil era clearly visible for all iterations. As the blue line lies comfortably near the centre of the distribution, we are assured that our synthetic control estimate is not owed to the relatively few pre-treatment observations at our disposal, but rather an effect of Norway growing substantially different from its peers throughout the post-treatment periods. Naturally, the distribution spreads out towards the end, as the synthetic control grows more sensitive to slight alterations between country-weights through time.

We also control for whether the results of the synthetic control is owed to a particular country performing significantly worse through the post-treatment period by conducting a leave-one-out cross-validation. We re-run the model, each time leaving out one of the 10 donor countries. The right-hand panel of *Figure 14* shows that the initial control is not very sensitive to omitting individual countries from the donor pool. Notably, the banking crisis of the 1990s is significantly reduced in magnitude when either Finland or Sweden is omitted. Still, the synthetic control proves robust. Note that the growth rate of the synthetic control after 2010 is positive in two of the placebo scenarios, contrary to the zero-growth for Synthetic Norway. As Finland and Belgium, the two largest weights, have negative and zero growth rates after 2010, respectively, we must be careful not to emphasise the results after this period.

Although the placebo tests consistently indicate that there has been a detachment in GDP per capita growth between Norway and comparable OECD countries since the 1970s, we cannot exclude the possibility that this effect is owed to other factors in the Norwegian economy than having a petroleum sector. Fortunately, oil and gas resources were also discovered in the British sector of the North Sea only a few years after Norway, making it an ideal country for comparison. Although Britain's oil reserves and petroleum sector are of modest size compared to Norway's, if we are able to identify a positive treatment effect for the United Kingdom, it would strongly

Figure 14:
Leave-one-out cross validation

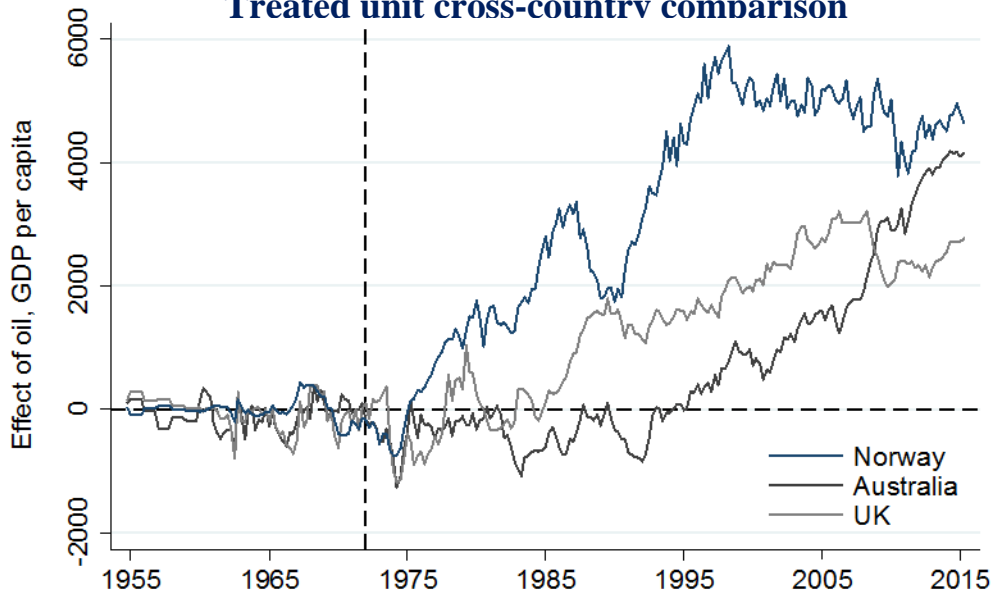


Notes: Panel A displays treatment effect for synthetic Norway while iteratively leaving out one of the donor countries from the donor pool, in percentages of real Norwegian GDP per capita. Panel B show each leave-one-out iteration and our synthetic Norway compared to real Norwegian GDP per capita.

indicate that oil and gas resources is the explanation for Norway’s deviation from synthetic trend. We also control for Australia as the treated unit, for the same reasons as for the United Kingdom.

Figure 15 shows these results: Clearly, there is a positive, albeit delayed, positive treatment effect in the United Kingdom. As their oil and gas reserves were discovered only in 1975, this is in accordance with the effect we find for Norway. As for Australia, the mining boom of the late 1990s is clearly visible in the data, showing a rising treatment effect at the end of the series. These are clear indications that the positive treatment effect for Norway can be owed to the petroleum resource boom.

Figure 15:
Treated unit cross-country comparison



Notes: Treatment effect is estimated by running SCM model with Australia, the United Kingdom and Norway as treated units with our OECD 10 as donor pool. GDP per capita in 1990 USD PPP.

5.8 Historical analysis

A first approach to validate the development in our synthetic GDP series is to discuss special characteristics in the three most important donor countries from *Table 4*: Belgium, Finland and New Zealand. This is done to assess whether it is plausible that our estimates of a synthetic Norway is not owed to shocks and special characteristics within the donor economies.

5.8.1 Special characteristics of the countries in the donor pool

Belgium

As it is the country with the highest weight in the donor pool, weighted 53 % of the synthetic control, Belgium's economic development largely determines our counterfactual. Belgium is a small, open economy, resembling Norway also in other characteristics than those included in our model, such as a highly developed social security system. Among the strongest similarities in the pre-treatment period is the relatively high labour productivity (GDP per hours worked), trade openness index (exports/imports as share of GDP) and human capital index (average years of schooling). Furthermore, the two countries have about the same development in higher education and average years of schooling as well as a similar government consumption share before and after the pre-treatment period. As such, it seems reasonable to include it in the synthetic control.

Nevertheless, there are some differences. There seem to be a stronger deindustrialization tendency in Belgium from the 1970s until 2010, with a reduction of the industry share of the manufacturing sector from over 40 % in the mid-1970s to just above 20 % since 2000. As a comparison, the Norwegian manufacturing share of GDP decreased from its peak of 41 % in the early 80's to 34 % in 2010.⁶⁰ However, if the slow downscaling of the Norwegian manufacturing sector during the post-treatment period is caused by spillover effects from the petroleum sector rather than other, special Norwegian characteristics, the synthetic control will still be valid. Contrary to the enormous growth in Norwegian exports compared to imports (as a share of GDP), Belgian exports and imports increase at an equal rate during our sample period. This development is similar to the trade expansion observed in the other OECD countries in our sample.⁶¹ Furthermore, the Belgian unemployment rate in the pre-treatment period was about 5 % compared to the low Norwegian rate of 2 %. While Norwegian unemployment rates remained quite low during the post-treatment period at an average of 3.4 %, Belgium's unemployment rate averaged 8.9 % in this period, closer to other OECD countries. Two major recessions, 1980/1982 and 1992/1993, contributed to this effect. Whether or not the continuous, low Norwegian unemployment rate was caused by the impulse from the petroleum sector, or other, special Norwegian characteristics, is hard to say. If the latter case is true, this could artificially widen the gap between GDP per capita in Norway and the synthetic control. This will be discussed further in part 5.8.3.

As the first country to undergo an industrial revolution in Europe in the early 19th century, Belgium was heavily dependent on traditional industries such as steel and mining during the post-war period. When these industries were heavily invested in instead of newer industries, Belgium failed to modernize its economy during the early post-war period. However, a generally high growth level delayed the restructuring of the Belgium economy until the oil price shocks of 1973 and 1979, followed by shifting international demand (as visible in most OECD countries) and a Belgian recession in 1980/1982 (Hansen, 2001). As the government linked the Belgian franc to German mark through interest rates in 1990, increasing German rates lead to a period of reduced

⁶⁰ More similar to Belgium, the Swedish manufacturing industry share decreased from 40 % in the mid-1960s to 26.5 % in 2010.

⁶¹ One exception is Ireland, experiencing a tremendous increase in exports relative to imports (as a share of GDP) from around 25 % in the early 1970s to 80 % in 2010.

economic growth. Thus, Belgium experienced its worst recession since World War II from 1992-93 (Mommen, 1994).

Fortunately, these two crises coincide with the development in many OECD countries, and the latter also with the Scandinavian Banking crisis. Since the downturns caused by global oil and demand crisis in these periods occur in most non-oil producing OECD countries, it seems plausible that the Norwegian development in a counterfactual scenario would coincide somewhat with the Belgian development. Furthermore, as the Scandinavian crisis in the late 1980s and early 1990s, caused by devaluations and other mistaken political actions, did occur in non-oil producing Scandinavian countries such as Sweden and Finland, it would be reasonable to observe a similar development in the synthetic control.

Brussel as a European Centre

Brussels has a long history of hosting different institutions, including the European Union, starting in the late 1950s (Seat of the European Commission, 2012). During the post-war boom years, the establishment of both the European Union and NATO headquarters in Brussels, enhanced economic growth as foreign investments increased significantly in the late 1960's. After the EU single-market program of 1992, many companies have selected Brussels for their headquarters and today, foreign businesses in Belgium account for around 11 % of the total work force (CIA World Factbook, 2015).

As the events occurring before the treatment period is accounted for in the synthetic control, only events causing a substantial shocks in the Belgian economy in the post-treatment period could artificially lessen the gap between the Norwegian economy and the synthetic control. Thus, if the single-market program of 1992 lead to a significant increase in foreign investments, growth in the synthetic control could be overestimated after 1992. However, we find a decreasing difference between the Belgian GDP per capita and the synthetic control from 1992 until 2008, indicating that the development is equally driven by the recovery in other donor countries and not the single-market program.

Finland

Similar to Norway, Finland is a small, open economy in the outskirts of Europe that has built its economic growth on trade. Despite its proximity to Russia, Finland's economy has remained

orientated towards its Nordic neighbours. This is evident in the country's economic development, which has had a strong resemblance with both the Swedish and Norwegian economy since the industrialisation (Ljungberg & Schön, 2013). One point of difference is in terms of government consumption. In the post-WWII era, Finland sustained one of Europe's highest labour productivity growth rates, partly explained by above average levels of capital stock per worker (van Ark, 2011). This did, in turn, facilitate an IT-industry boom in the late 1990s, making it one of the booming economies of the period (Daveri & Silva, 2004). It is unlikely that a counterfactual Norway would have supported a similar boom, suggesting that the economic growth shown by our synthetic control in this period could be somewhat exaggerated.

New Zealand

Between 1985 and 1992, New Zealand performs worse than the synthetic control, with GDP per capita growing at 1.7 % less per year – on average. This gap is explained by both a currency crisis and a subsequent recession hitting New Zealand in 1984. The recession, exposing the weaknesses of fixed exchange rates and inefficient macroeconomic policies, paved way for a series of economy-wide reforms.⁶² Such a recession was neither a unique event among OECD countries, nor does it affect the synthetic control substantially, as shown in the leave-one-out validation test presented in part 5.7.⁶³ Although preceding the Norwegian crisis by a few years, New Zealand's recession occurred under similar circumstances and was of a similar magnitude.⁶⁴ As mentioned earlier, most Western economies were hit by recessions in the period, making it rather unlikely that a counterfactual Norway without oil would have been left untouched. Consequently, a mid-1980s recession in a donor country does not qualify for ejection from our donor pool.

⁶² Areas that were subject to these reforms were, among others, monetary policy, export tariffs, financial market and public spending, establishing New Zealand as a modern, free market economy. For a thorough review of the reforms, and their impact on the economy in the preceding years, see Evans, Grimes, Wilkinson & Teece (1996).

⁶³ Our leave-one out analysis tests to see if there are any particularities in specific countries that should warrant rejection of our results. We find this not to be the case. Although when New Zealand is not included in the sample, synthetic GDP is estimated an average of 2.9 % higher each period, reducing the aggregate treatment effect by 18 %.

⁶⁴ Unemployment peaked at 11 % in New Zealand (1992) and 8 % in Norway (1993), none of which were substantially different from OECD averages at the time.

