BI Norwegian Business School - campus Oslo

GRA 19703

Master Thesis

Thesis Master of Science

What are the impacts of government spending on the Norwegian economy?

Navn: Chandni Patel, Nina Moghal Sandnes

Start: 15.01.2020 09.00

Finish: 01.09.2020 12.00

Abstract

To analyse the effects of government spending, we use a structural vector autoregressive (SVAR) model. The recursive approach relies on the Cholesky ordering and is applied to identify a government spending shock. We apply quarterly data from Norway, with sample period 1991:1-2019:3. In the baseline model we find a short-lived, positive and significant effect on GDP, inflation and interest rate. The resulting multiplier is below one for all horizons, which could be consistent with the New Keynesian model. Extending the model, a shock to the two components of government spending, public consumption and public investment, is applied. Our main findings suggest that public investment has the largest impact, leading to a persistent and positive effect on GDP. However, the effect on GDP may also be influenced by a fall in the interest rate. Private consumption is included as another extension. The effect on private consumption is not positive, although it does not have a clear fall either, being insignificant for the whole period. Because consumption does not rise, as well as the interest rate reacts negatively, our results are leaning more towards the New Keynesian model.

Acknowledgements

This thesis completes our Master's degree at BI Norwegian Business School spring 2020. We would like to give special thanks to our supervisor Professor Gisle J. Natvik for guidance and helpful comments throughout the process. A big thank you goes to assistant professor Jamie Cross and Ph.D candidate Jon Ellingsen for helping us with the Matlab codes. We also want to thank our fellow students Remi Strømsnes and Ulrik Gierløff Ræder for discussions and help in the process. Last, but not least, we would like to thank our friends and family for their support during the whole process.

Table of contents

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF BOXES

Chapter 1 - Introduction

The objective of this thesis is to investigate the effectiveness of fiscal policy as a tool to stimulate the Norwegian economy. Government spending is one of the main instruments of fiscal policy and will be the measure of fiscal policy in our thesis. This is an interesting view because the strength of the effect of government spending is disputed, as some papers state that other instruments like tax change might have larger impacts (Midthjell, 2011). Furthermore, there are already many existing papers studying the effects of fiscal policy. However, as we have seen, and also according to Perotti (2007, p. 7), much of the existing evidence refers to the U.S or other European countries. Therefore, we want to investigate the effects of fiscal shocks on Norwegian macroeconomic variables.

The research question we will investigate in this thesis is: *"What are the impacts of government spending on the Norwegian economy?".* The vector autoregressive (VAR) model consists of government spending, GDP, inflation and interest rate, with private consumption added as an extension. To study the effects of government spending, we use a structural vector autoregressive (SVAR) model. To identify the structural shocks, a recursive approach relying on the Cholesky ordering is applied. In the analysis, we apply quarterly data on Norway, with sampling period ranging from 1991:1-2019:3. Government spending consists of the two components; public consumption and public investment. We extend the baseline model by adding shocks to these two variables. The effects of the baseline model and the extension models will be presented and analysed through impulse response functions (IRFs), both spending multipliers and cumulative multipliers, and forecast error variance decompositions (FEVD).

Through the literature review, we present the multipliers in the Keynesian, Neoclassical -and New Keynesian models. The main conflict of the three models regards the effect on private consumption following an increase in government spending. According to the Keynesian theory, output will increase, leading to a rise in consumption, which increases output even more. Based on this argument, a Keynesian multiplier is typically above one in the literature. The Neoclassical theory states that consumption falls, which increases hours worked, leading to lower wages and higher output. A Neoclassical multiplier resting on this argument is typically less than one. Following the New Keynesian theory, the size of the multiplier is largely dependent on the actions of the Central Bank, as the real interest rate can either be increased or decreased. Consequently, the response of consumption also varies. A New Keynesian multiplier can be both above and below one. Resulting multipliers from quantified models are also presented. Next, we look into four different identification approaches. The main findings of these approaches illustrate the conflict in the literature, especially regarding private consumption. The Blanchard and Perotti approach (henceforth referred to as BP approach), recursive approach and sign restrictions approach suggest government spending shock causes a rise in private consumption (Fatas & Mihov, 2001; Blanchard & Perotti, 2002; Galí, López-Salido & Vallés, 2007; Caldara & Kamps, 2008; Burriel et al., 2009; Tenhofen, Wolff & Heppke-Falk, 2010). In the narrative approach, a shock to government spending affects private consumption negatively (Ramey & Shapiro, 1998; Edelberg, Eichenbaum & Fisher, 1999; Burnside, Eichenbaum & Fisher, 2004).