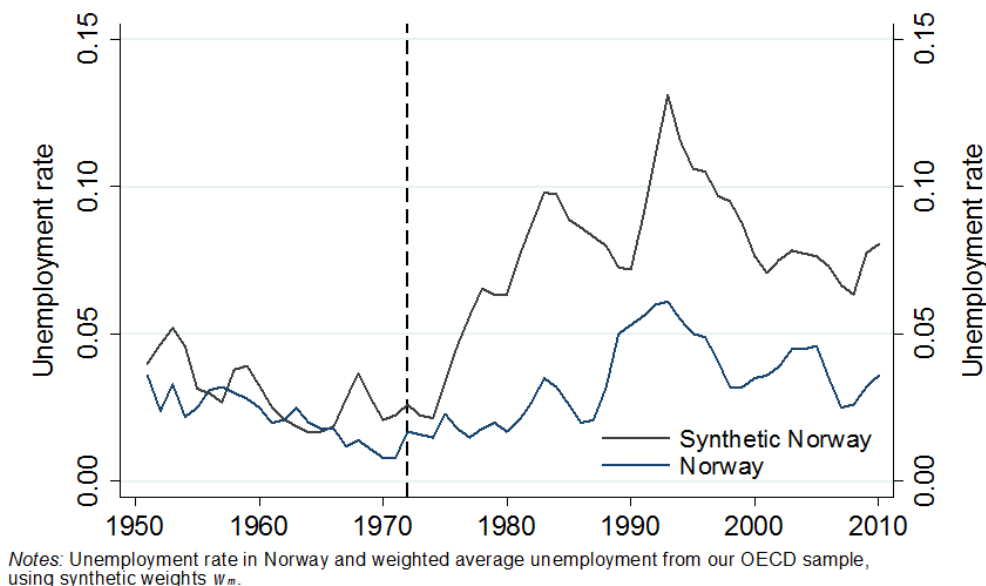
5.8.2 Spillover effects

Finland is engaged in bilateral trade with Norway, although its impact on economic growth is unlikely to have had a considerable effect. Since 1970, Norway has accounted for 3.4 % of Finland's total exports, while providing 2 % of their non-oil imports. Since the fall of the Soviet Union, Norway has accounted for 11 % of Finland's fuel imports (United Nations, 2015). Although the Nordic countries are tightly knit in many aspects, Norway's petroleum revenues do not seem to have resulted in significant alterations in foreign direct investment flows between the countries. Bilateral FDI between Norway and Finland accounted for less than 0.5 % of Finland's GDP by the end of 2012, compared to 1.5 % between Finland and Sweden (Mircheva & Muir, 2015). Thus, spillover effects from the Norwegian petroleum sector do not seem to alter the development of the Finnish GDP per capita growth.

5.8.3 Special Norwegian characteristics in the pre-treatment period

As long as the synthetic control cannot reproduce precisely the characteristics of the Norwegian economy before the petroleum discovery, it is important to be aware of that some of the gap can originate from differences in growth predictors between Norway and the synthetic control, or other dissimilarities not revealed in our data. As the average Norwegian unemployment rate between 1951 and 1971 was about 2 %, while the synthetic control average amounted to 3 %, it could be argued that a part of the difference between Norway and the synthetic control comes

Figure 16:
Unemployment levels in synthetic and real Norway



from the higher level of unemployment in the synthetic Norway. While the average post-treatment unemployment rate increased to 3.4 % in Norway, indicating a particularly low unemployment rate before 1972, the average, synthetic unemployment rate rose to 7.7 % in the post-treatment period.⁶⁵ Studies have attributed this development to the oil price hikes and failed macroeconomic policies in many OECD countries in the 1970s. Growth in most OECD countries slowed down markedly in 1979-1982, with zero or negative overall growth across the OECD. In the first half of the 1980s, unemployment levels rose to an average of 8 % in the large economies, and 12 % in the smaller countries (Coe, Durand, & Stiehler, 1988).

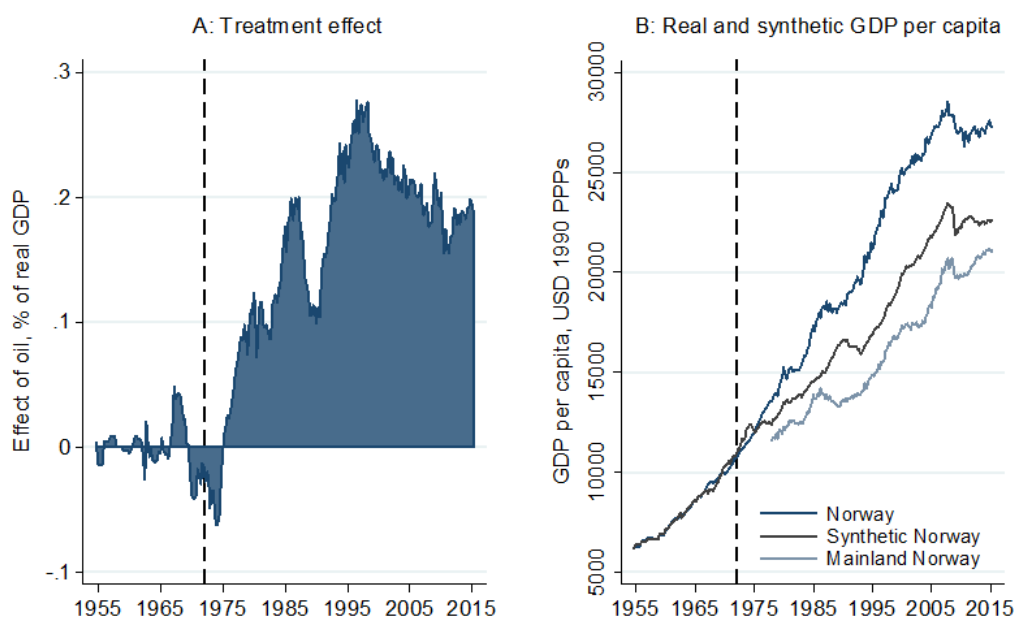
As these trends are shared among all OECD countries we have to accept that these events will distort our data. However, it seems likely that a Norway without oil would be more dependent of the global economic activity level, thus also affecting the unemployment rate of a counterfactual Norway in a similar manner. More importantly, although we do not dismiss the potential importance of such differences in growth predictors, it is undisputable that the difference in unemployment rates between Norway and the synthetic control cannot fully explain the gap in GDP between the two units during the sample period.

⁶⁵ Note that this is the underlying unemployment rate in the donor countries in our counterfactual Norway, and not an estimate of the counterfactual unemployment level in Norway. Studying the latter would require the same procedures as presented in part four, but using a dataset containing determinants for population growth and unemployment. This has not been done as it warrants a separate study.

6 Analysis

In order to structure our analysis, we separate it into two parts. First, we interpret the findings from part 5, explaining the differences between the synthetic, total and mainland Norwegian GDP per capita growth during different periods.⁶⁶ We compare our findings with the development of the OECD countries and the empirical studies referred to as the Norwegian tradition. In the second part, we discuss implications for the future development of the Norwegian economy, illustrated with three different scenarios in which the petroleum sector is gradually downscaled and, finally, phased out. We conclude by explaining the adjustment process towards a non-petroleum economy, considering costs of adjustment and different policy measures.

Figure 17:
GDP per capita and deviation from synthetic Norway



Notes: Panel A: Effect of oil is the difference between real and synthetic GDP per capita in terms of real GDP.
Panel B: Mainland Norway is GDP per capita for all mainland industries plus ocean transport.
Sources: OECD, Statistics Norway, own calculations

⁶⁶ Contrary to the common notation *Mainland Norway*, used by Statistics Norway and others, we will use the term to refer to Norway's non-petroleum economy, i.e. mainland industries plus ocean transport. This is done to highlight the measurable difference between total and non-petroleum output from the national accounts (see Appendix C).

6.1 Analysis of findings

Comparing the development of real Norwegian GDP per capita with our counterfactual, the riches of having an extractable petroleum resource are evident. Displayed in panel A of *Figure 17* is the output gain for the total Norwegian economy, measured as the difference between real and counterfactual GDP per capita in percentages of real GDP per capita. By this measure, Norway's economy has, since 1972, been an average of 15.6 % larger than it would have been had it not structured its economy for petroleum extraction. In the same period, the Norwegian mainland economy would have been an average of 12.4 % higher in the counterfactual scenario. As of 2014, these effects were 19.2 % and 6.7 %, respectively. In panel A we can observe a distinguishable cyclical pattern in the treatment effect, peaking in 1998, followed by a substantial decline leading up to the financial crisis of 2008. This provides an illustration of a petroleum-driven supercycle in the Norwegian economy that has inflated GDP per capita substantially relative to the counterfactual. It is worth noting that the peak in the treatment effect precedes the peak in petroleum production and net cash flows to the government by 6 and 10 years, respectively. This suggests that the contraction-phase of this supercycle is more mature than previously assumed.

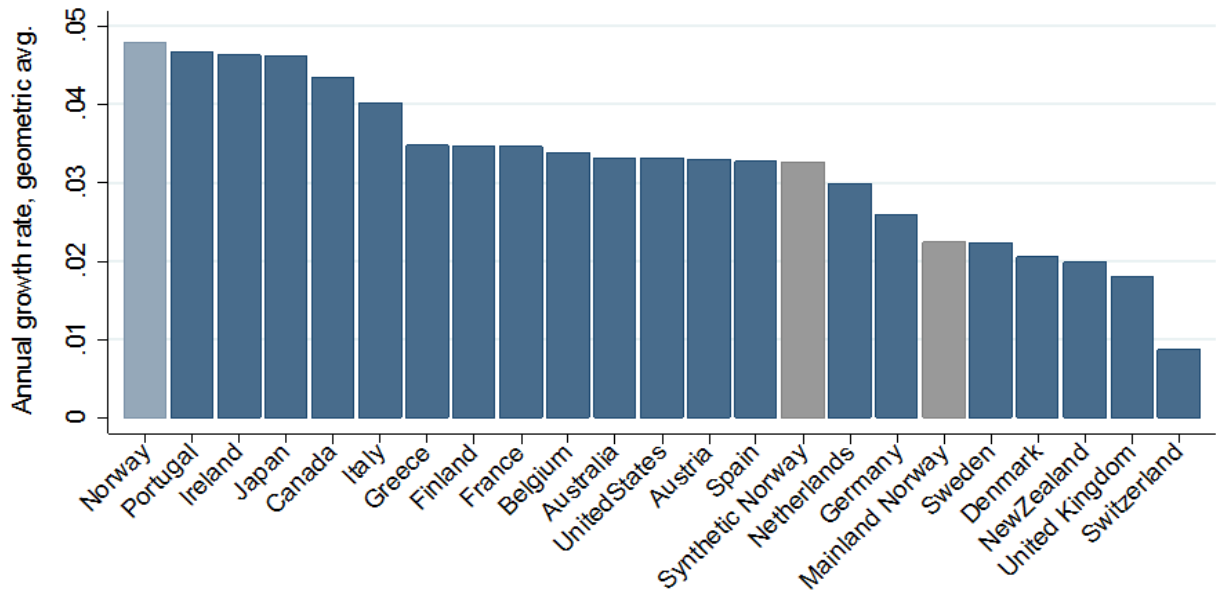
6.1.1 The total economy

Examining specific periods in detail, the initial investment period, lasting until 1975, saw a temporary negative effect on GDP per capita relative to the counterfactual. One explanation for this lies in the composition of early petroleum investments; of 150 billion NOK (in 2012 prices) invested, 90 % were imports. Although investments have kept rising since 1975, the import share has been substantially reduced, falling to a level between 40 and 60 %.⁶⁷ While the OPEC oil price shock of 1973/1974 resulted in low growth rates across OECD economies, the dawning petroleum industry shielded Norwegian industries from higher oil prices and enabled the government to run an expansionary fiscal policy with security in future oil revenues.⁶⁸ This had an immediate effect on economic growth. Already by 1980, we find that Norwegian GDP per capita was 10 % higher than what it would have been in the absence of a petroleum industry. Annualized GDP growth averaged 4.7 % in the period of 1972 to 1980, making Norway the

⁶⁷ See Eika, Prestmo & Tvetter (2010).

⁶⁸ See e.g. The Norwegian Ministry of Finance (2015).

**Figure 18:
Annualized growth in GDP**



Notes: Annual growth rates 1972 - 1980, geometric averages.

fastest growing OECD economy. As a comparison, our counterfactual Norway would have ranked 15th among OECD members over the same period, with an average growth rate of 3.2 % per year (*Figure 18*). The apparent asymmetric boom and bust cycles between Norway and synthetic Norway will be discussed in detail in part 6.1.4.

While non-petroleum industries were struggling throughout the 1990s, optimism soon returned to the petroleum sector. Between 1990 and 1993, investments in the petroleum sector rose from 20 % to 36.2 % of total investments in Norway. This introduced a second petroleum boom for Norwegian economy, resulting in a petroleum effect on GDP per capita peaking at 27.2 % in early 1998. Towards the end of the 1990s, export and capital markets facilitated high growth rates across all OECD countries. Despite petroleum extraction volumes not peaking until 2004, and net cash flows from the petroleum industry peaking in 2008, their contribution to Norwegian GDP growth was eclipsed by the international growth trends benefiting synthetic Norway since 2000.⁶⁹ This picture has sustained, as the difference between synthetic and real GDP has been reduced by a third since the peak in 1998. However, the development was halted by the financial crisis in

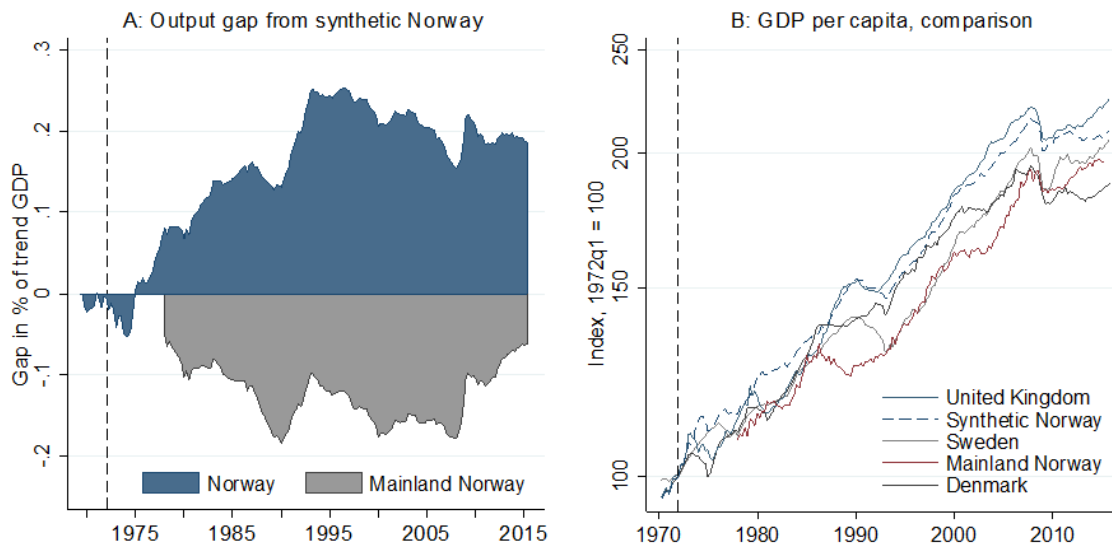
⁶⁹ A significant factor in synthetic Norway's high growth rate between 1997 and 2008 is the ICT-boom in Finland. However, the peak is identified in 1997/1998 in all placebo tests – including the leave-one-out iteration where Finland is excluded. The exact size of this peak is subject to scrutiny, but its timing is not.

2008, keeping real GDP per capita an estimated 19 % above the counterfactual through the first half of 2015.

6.1.2 The mainland economy

The other side of the coin is the performance of Norway’s non-petroleum economy, i.e. the mainland industries including the public sector plus ocean transport. Even though the outlook to future net cash flows from the petroleum industry gave leeway for expansionary fiscal policy in the 1970s, and demand from the growing petroleum sector was redirected towards domestic markets, the mainland economy did not show a similar growth rate as the total economy. In terms of GDP per capita, the level of mainland Norway’s output in 1980 is estimated to be 9 % lower than in the counterfactual. As labour and capital gravitated towards higher marginal products in the petroleum sector, fewer resources were left for production in the mainland economy. The resulting gap is evident as the difference between synthetic and mainland Norway (see panel B of *Figure 17* and panel A of *Figure 19*).⁷⁰

Figure 19:
Output gap from synthetic Norway and growth in comparisons countries



Notes: Panel A: Deviation between log of synthetic Norway and HP-filtered trends for Norwegian total and mainland GDP. Panel B: GDP per capita, indexed 1978q1 = 100. Logarithmic scale. Synthetic Norway is counterfactual Norway as described in part 5. Mainland Norway is all mainland sectors plus ocean transport. Series start in 1978q1.

⁷⁰ Although Statistics Norway does not make a distinction between the mainland and total economy in years prior to 1978, we utilize the fact that before the oil discoveries in 1969, no distinction was necessary (as we include ocean transport in our mainland estimates).

Looking at annualized real GDP growth between 1972 and 1980 (*Figure 18*), mainland Norway was on par with the growth rates of Sweden, Denmark and the United Kingdom, all of which economies that are frequently used as comparisons. However, these gravely underestimate Norway's potential for growth in the period. Given the level of resources and development in the pre-treatment period, Norway would have seen a higher growth in GDP per capita than the abovementioned trio, even in the absence of a petroleum sector. After recovering from the banking crisis by 1994, growth in mainland Norway outperformed both synthetic Norway and the Nordic neighbours. After growth picked up across OECD economies and synthetic Norway in the early 2000s, the output gap widened again. Seemingly, strong appreciation of the real effective exchange rate left mainland Norway unable to utilize the growing export markets in Europe. After the financial crisis in 2008, as the abovementioned export markets contracted, the gap has been reduced to less than 10 % of mainland trend GDP – a level not seen since the 1980s.

6.1.3 Resource movement

Using the terms of Corden & Neary (1982), the output gap between mainland Norway and the counterfactual is partly owed to a resource movement effect, albeit not one limited to resources moving between the manufacturing and service sectors, but rather from the mainland economy to the resource extracting sector.⁷¹

Although the petroleum industry employs less than 2 % of the total labour force, it has a significant effect on the Norwegian labour market. Specialized knowledge and high profitability within the sector has ensured bargaining power for its employees, resulting in high wages.⁷² This, in turn, would lead to increased spending and the boom dynamics presented in part 3.⁷³ High wages have also given the industry an advantage in competition for “the best and the brightest”, drawing highly productive labour away from mainland industries. These are employees that could

⁷¹The petroleum sector's demand for intermediate goods might also have had an adverse effect on domestic industries. Assuming that manufacturers cater to the industries with the highest willingness to pay, they would direct their activities towards the petroleum industry. This is indicated by the clusters of petroleum support industries located in south-west Norway. Although a higher real effective exchange rate has allowed competing industries to import production factors at lower prices, the net efficiency gains and losses from this allocation contributes to the gap between our counterfactual Norway and the mainland economy. The gap indicates that net profits from having a support industry comes in the form of increased output in the petroleum sector itself – not in its support industries.

⁷² Between 1995 and 2015, the petroleum sector employed an average of 1.6 % of the labour force, but accounted for 3.6 % of total labour costs in the Norwegian economy (Statistics Norway, 2015).

⁷³ The development in the petroleum industry has thus been a focal point in studies on the Norwegian labour market, e.g. Cappelen, Eika & Prestmo (2013).

have created innovations and developed existing industries in other sectors, slowing down the mainland economy relative to the counterfactual. Still, its modest share of the total labour pool makes it unlikely to explain a majority of the output gap to the counterfactual.

To this effect, capital investments might be an explanation. Since 1978, the petroleum industry has accounted for an average of 23 % of total investments in the Norwegian economy.⁷⁴ Still, in absence of a petroleum sector offering high returns on investment, both available funds and political willingness to invest would likely have been constrained. This is supported by a significantly higher investment rate in Norway than in the synthetic control throughout the period.⁷⁵ Thus, these funds overestimate foregone investments for non-petroleum industries.

In addition to resource movement effects, real effective exchange rate appreciation may have had adverse impacts on export-competing industries, further contributing to adjustments in Norwegian mainland industries. Although studies have suggested that the petroleum industry may have contributed to increased productivity in the mainland sector either through learning (see e.g. Bjørnland & Thorsrud, 2013), or by creating markets for specialized services and support industries, the aggregate effect on the total economy is ambiguous. As all production in mainland industries is included in mainland GDP, including those catering to the petroleum industry, any net benefits in these industries have been unable to eliminate the output gap relative to the counterfactual. This means that output in mainland Norway has been crowded out by the petroleum sector, raising concern for a future in which the petroleum industry is phased out.

6.1.4 Real and counterfactual Norway during crises

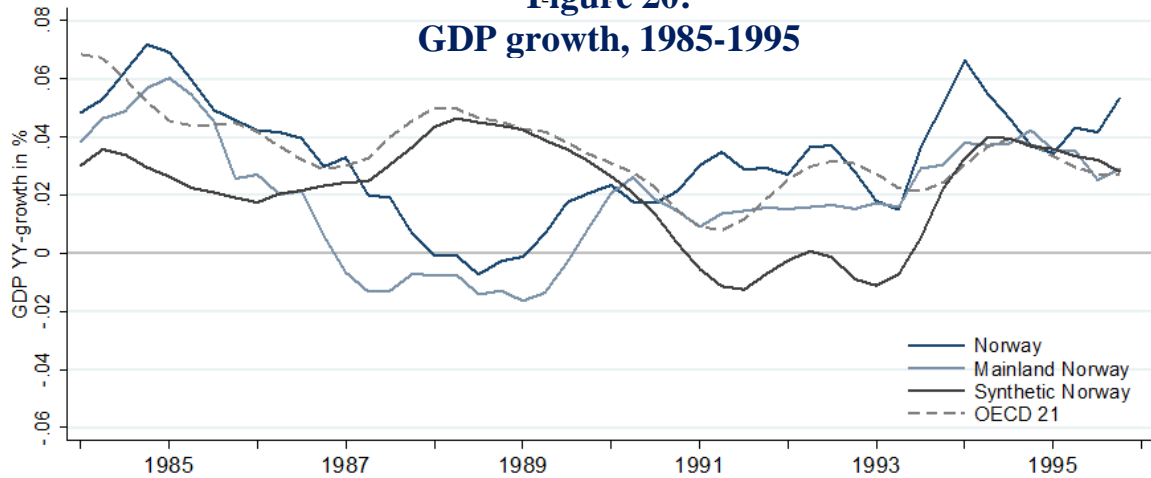
The crisis of 1987

As discussed in part 4, the Norwegian bust starting in 1987 was most likely inevitable, due to an unsustainable consumption growth since the late 1970s and financial instabilities following liberated credit markets. From *Figure 20*, we see that Norway would have seen negative growth rates entering the 1990s even in our counterfactual scenario, despite the petroleum industry seem

⁷⁴ The share of total investments is estimated from 1978q1 to 2015q2, due to missing quarterly data for prior years. Since 1971, over 4500 billion NOK have been invested in the petroleum sector (2016 prices). Of these, 329 billion NOK were invested between 1971 and 1978 (The Norwegian Ministry of Finance, 2015). This amount equals the total Norwegian investments in 1978.

⁷⁵ A two-sided t-test for differences in means in investment rates for Norway and synthetic Norway proves the former to be significantly larger than the latter (t-value 6.16).

**Figure 20:
GDP growth, 1985-1995**



Notes: Year-on-year growth in three quarter moving averages. OECD 21 is population-weighted average of all OECD countries, except Iceland, Luxembourg and Turkey - as explained in part 5.

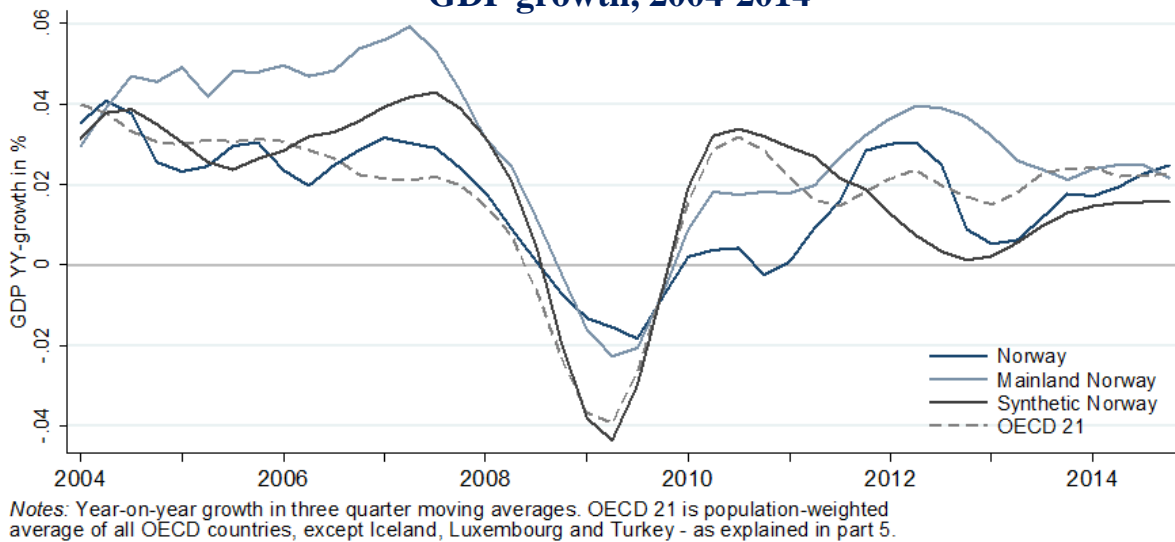
to have accelerated the bust. Petroleum revenues amplified growth in the preceding years, in line with consensus from existing literature, by 3 % to 4 % per year, before growth rates dropped with falling oil prices and contractionary fiscal policy from 1986.

Synthetic Norway sees its highest growth rates in the late 1988, when real Norway is in its fourth consecutive quarter with negative growth rates. The counterfactual would benefit from low oil prices, before being engulfed in the Nordic banking crisis from 1991, lagging the Norwegian bust by almost two years. The crisis hit both real and counterfactual Norway hard, with zero or sub-zero growth rates in 11 and 10 consecutive quarters, respectively.