Our main results of the baseline model imply that a government spending shock leads to a short and significant rise in GDP. Our findings seem to be consistent with the New Keynesian model, as the increase in interest rate occurs with some delay after the rise in inflation. This might indicate an active monetary policy. The spending multiplier is computed by dividing the change in GDP by the change in government spending. The impact multiplier is 0.25, meaning one additional NOK of government spending delivers NOK 0.25 of additional output. The peak multiplier of 0.49 is reached in quarter two, and thereafter returns to a size of 0.25 where it stabilizes. A possible reasoning for the persistency of a rather low multiplier could be the rise in interest rate around quarter ten. This could be consistent with the New Keynesian model assuming zero lower bound (ZLB) and deviations from the standard Taylor rule. The cumulative spending multiplier is calculated by dividing the sum of the change in GDP by the sum of the change in government spending. The cumulative spending multiplier is less than one for all horizons, being steady with a size of around 0.33, which is also the maximum response. By the FEVD, our results suggest that a government spending shock explains most of the variation in GDP, compared to the inflation and the interest rate.

The first extension considers a shock to public consumption and public investment, with consumption ordered first, investment second and thereafter, GDP, inflation and interest rate (Model X). Comparing the effects of the two components, we find that a public investment shock has the largest impact, with a persistent and positive significant effect on GDP. Yet, the interest rate falls in response to the public investment shock, possibly inducing the rise in GDP. This can affect the credibility of the public investment shock. In FEVD the response of public consumption shock explains a larger share of the variation in the Norwegian economy in the short-run, whereas the response of public investment explains a larger share in the long-run. In a robustness test, the ordering of public consumption and public investment is reversed (Model Y). This does not appear to alter the results of the two shocks, and seem to be true when comparing the FEVD of the two models.

In the second extension, we add private consumption to the baseline model. Following a government spending shock, we find a statistically insignificant response of private consumption for the whole period. The response does not rise, although it does not have a clear fall either. It is not clear whether the private consumption response supports one specific theoretical model. Nevertheless, the increase in the interest rate can explain why private consumption is not rising. Resting on these findings, our results are leaning more towards the New Keynesian model. The impact multiplier is 0.26 and is smaller than one for all horizons. In quarter four, we find a peak multiplier of 0.57. Consumption has an insignificant positive response in the same quarter, as well as a significant negative response in the interest rate. Our findings are therefore still pulling towards the New Keynesian model.

It is worth noticing that “*The cyclical position of the economy is often seen as an important element when assessing the impact of fiscal policy on economic activity*” (Hemming et al., 2002, referred in Giordano, Momigliano, Neri & Perotti, 2007, p. 709; Auerbach & Gorodnichenko, 2012). In this respect, the results presented above should be considered as “average effects”. This means that our findings need not offer a general guidance for the effects of fiscal shocks under extreme economic circumstances, such as a deep recession or a boom.

Comparing our results from the baseline model with empirical findings from different identification approaches, the results are quite similar, with a short-lived increase in GDP, inflation and interest rate (Burriel et al., 2009; Fernández & de Cos, 2006; Caldara & Kamps, 2008)[1]. Also, our impact multiplier is consistent with Spilimbergo, Symansky & Schindler (2009) and Asche and Kristiansson (2019). The rather early peak of the multiplier in quarter two is not found to be consistent with other studies. However, the cumulative multiplier is consistent with Burriel et al. (2009), and in the earlier horizons it is also consistent with Asche and Kristiansson (2019).