The 2008 financial crisis

While the 1990s crisis was equally pronounced in both the actual and counterfactual scenario, although delayed, there are significant differences in the latest financial crisis. Leading up to 2008, synthetic Norway has growth rates slightly lower than the mainland economy. As growth rates dropped in response to the collapse in international financial markets, synthetic Norway sees GDP growth rates falling to -4 %, in line with the OECD average, while Norway contains negative growth at -2 %. There are at least two factors contributing to this difference. First, in the counterfactual scenario, the Norwegian economy would be more exposed to European export markets. Consequently, the impact of an international depression would be greater. Second, in 2008, Norwegian institutions had both monetary and fiscal policy at their disposal to counteract the negative impulses from international markets. A major difference from the crisis in 1987 was the institutional capabilities, of which the sovereign wealth fund was a significant contribution.

**Figure 21:
GDP growth, 2004-2014**



A positive net fiscal position and its own currency in 2008 was a luxury Norway did not share with most European economies, not least the counterfactual (of which 3 of 4 donor countries are members of the European Union). These factors can all be derived from the petroleum resource, indicating a wider impact of oil in the Norwegian economy than what is visible through its contribution to GDP per capita.

6.1.5 Comparison with earlier studies

In the 1996 counterfactual study of Cappelen, Choudhury and Eika, the petroleum sector was estimated to have increased Norwegian GDP by 29 % on average in the 20-year period of 1973 – 1993. Furthermore, GDP in 1993 was an estimated 51 % higher than in the absence of petroleum, equalling a 2 % contribution to annual growth.⁷⁶ Comparing this to our synthetic control, we find their study to greatly overestimate the significance of petroleum to Norwegian GDP. Our findings indicate the Norwegian GDP to be 19.5 % higher than the counterfactual in 1993 (the mainland economy is 10 % smaller), while the average contribution to GDP per capita averaged 10.7 % per year over the period. This translates to an annualized contribution to growth equal to 0.9 %.

Furthermore, the Cappelen et al. (1996) claim that Norway without petroleum would have been quite similar to the European average, with somewhat lower consumption, less Dutch disease-

⁷⁶ They also claim that the petroleum sector increased mainland GDP by 19 % in this period.

symptoms and a smaller public sector.⁷⁷ Moreover, they state that economic growth between 1973 and 1993 would have been significantly lower than in other OECD countries – amounting about half the average OECD growth rate (or ½ percentage point lower growth rate year-on-year than OECD). This coincides with our findings, as the synthetic growth level is, for the most part, lower than the 21 OECD countries in our sample.

In a recent study, Eika and Martinussen (2013) estimated that 20 % of mainland GDP growth between 2003 and 2012 came from higher oil prices and increased activity in the petroleum sector. During this period, mainland GDP converged on that of synthetic Norway, although not surpassing it until after the financial crisis. We are unable to decompose the contributions to growth using our methodology. If a significant part of mainland GDP growth in this period is attributed to an increased dependency on the petroleum industry, a future downscaling of the petroleum industry would require large restructuring of mainland industries.

6.2 Future implications

In this part we use counterfactual Norway to study three possible future scenarios for the long-term level of Norwegian GDP per capita, when the petroleum impulse in the Norwegian economy is gradually reduced. We assume synthetic Norway to follow projected growth rates for advanced economies provided by the OECD (2012).⁷⁸ These imply a somewhat lower future growth rate than what has been seen over the past decades, caused by an ageing population and lower future growth potential in countries with high productivity. Following this, we discuss the adjustment towards a post-petroleum economy, considering cost of adjustment and different policy measures. The latter is illustrated with two policy responses named the “reluctant alternative” and the “sustainable alternative”. This part may also serve as a motivation for future studies on the adjustment towards a non-petroleum economy.

⁷⁷ Former Central Bank governor, Svein Gjedrem, argues that Norway had all the symptoms of a Dutch disease in the 1980s, and was not cured until the late 1990s. He has repeatedly warned of potential dangers that come with high resource revenues, some of which are related to issues we discuss in this thesis (Gjedrem, Economic perspectives [Økonomiske perspektiver], 2001).

⁷⁸ Specifically, we use the forecasted growth rates for the underlying economies (Belgium, Finland, New Zealand and Sweden), weighted with their respective contributions to synthetic Norway. Unless otherwise noted, growth rates for Norway and real Norway are illustrative.

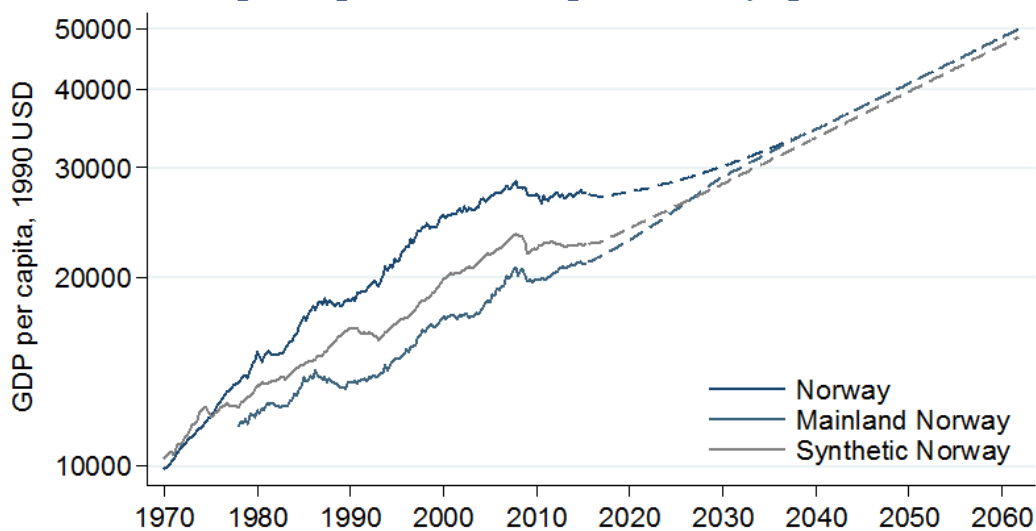
6.2.1 Future scenarios

Scenario 1: Productivity spillovers

Starting with the potential success story of the Norwegian oil adventure, we follow the legacy of Bjørnland (2013) and Cappelen, Eika and Prestmo (2013), among others. In this scenario, there are shared productivity dynamics, where learning-by-doing and productivity expertise (knowhow) from the high-tech petroleum industry have substantial spillover effects to the mainland industries (Bjørnland & Thorsrud, 2013). Furthermore, the competence and business concepts related to the petroleum industry can be utilized in other industries when the petroleum sector is downscaled, without incurring large restructuring costs (Cappelen et al., 2013).

In this sense, a gradual downscaling of the petroleum industry would transfer both productive labour and a significant amount of capital over to the mainland economy. In addition, existing support industries will direct their production towards the mainland economy. While the growth impulse from the petroleum industry on the Norwegian economy will be gradually reduced, productivity in the mainland economy increases, raising the growth rate of mainland GDP. If the productivity spillovers from the petroleum industry to the mainland industries are persistent, and these industries can utilize the technology and competence “released” from the petroleum sector, the total- and mainland GDP are likely to converge on a higher level than that of the

Figure 22:
GDP per capita forecasts, productivity spillovers



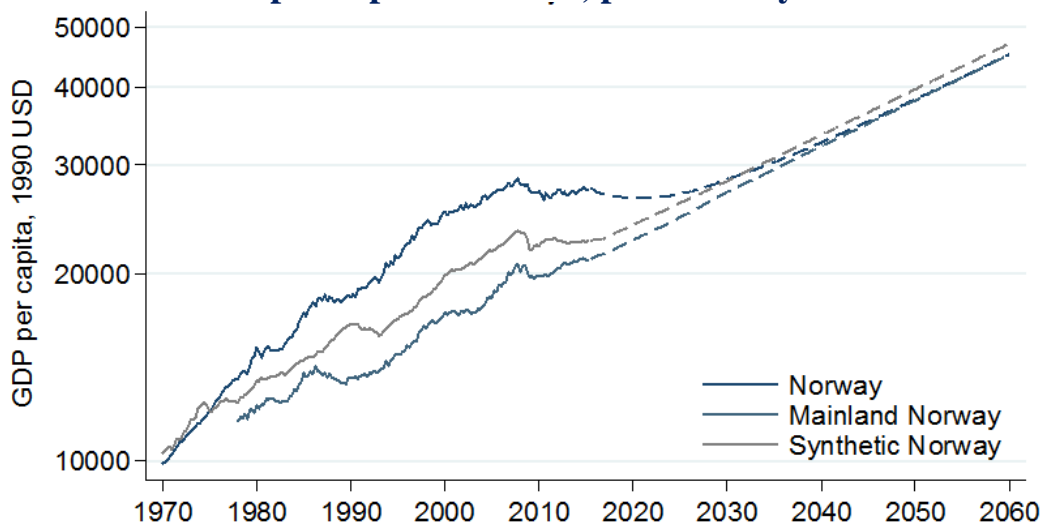
Notes: Growth in synthetic Norway is equal to 2005q2 - 2015q2 average until 2017. From 2017 to 2030 we use a synthetic-weighted average of OECD estimates for long-term GDP per capita growth: 1.64 % p.a until 2030 and 1.72 % until 2060. Growth rates for Norway and Mainland Norway are illustrative. Logarithmic scale.
Source: OECD (2012)

counterfactual, as illustrated above. However, this scenario seems somewhat unrealistic as the growth rate of the Norwegian mainland economy would have to be 2.2 % in the transitional phase. This would imply the same level of growth as predicted growth rates for countries with high growth potential such as Poland, Slovakia, Hungary and Mexico (OECD, 2012).

Scenario 2: Productivity loss

The second scenario paints a more pessimistic picture of the post-petroleum economy, in line with classical Dutch disease literature and empirical literature on impulse responses from the petroleum demand on the mainland economy.⁷⁹ One example from the Norwegian tradition is Eika, Prestmo and Tveter (2010), claiming that a gradual downscaling of the total resource demand from the petroleum sector from 18.5 % to 10 % of mainland GDP towards 2019 would result in a yearly, negative demand impulse of 0.6-0.85 % of mainland GDP. Moreover, if the classical Dutch disease effects of a downsized manufacturing industry are valid, combined with no spillover effects of productivity expertise from the petroleum industries to the mainland industries, mainland industries have reduced its productivity over the past 45 years.

**Figure 23:
GDP per capita forecasts, productivity loss**



Notes: Growth in synthetic Norway is equal to 2005q2 - 2015q2 average until 2017. From 2017 to 2030 we use a synthetic-weighted average of OECD estimates for long-term GDP per capita growth: 1.64 % p.a until 2030 and 1.72 % until 2060. Growth rates for Norway and Mainland Norway are illustrative. Logarithmic scale.
Source: OECD (2012)

⁷⁹ See e.g. Eika, Prestmo, & Tveter (2010) and Cappelen, Eika, & Prestmo (2013; 2014).

As noted in part 2, Bjørnland's (1998) findings of the manufacturing output benefitting from an energy boom could in fact indicate that the tradable industry has become more "oil-dependent", as their activities have been more directed towards the petroleum industry than in the counterfactual event (Torvik, 2015). As such, the consequences of a reduction in the demand impulse from the mainland economy could be even more severe than first anticipated. Thus, re-establishing the productivity level of these industries after the petroleum industry has been phased out will result in a persistently lower growth path for Norwegian GDP than the synthetic Norway.

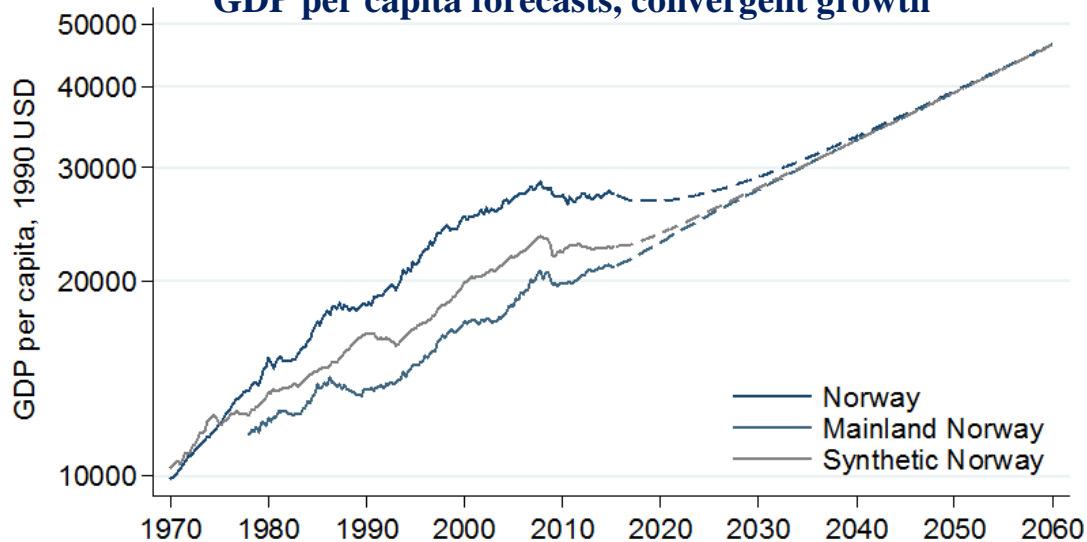
Note that the OECD forecasts draw a picture of an increasing negative gap between the synthetic Norway and the mainland economy, indicating an expectation of the Norwegian productivity level progressively lagging behind towards 2060.⁸⁰

Scenario 3: The "diplomatic" scenario

A perhaps more realistic scenario is the combination of both scenarios presented above. While some of the technical expertise and business concepts can be utilized in other industries, others are closed down and forgotten. Not knowing which of the two effects that will dominate, we move on to the next part assuming that in the long term, Norwegian GDP will converge on synthetic GDP. Here, the negative impulse of reduced demand from the petroleum sector will adjust Norwegian GDP per capita to a trajectory below its long-term potential (represented by the counterfactual), while the positive impulse from released capital and labour as well as new productive concepts directed towards the mainland industries, will raise mainland GDP to a level higher than initially, resulting in a convergence to the counterfactual.

⁸⁰ See *Figure 35* in Appendix C.

**Figure 24:
GDP per capita forecasts, convergent growth**



Notes: Growth in synthetic Norway is equal to 2005q2 - 2015q2 average until 2017. From 2017 to 2030 we use a synthetic-weighted average of OECD estimates for long-term GDP per capita growth: 1.64 % p.a until 2030 and 1.72 % until 2060. Growth rates for Norway and Mainland Norway are illustrative. Logarithmic scale.
Source: OECD (2012)

6.2.2 The adjustment process

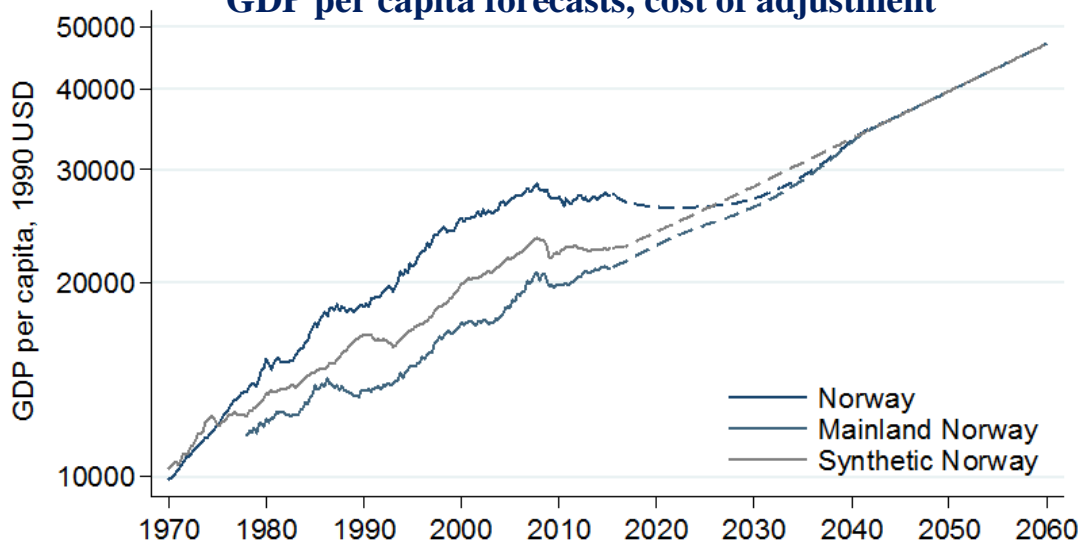
Using the illustration from the “diplomatic” scenario, we illustrate the implications of adding cost of adjustment to the process, where Norwegian total- and mainland GDP gradually converges on synthetic Norway. Then, we expand this discussion with two possible policy responses.

Cost of adjustment

When the petroleum industry is phased out the labour force available for production in mainland industries will increase by 2 %, or approximately 60 000 workers.⁸¹ This increase will have its largest effect on the labour intensive non-tradable sector: Whereas labour is no longer scarce, real wages are expected to fall. Furthermore, a depreciating real effective exchange rate will enable production of tradable goods to increase. Thus, even though domestic demand falls when income from the petroleum sector decreases, production in both the tradable and non-tradable sector rises. This is illustrated by an increased growth rate in mainland GDP after the petroleum sector is phased out, as in part 6.2.1.

⁸¹ The share of the labour force employed in petroleum industries, i.e. petroleum extraction including services and pipeline transport, gathered from national accounts (Statistics Norway, 2015).

**Figure 25:
GDP per capita forecasts, cost of adjustment**



Notes: Growth in synthetic Norway is equal to 2005q2 - 2015q2 average until 2017. From 2017 to 2030 we use a synthetic-weighted average of OECD estimates for long-term GDP per capita growth: 1.64 % p.a until 2030 and 1.72 % until 2060. Growth rates for Norway and Mainland Norway are illustrative. Logarithmic scale.
Source: OECD (2012)

Introducing costs of adjustment, this transformational process would be more time-consuming, resulting in a prolonged period of reduced production in the mainland industries. As training costs would demand both a training period for new workers, as well as a temporary withdrawal of skilled labour from production, the new output level must be lower than its potential.⁸² Consequently, the adjustment towards a long-term level of Norwegian non-petroleum GDP would temporarily decelerate growth in the mainland economy, inducing a “dip” in the slope of the total economy, before it again stabilised at a new level.

Policy responses

In the case of a gradual downscaling of the petroleum industry, with increased unemployment and reduced net cash flows from the petroleum sector, politicians and decision makers may be tempted to respond to calls for policy measures alleviating the troubled industry. In this case, policy responses of an expansive character, such as industry subsidies or higher government consumption, would prolong the adjustment process needed to reach the new

⁸² In reference to Steigum’s (1988) framework, presented in part 3, this would result in a production allocation on the inside of the Production Possibility Frontier.

sustainable equilibrium.⁸³ Thus, fiscal policies aimed at promoting a restructuring of the economy (for example through reducing industry subsidies), would not reduce adjustment costs in the short run, but allow gains to materialize in the long run (The Norwegian Ministry of Finance, 1988). Furthermore, expansive policy measures would require financing, either through funds drawn from the sovereign wealth fund or by increasing public debt (i.e. funded by future generations), or by reducing taxes.⁸⁴ Combined with the predicted government net cash flow from petroleum production approaching zero in 2060, as well as an aging population (dramatically termed “the grey wave”), this would put a significant strain on public finances (The Norwegian Ministry of Finance, 2015). Consequently, policy measures that prolong the adjustment process while adding to the future fiscal burden are ill-conceived.

The adjustment processes following a downscaling of the petroleum sector will depend, to some extent, on policy responses. We illustrate the consequences following two different alternatives to policy response, denoted as the “reluctant scenario” and the “sustainable scenario”.

The reluctant scenario

It might be an attractive goal for politicians to intervene in order to ease the downscaling of the petroleum industry. Although a reduction in (future) revenues from the petroleum sector would require a reduction in public spending, temporarily higher budget deficits (even within the frames of the fiscal policy rule) might be deemed necessary to keep unemployment rates low. Such policies have proved effective in the past and are likely to keep unemployment rates low, relative to a scenario in which no action is taken (The Norwegian Ministry of Finance, 1988). However, as it will take more time before the relative product wages adjust to the new equilibrium, the process of moving labour from the petroleum sector to the mainland economy is slowed down. As the adjustment process is prolonged, the period of temporarily increased unemployment and lower growth rates for the mainland economy will be prolonged.

⁸³ Given the structural budget deficit $b^* = \frac{B^*}{Y^*} = \frac{B-K}{Y^*}$, where B is the actual budget balance, K is corrections, Y is GDP and $*$ denotes the normal or structural level of each variable, the optimal target for the ministry of Finance is $b = b^*$ to remain stable through time. Our analysis is predominantly related to future levels of Y^* , whereas policy responses discussed, would affect B and K , potentially deviating from B^* .

⁸⁴ In the presence of adjustment costs, running a budget deficit in the adjustment period would be an optimal response. Increased public debt to smooth the transition can be shown to be beneficial, also in an intergenerational perspective. See Steigum and Thøgersen (2003).

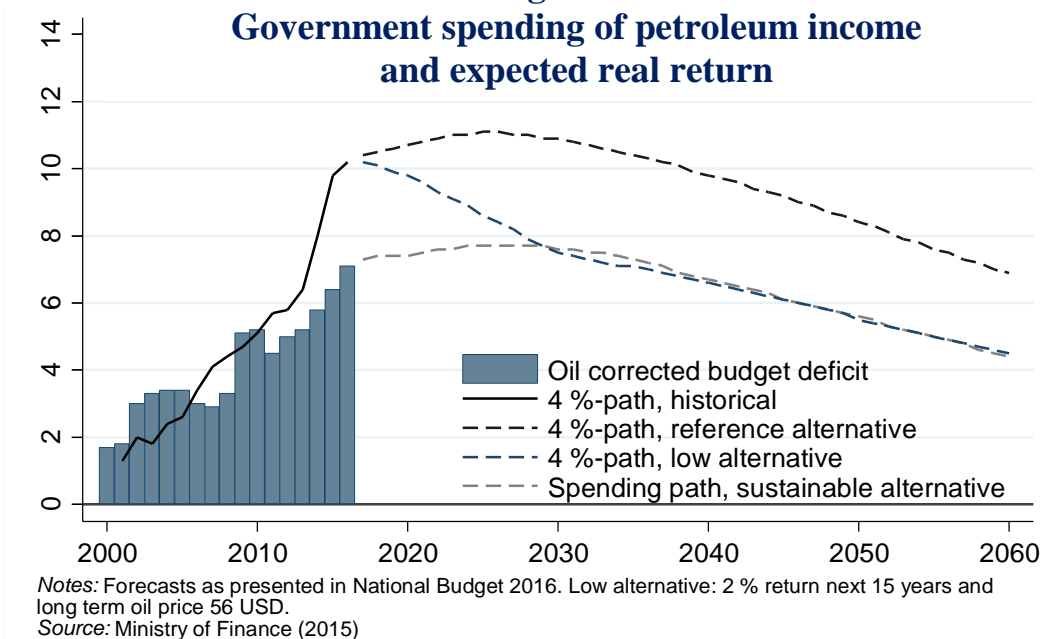
Similarly, while the current share of petroleum income in government spending is far below the 4-percent path given in the fiscal policy rule, a mechanical interpretation would allow for increased government expenditures/reduced taxes in the coming years. Such an increase would soon reach the four-percentage “roof”, making any further increases incompatible with the fiscal policy rule. As the underlying expenditures are expected to grow due to an aging population, this would force a reduction in other government expenditures (The Norwegian Ministry of Finance, 2015).⁸⁵

The sustainable alternative

An alternative scenario is that government expenditure growth is instead smoothed so that the use of petroleum income does not increase as a percentage of GDP in subsequent years. In this case, the downscaling of the petroleum sector will reduce private consumption and increase unemployment rates substantially in the short run. Although more painful in the short term, the adjustment towards a new equilibrium will go faster than in the reluctant scenario, as factor prices will reflect a sustainable level of factor employment. Consequently, both production and private consumption would eventually rise, increasing the growth rate of the mainland economy. By allowing these structural adjustment processes, the productivity level in the mainland economy will stabilize sooner, reducing the relative importance of the sovereign wealth fund (The Norwegian Ministry of Finance, 2015).

⁸⁵ The middle alternative of Statistics Norway’s population projections from June 2014 assume that the number of people over the age of 67 relative to the working stock will double towards 2060 (Statistics Norway, 2014).

**Figure 26:
Government spending of petroleum income
and expected real return**



Furthermore, smoothing government spending of petroleum income will facilitate a sustainable development in taxes and public services. As illustrated in *Figure 26*, a few years of increased spending of the petroleum wealth is expected to be followed by many years with a gradual reduction in the oil corrected budget deficit. Moreover, as public expenses will rise with an ageing population, a reduction in non-age related government spending will be required. By not increasing petroleum wealth spending, the “grey wave” can be met by a smoother downscaling of non-age related expenditures. Otherwise, there is no more room for increasing the phasing in of petroleum income when the “grey wave” occurs. Thus, “cutting” the temporary top of the 4-percent path seems reasonable (The Norwegian Ministry of Finance, 2015).

7 Conclusion

This thesis has summarized theoretical and empirical contributions on the relationship between resource discoveries and the development in the rest of the economy. It has aimed to provide an empirical analysis of how the Norwegian economy has been affected by the evolution of its petroleum sector the previous 45 years.

Studying the macroeconomic responses to resource price booms and -busts in two resource economies, Norway and Australia, and a non-resource economy, Sweden, we find that the variables in the resource economies largely behave as predicted by a theoretical two-sector model (The Norwegian Ministry of Finance, 1988). As expected from the relatively larger importance of the Norwegian petroleum industry, the effects are more pronounced in Norway than in Australia. The responses have also changed through time, as with the linkage between real effective exchange rate (REER) and the oil price. In accordance with the model, the REER responds to booms by appreciating and, vice versa, with the opposite sign in Sweden. With floating exchange rate regimes, this linkage is more pronounced, thus shielding the remaining economy. Other institutional effects, such as a budgetary rule, sovereign wealth fund and inflation target setting might also have contributed to this effect. Trade balances also behave in the predicted fashion, with import volumes increasing substantially during booms, and contracting during busts. An exception is Australia during the current commodity price bust, experiencing a substantial fall in non-resource exports relative to imports, indicating Dutch-disease symptoms.

Contrary to the predictions from the theory of cost of adjustment (Steigum, 1984), Norwegian unemployment does not seem to increase during these price booms and -busts, but follow a similar pattern as in Sweden and thus the general business cycle. This also seems to be the case for Australian unemployment. A reduction in manufacturing employment is evident in all three countries, indicating a development in line with a more general trend. Furthermore, our findings support that, in particular, employment in business related and real estate services is positively affected by resource price booms, in line with other industries directing their services towards the booming petroleum sector. As expected, there is a higher government spending level in Norway and Sweden than in Australia. However, while Swedish public spending saw a substantial decline through the 1980s, the Norwegian public spending remained about the same level. Seemingly,

our petroleum wealth has reduced the need for cutting back on public expenditures and restructuring the public sector in Norway.

Using a weighted average of Belgium, Finland, New Zealand and Sweden, we have estimated the Norwegian GDP per capita for a counterfactual scenario in which petroleum resources was not discovered on the Norwegian continental shelf. We find that, since 1972, real Norwegian GDP per capita has been an average of 15.6 % larger than it would have been had it not structured its economy for petroleum extraction. Over the same period, the Norwegian mainland economy is an average of 12.4 % smaller than in the counterfactual scenario. The impact of a petroleum industry on economic growth is most pronounced between 1972 and 1980: While Norway was the OECD's fastest growing economy, the counterfactual ranked 15th. As growth in mainland- and counterfactual Norway stagnated during the banking crisis of the early 1990s, the petroleum industry facilitated a high growth rate for the Norwegian economy. We find a petroleum-driven supercycle that has inflated GDP per capita substantially, reaching a record high 27.2 % above the counterfactual by 1998. The difference has since been reduced by a third, suggesting a contraction of the petroleum supercycle in the Norwegian economy, which is more mature than previously assumed. However, convergence has been temporarily postponed by the financial crisis in 2008.

Annualized real GDP growth between 1972 and 1990 for mainland Norway was on par with the growth rates of Sweden, Denmark and the United Kingdom, countries frequently used as comparisons. However, we find that mainland Norway would have seen a higher growth in GDP per capita than the abovementioned trio, in the absence of a petroleum sector. From the early 2000s, the counterfactual scenario has developed more in line with the growth rates of these countries. Our findings also indicate that investment levels would have been lower in the counterfactual Norway, and that net benefits from the petroleum sector on the mainland economy is unable to eliminate the output gap relative to the counterfactual development. This means that output in mainland Norway has been crowded out by the petroleum sector, raising concern for a future in which the petroleum industry is phased out.

Studying the crisis in the 1990s, the downturn in counterfactual Norway would have been equally pronounced as in mainland Norway, although delayed by two years. Benefitting from low oil prices in the late 1980s, the crisis would not have entered until 1991. However, in the latest

financial crisis, growth rates would have been 2 percentage points lower in the counterfactual scenario, in line with the OECD average (– 4 %). As such, being more exposed to the world export demand, the impact of an international depression would have had a greater impact in a Norway without oil.

As a motivation for future studies, we also discuss three possible, future scenarios for the Norwegian, long-term level of GDP per capita when the petroleum sector is gradually phased out. Depending on whether productivity spillover effects or Dutch disease- and reduced demand impulse effects from the petroleum sector are dominating, the GDP per capita trajectory would end up above or below the synthetic, long-term level. Furthermore, we illustrate that cost of adjustment would result in a prolonged period of reduced output in the mainland industries, temporarily decelerating growth in the mainland economy before converging to its long-term potential. Moreover, expansive fiscal policy responses could prolong the adjustment process needed to reach a new, sustainable equilibrium. Combined with the reduction of government net cash flows from the petroleum sector and the coming “grey wave” of an aging population, this would put significant strains on public finances. Thus, smoothing government spending of the petroleum wealth by “cutting” through the temporary top of the four-percentage path, would be in line with sooner stabilization of the mainland economy as well as a sustainable development in taxes and public services.

Appendix

We have split our Appendix into three parts. Appendix A is related to part 4 of the thesis, the comparative analysis between Norway, Sweden and Australia, Appendix B is related to part 5, synthetic control method and Appendix C is related part 6.

Appendix A

A.1 Data sources

For our cross-country comparisons, we use a wide range of quarterly indicators from each country's national accounts, supplied with data from the OECD, World Bank or UN Comtrade database when necessary.

- Australian mining investment. (National currencies, constant prices). Capital expenditure in the mining sector. Source: Australian Bureau of Statistics (ABS).
- Commodity price index. (2012 = 100). Export-weighted index of non-rural commodities in US dollars. Monthly data converted to quarterly by taking 3-month averages. Deflated using GDP-deflator. Source: Reserve Bank of Australia.
- Employment. (Index). Employment by sector, time series. Sweden and Australia are OECD-numbers. Sources: Statistics Norway (SSB) and Macrobond.
- Government spending, less transfers. (National currencies, constant prices). Government consumption from national statistics, plus general government gross fixed capital formation. Sources: Statistics Sweden (SCB), SSB, ABS and Macrobond.
- Gross domestic product. (PPP, 2012 USD). Quarterly, seasonally adjusted GDP series from OECD Economic Outlook. Starting in 1960q1, used for long-term trend estimation. Sources: Macrobond.
- Gross domestic product. (National currencies, constant prices). From national accounts of respective countries, seasonally adjusted using the procedure described in appendix A.2.1. Australia and Sweden at chained volume measures. Norway in 2012 NOK, excluding petroleum and ocean transport. Sources: SCB, SSB and ABS.
- Petroleum production. (Million tonnes oil equivalents). Annual series from the Statistical Review of World Energy. Sources: British Petroleum, 2015.

- Real effective exchange rate. (Index). Multilateral trade-weighted effective exchange rate index. Monthly series converted to quarterly by taking quarterly means. Source: Bank of International Settlements.
- Real investments. (National currencies, constant prices). Gross fixed capital formation from national accounts. Seasonally adjusted using the procedure described in appendix A.2.1 Sources: ABS, SCB and SSB.
- Real oil price. (Real US dollars per barrel). Average price of WTI, Dubai and Brent. Source: World Bank.
- Real wages. (Index). Sectoral wage costs divided by work hours before taking logs. Rebased indexes. Sources: SCB, SSB and ABS.
- Terms of trade. (Index). Combining unit-price indices for imported and exported goods.⁸⁶ Sources: SSB, SCB and ABS.
- Trade balance. (National currencies, constant prices). Converted from monthly to quarterly averages for Sweden and Norway. Sources: SSB, SCB and ABS.
- Trade composition. (Million US dollars, current prices). Trade data from the United Nation's Comtrade database, found at <http://wits.worldbank.org>. Converted to constant prices using US GDP-deflator. Source: United Nations.
- Unemployment. (Percentage of working population). OECD estimates from the annual Economic Outlook series. These estimates are consistent with those of the International Labour Organization, and are comparable across countries. Comparing with Norwegian national accounts, they are consistent with survey-measured unemployment (AKU). Thus, workers on (temporary) leave and long-term unemployed are not part of this statistic. Source: Macrobond.

⁸⁶ For a thorough explanation of unit price indices, see United Nations (1981).

A.2 Methodological Approach

Acknowledging that the empirical results of our analysis might be influenced by the specification of our dataset, we clarify the different assessments and methodological choices that have been made in the process.

A.2.1 Seasonally adjusting

The Swedish and Norwegian GDP series show monotonic seasonal fluctuation for the whole time period, and is thus seasonally adjusted in one step for the whole period. The GDP series of Australia also show strong seasonal variation, but these seasonal fluctuations differ in magnitude across the sample, with larger amplitudes between 1960 and 1990. Therefore, we split the series in two periods, 1960-1990 and 1990-2015, before seasonally adjusting.

The time-series can be decomposed into:

$$Y_t = S_t * C_t * L_t * I_t, \quad (\text{A.1})$$

where L_t denotes long-term trend (which is allowed to change through time), S_t the seasonal component, C_t is cyclical variation and I_t is noise. Time-series plots of our series confirm that seasonal variation is monotonic over quarters. Consequently, we remove noise and seasonal effects by taking four quarter moving averages:

$$YLC_t = L_t * C_t = \frac{1}{4} \sum_{t=t-1}^2 Y_t, \quad (\text{A.2})$$

and isolate seasonal and noise components by:

$$S_t * I_t = \frac{Y_t}{YLC_t} = YSI_t. \quad (\text{A.3})$$

Then, we find a seasonal index by:

$$S_q = \frac{4}{T} \sum_{t=2}^T YSI_t * \delta_q ; q \in \{1,4\}, \quad (\text{A.4})$$

where δ_q is a quarterly indicator, so that S_q is the average of all YSI_t for quarter q . Normalizing S_q to sum to one by $S_t = \frac{S_q}{S}$, we find the seasonally adjusted series $YLCI_t$ as:

$$YLCI_t = \frac{Y_t}{S_t}. \quad (\text{A.5})$$

A.2.2 Estimating trend

We follow standard economic theory and assume output to be fluctuating around long-term trends that slowly change, where deviations from trend represent an over- or underutilization of resources that give cause to unbalances in the economy. We use the Hodrick-Prescott filtering (HP-filter) technique to calculate the technical trend in GDP. The method allows for gradual changes over time, and is widely used for decomposing seasonally adjusted time-series into a trend component and a cyclical component.

The Hodrick-Prescott filter, presented in Hodrick and Prescott (1997), isolates a seasonally adjusted time series y_t into a cyclical- and a trend (growth) component by minimizing the following problem:

$$\min_{\{g_t\}_{t=-1}} \left\{ \sum_{t=1}^T c_t^2 + \lambda \sum_{t=1}^T [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \right\}. \quad (\text{A.6})$$

Here, c_t is the cyclical deviation from the long-term growth g_t , and $c_t = y_t - g_t$. y_t is the natural logarithm of the time-series to ensure that changes in the growth component corresponds to a growth rate. λ is a parameter which penalizes deviations from the long-term growth of the series. As λ approaches infinity, the trend approaches linearity. The appropriate λ can be shown mathematically to depend on the true variance of the growth and cyclical components of the series. In a 1997 paper, Hodrick and Prescott recommends $\lambda = 1600$ for quarterly GDP data for the United States, based on their prior views on what would be deemed as “moderately large” variation in quarterly GDP – a statement that has since been subject to scrutiny. More sophisticated methods to determine an appropriate λ *ex-ante* have since been developed. However, in a cross-country comparison of such methods, $\lambda = 1600$ was still found to be appropriate for quarterly GDP for most OECD-countries – including Australia (Marcet & Ravn, 2003).

Thus we elect $\lambda = 1600$ for estimates of the Swedish and Australian output-gaps. As is customary in Norges Bank’s own estimates of the Norwegian output gap, we set λ to 40 000 for Norwegian quarterly data (Sturød & Hagelund, 2012).

By selecting different lambda values between countries, there will be some deviations in estimated trend growth between periods. However, redoing the analysis with alternative lambda

values does not alter the findings substantially. The only exception being Sweden, where the financial crisis of the 1990s is largely being explained by the trend component when $\lambda = 1600$.

A.3 Plots

Figure A27:
Resource prices and investments

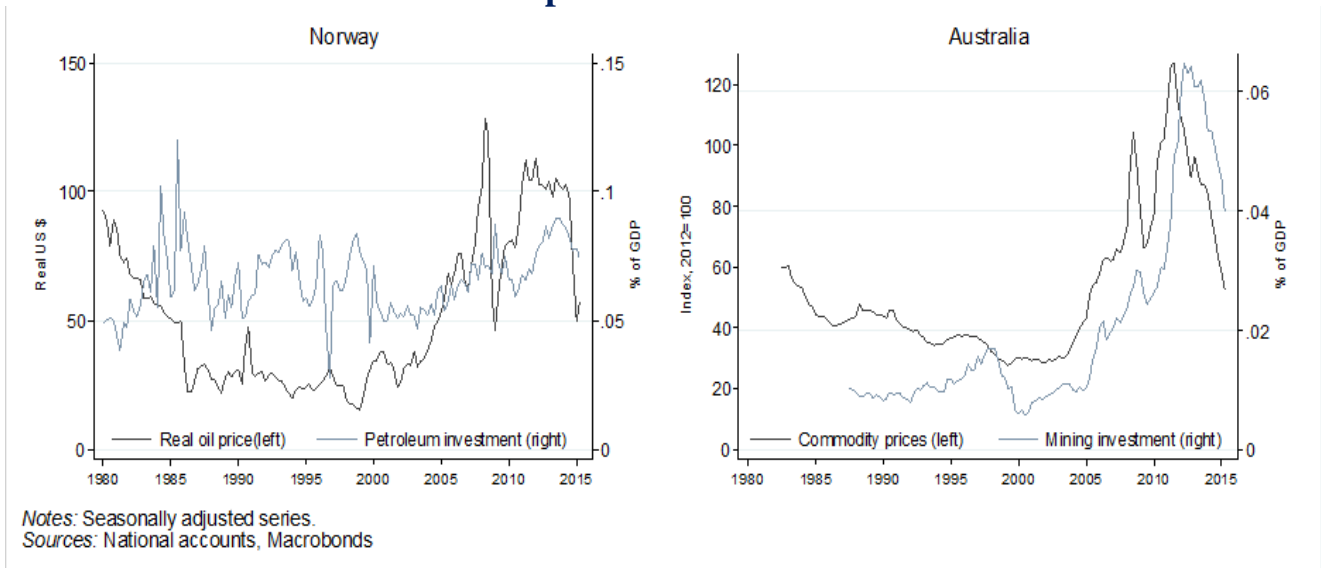
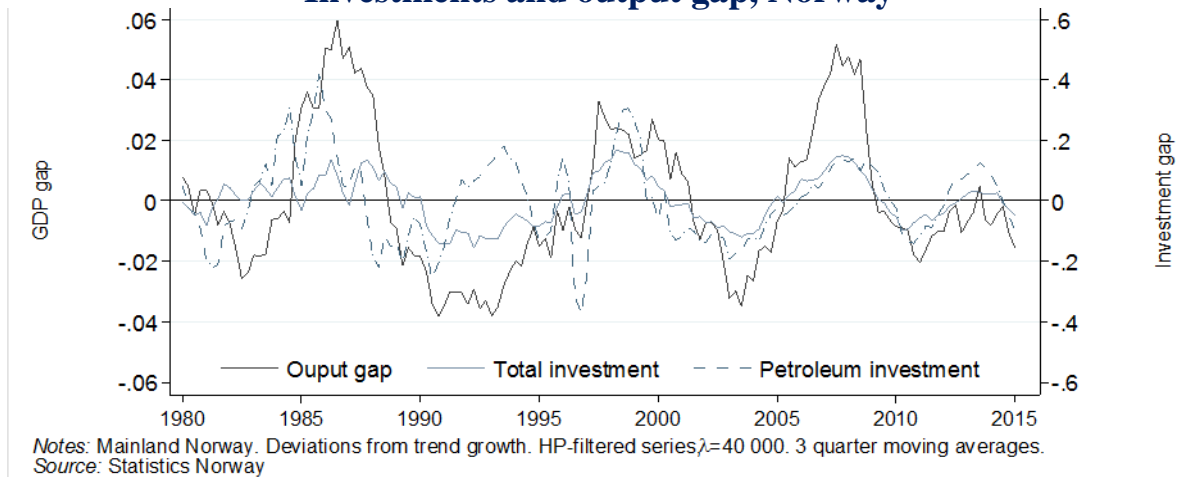
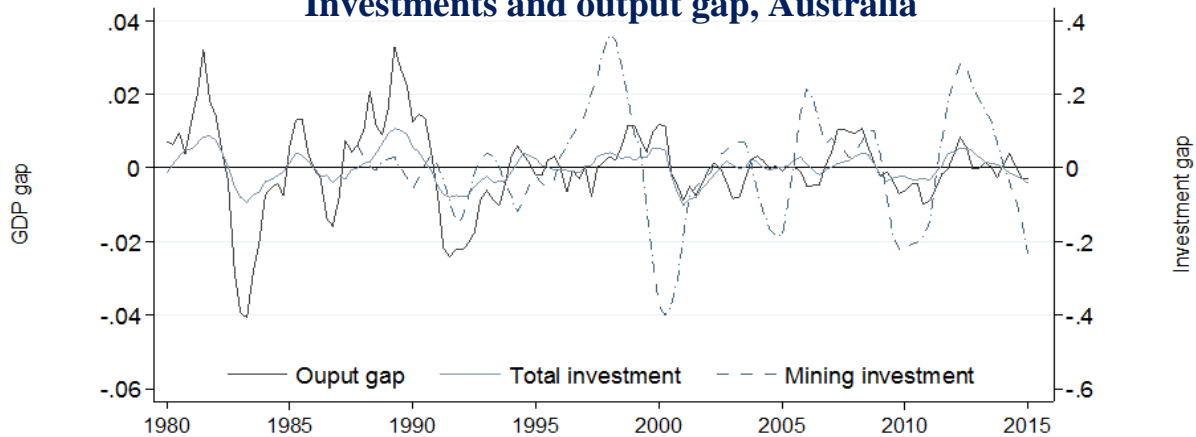


Figure A28:
Investments and output gap, Norway

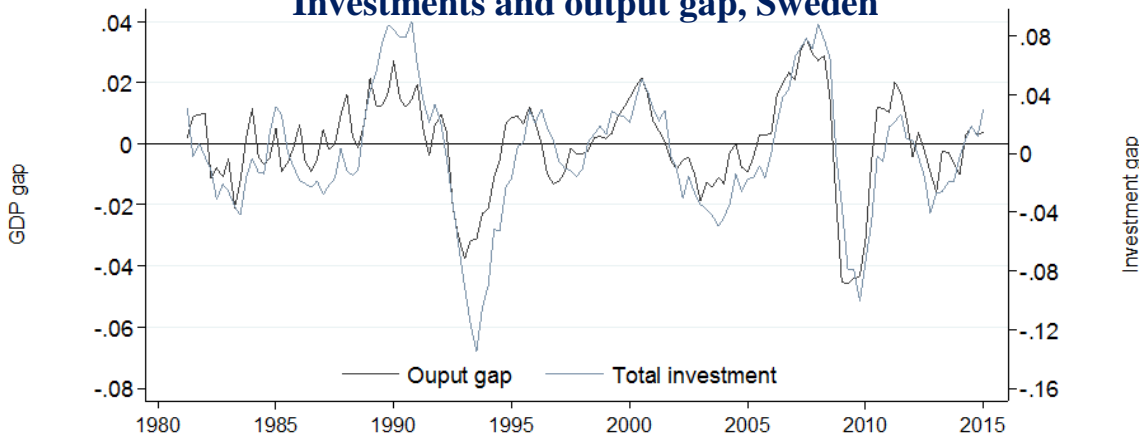


**Figure A29:
Investments and output gap, Australia**



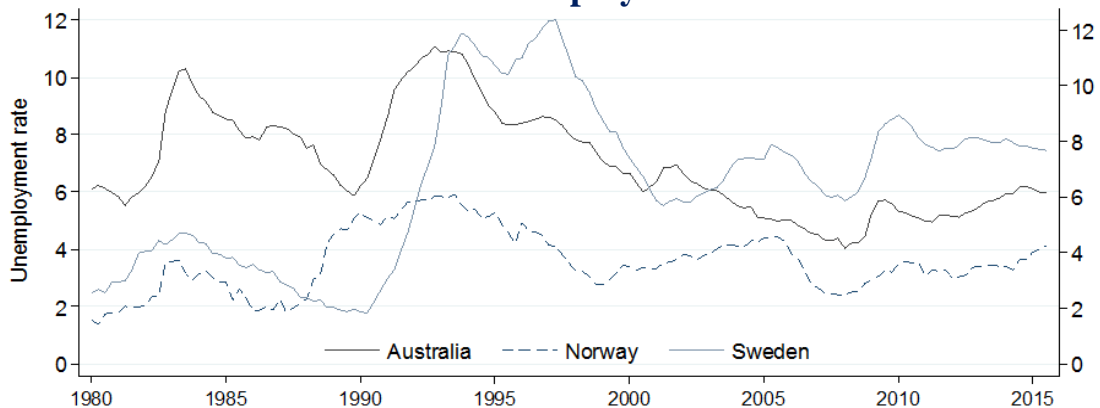
Notes: Deviations from trend growth. HP-filtered series, $\lambda = 1600$. 3 quarter moving averages.
Source: Australian Bureau of Statistics

**Figure A30:
Investments and output gap, Sweden**



Notes: Deviations from trend growth. HP-filtered series, $\lambda = 1600$. 3 quarter moving averages.
Source: Statistics Sweden

**Figure A31:
Unemployment**



Notes: Percentage of working force that is unemployed. Seasonally adjusted.
Sources: OECD, Macrobonds.

Figure A33:
Price of oil an real effective exchange rate,

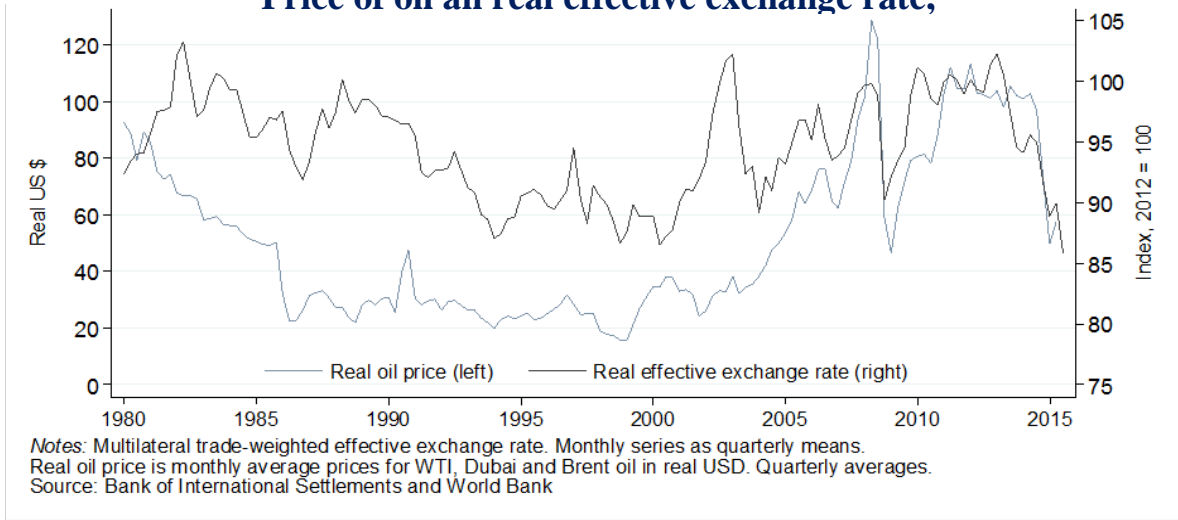


Figure A32:
Swedish labour market

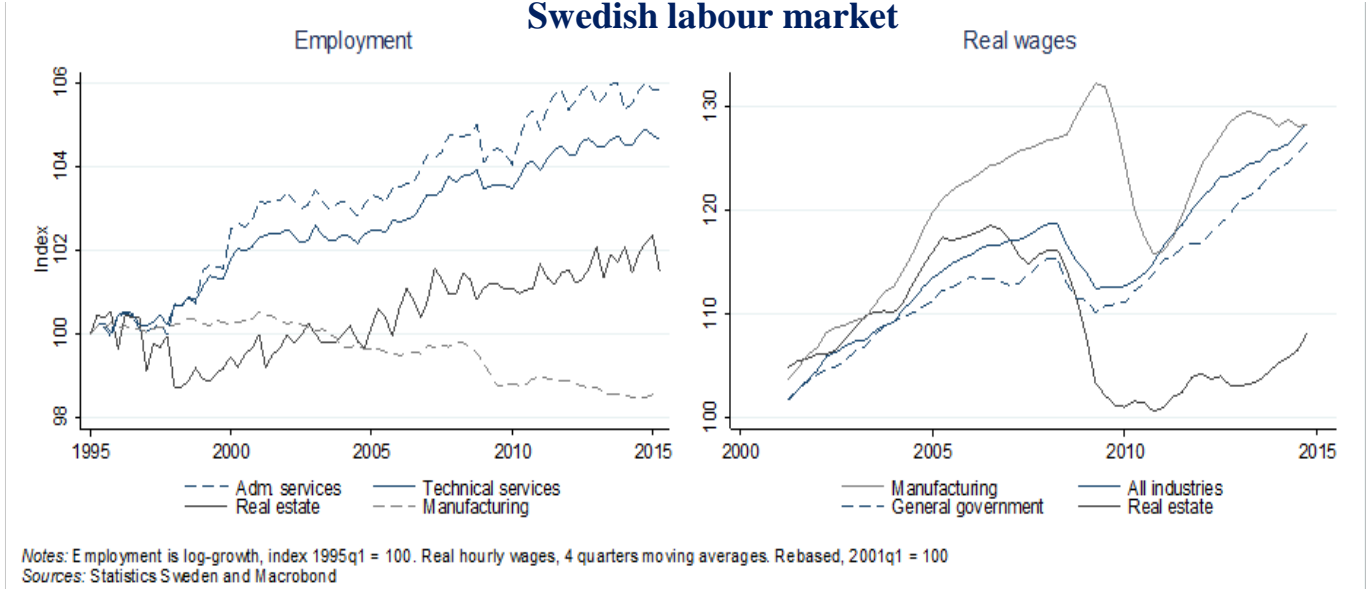
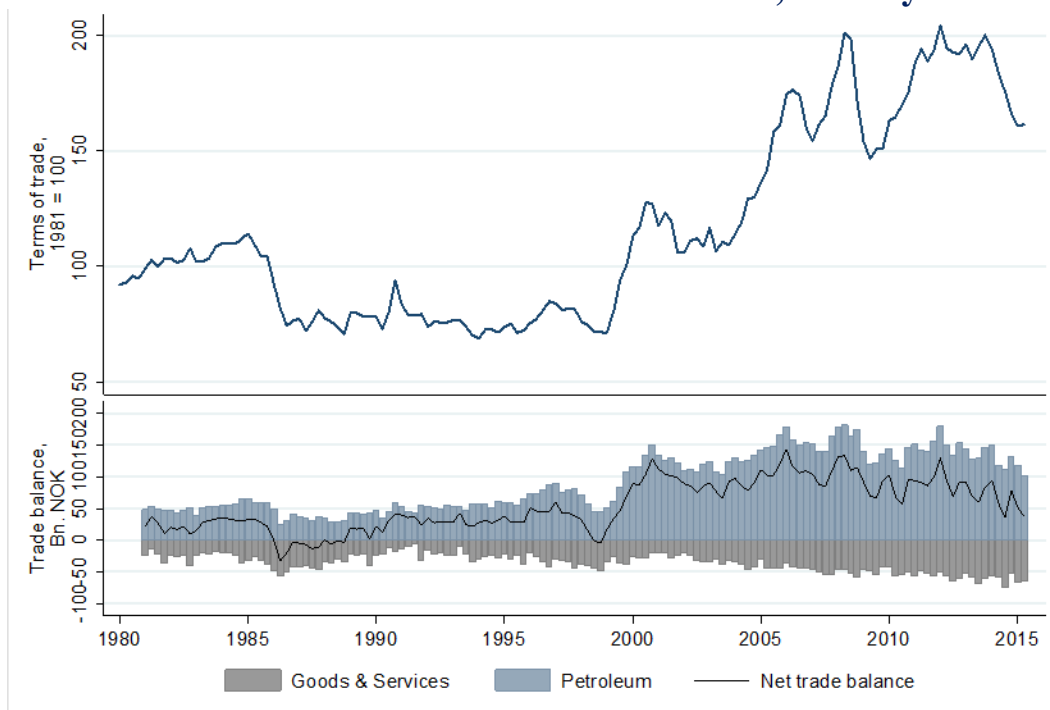


Figure A34:
Trade balance and terms of trade, Norway



Appendix B

B.1 Data set for synthetic control method

The dataset used in part 5 is built on a comprehensive annual dataset developed by fellow NHH student Hjalmar Richter Kolsaker. His original dataset consists of 42 variables across 21 countries observed annually in the period between 1945 and 2010, with data gathered from a wide range of sources. We have not used all of these variables in our final results, but all of them have been applied in robustness tests of the model.

We converted these annual series to quarterly data by expanding each year into quarters. As none of the variables are disaggregated nor are accumulated over the panel, data validity is not compromised by this approach. This does not alter the country weights attributed in the synthetic control, as explained in part 5.2.

The data sources employed for the synthetic control method are as follows:

- Gross domestic product (quarterly) (PPP, 2012 USD). Source: Economic Outlook 2015 (OECD, 2015), collected from Macrobonds. Combined with population numbers to generate GDP per capita. Spliced with GDP per capita (1990 USD) using the approach presented in appendix B.2.
- Gross domestic product (annual) (PPP, 1990 USD). Source: The Maddison Project, found at <http://www.ggd.net/maddison/maddison-project/home.htm>, 2013 version. Collected by Hjalmar Kolsaker.
- Population (quarterly). Source: American Census Bureau (United Nations World Index for Sweden and Switzerland), collected from Macrobonds.
- Inflation (annual). Percentage change in CPI. Source: The OECD database for consumer prices, available at stats.oecd.org, supplemented with B.R Mitchells book series on International Historical Statistics 1750-2005 (2005). Collected by Hjalmar Kolsaker.
- Human capital index (annual). Index of human capital based on average years of schooling. Source: (Feenstra, Inklaar, & Timmer, 2015). Collected by Hjalmar Kolsaker.
- Labour productivity per hour (annual). Measure of productivity, GDP per hour worked. Measured in 1990 USD. Source: (The Conference Board, 2015). Collected by Hjalmar Kolsaker.
- Merchandise Imports / Exports (annual). The sum of export and imports as share of GDP forms trade openness index. Source: (The Conference Board, 2015). Collected by Hjalmar Kolsaker.
- Government consumption as a share of GDP (annual). Source: (The Conference Board, 2015). Collected by Hjalmar Kolsaker.
- Unemployment (annual). Percentage of civilian workforce. Source: (Mitchell, 2005). Collected by Hjalmar Kolsaker.

B.2 Splicing GDP series

The variable of interest for our synthetic analysis is GDP per capita. In the annual panel data set, these are measured at 1990 PPP USDs, while our quarterly GDP series, from OECD's Economic Outlook 2015, is measured at 2012 PPP USDs.⁸⁷ We wish to utilize the variation in the quarterly GDP per capita for our comparison, but also need GDP per capita for the years before 1960 as to not shorten our pre-treatment sample unnecessary. Indexing and comparing the two GDP-series reveals that they share identical properties. Thus, there exists an implicit conversion factor between the 1990 PPPs and 2012 PPPs series that can be identified through a log-linear combination of the two series for each country.

We do this with the following OLS specification:

$$y_{it}^{A,1990} = \alpha_0 + \beta y_{it}^{Q,2012} + \delta_i + u_{it}. \quad (\text{B.1})$$

Here, $y_{it}^{A,1990}$ is the natural logarithm of annual GDP per capita in 1990 PPPs for country i in period t ; $y_{it}^{Q,2012}$ is the natural log of quarterly GDP per capita measured in 2012 PPPs, α_0 is a time-invariant constant, δ_i is a time-invariant country-specific indicator variable and $u_{it} = a_i + e_{it}$ is the composite error, where a_i captures all unobserved time-constant factors, and e_{it} the difference in variance between quarterly and annual GDP series caused by year-invariant annual observations in a quarterly panel. Thus, we adjust our quarterly GDP per capita to 1990 PPP without loss of variance by:

$$y_{it}^{Q,1990} = \beta * Y_{it}^{Q,2012} + \alpha_0 + \delta_i. \quad (\text{B.2})$$

This translates to:

$$Y_{it}^{Q,1990} = (Y_{it}^{Q,2012})^\beta * \alpha_0 * \delta_i, \quad (\text{B.3})$$

where $Y_{it}^{Q,1990}$ is quarterly GDP per capita on level form; β is a deflator approximately equal to unity; δ_i and α_0 are the implicit conversion rates.

⁸⁷ Quarterly GDP-series for 14 of the 21 countries start in 1960. Exceptions are: Austria (1970), Canada (1961), Denmark (1966), Germany (1991), Greece (1995), Ireland (1990) and Switzerland (1965). All are gathered from the OECD Economic Outlook, 2015.

Appendix C

C.1 Disclaimer

We discourage interpreting the synthetic line as an exact prediction of how Norway would have developed without oil. Significant uncertainties are related both to the slope and level of our synthetic estimates. Over the passing of time, the horizon of unobserved outcomes expands, with uncertainties adding up. As a result, the estimates near the end points of our series must be taken as mere suggestions.

The outcome we survey is thus a combination of political and economic decisions taken in four OECD countries, selected because of their similarities with Norway in the pre-oil period. Our results are intriguing, however, as these countries – although selected based on similarities prior to 1972 – have developed along similar paths. Abstracting from the fiscal freedom offered through Norway’s petroleum sector, our synthetic control units have responded to the same economic and global challenges in largely the same manner as Norway has. We cannot say that the actual effect of having oil is what we have estimated, but it provides as good an estimate as any.

C.2 Calculating a Norwegian economy without petroleum

We wish to compare the true value of the Norwegian economy without petroleum to our counterfactual. This requires us to create a GDP-series for mainland Norway including ocean transport, measured at market prices. However, sector products are only provided in basic values, where gross product in sector i is given by:

$$P_i = (q_i X_i - Tr) - C, \quad (C.1)$$

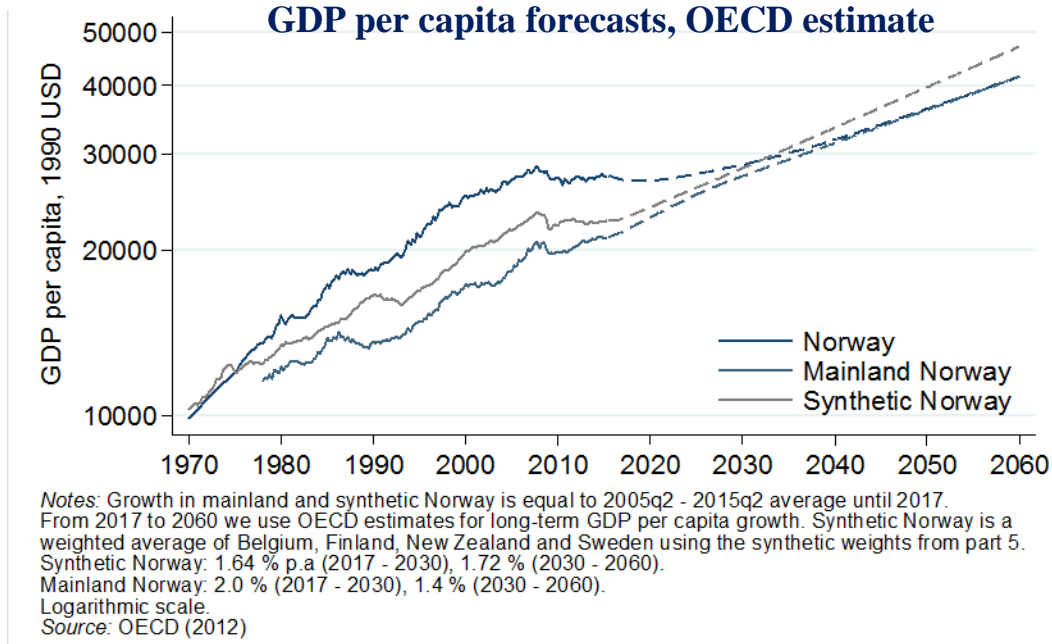
where Tr is net transfers (value added tax and product-specific taxes less subsidies) and C is the sector’s labour and capital costs measured at market prices (i.e. including payroll tax). Since only the costs are measured at market prices, the sum of all sectors’ gross product does not equal total GDP at market prices. As such, we combine Statistic Norway’s estimates for mainland Norway and ocean transport at basic values so that:

$$\dot{Y}^M = \left(\frac{P_{Main}^P + P_{OT}^P}{\sum P^P = Y^P} \right) * Y^M. \quad (C.2)$$

Here, Y^M is GDP of the Norwegian economy, less petroleum activities at market prices; Y^P is total GDP at market prices and P_i^P is output in sector i at basic values. Thus, that the nominator is equal to the products in the mainland economy and ocean transport at basic values and the denominator is the sum of all sectors at basic values. When compared to an indexed mainland economy at market prices, the two series show similar properties. All data is gathered from national accounts, specifically table SSB-9171-12 (output by sector in basis values, seasonally adjusted).

C.3 OECD forecast

**Figure C35:
GDP per capita forecasts, OECD estimate**



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