When investigating public consumption and public investment, we find some consistency with other empirical findings. Perotti (2004b) finds that in Germany, the effect on GDP is larger following a public investment shock. This is true for our findings. Fernández and de Cos (2006) find that only the public investment shock indicates positive effects after quarter four, which is in line with our findings. They find that inflation increases in response to both shocks, also being consistent with our results.

The effect of private consumption in the second extension model is difficult to reconcile with previous findings, as we get insignificant results with neither a clear fall nor a rise. Empirical results based on the narrative approach suggest a fall in private consumption on impact (Ramey & Shapiro, 1998; Edelberg et al., 1999; Burnside et al., 2004). While the results of the BP approach, the recursive approach and the sign restriction approach find a rise in private consumption (Fatas & Mihov, 2001; Blanchard & Perotti, 2002; Galí et al., 2007; Caldara & Kamps, 2008; Burriel et al., 2009; Tenhofen et al., 2010). The impact multiplier is 0.26, which is in line with Baxter and King (1993) referenced in Ramey (2011a, p. 674). The peak multiplier of 0.57 in quarter four is reached at an earlier stage compared to other studies. As before, the cumulative multiplier is in line with Burriel et al. (2009).

The rest of the thesis will be structured as follows: in chapter 2, we present the motivational background of fiscal policy and look into fiscal policy in Norway,

[1] BP approach, recursive approach and sign restrictions.

addressing the spending rule and the Norwegian oil fund. In chapter 3, a literature review of a multiplier in the Keynesian, Neoclassical -and New Keynesian models will be presented, and the belonging results of multipliers from quantified models. We introduce four different identification approaches in the VAR framework and the associated empirical findings. Chapter 4 presents the methodology and estimations behind the baseline model. Throughout chapter 5, results and analysis of the baseline model and the two extension models are presented. Robustness tests are analysed in chapter 6, and lastly, the conclusion is presented in chapter 7.

Chapter 2 - Fiscal policy

In this chapter, we give a short introduction of the motivational background of fiscal policy. Thereafter, fiscal policy in Norway is presented, involving the spending rule, the Norwegian oil fund and the advantage of having the oil fund during the current corona crisis.

2.1 The motivational background of fiscal policy

One of the main fiscal policy instruments available is government spending, in which public consumption and public investment are the two main components. The strength of the effect of government spending is disputed because some studies state other instruments like tax changes may have stronger impacts. The traditional Keynesian theory states that a change in government spending of goods and services have stronger effects than a tax change. This is reasoned with GDP being affected directly by public purchases of goods and services. Taxes have an indirect effect through the consumption and investment decisions of households and businesses. Moreover, cyclical conditions, economic expectations and fiscal policy credibility will have an impact on the effect of a change in fiscal policy on the real economy. The long-term effects of the extensive use of fiscal policy in case of financial crisis is not clear. On the other hand, the short-term effects of fiscal policy have prevented a drop in demand in many countries (Midthjell, 2011).

Before the financial crisis in 2008, there was little interest in the short-run macroeconomic effects of government spending. Research on monetary policy attracted higher interest than the topic of stimulus effects of fiscal policy. The implementation lags in fiscal policy were believed to be typically too long in order to combat recessions. Another reason was that Central Banks sponsored many more conferences than government treasury departments (Ramey, 2011a, p. 673). The financial crisis in 2008 led to a collapse of the financial markets and global macroeconomic consequences, such as increased unemployment and negative growth. Research on fiscal policy was considered important and necessary during the financial crisis, when the Federal Reserve (FED) reached the ZLB on the interest rate (Ramey, 2011a, p. 673). Because of ZLB, monetary and liquidity policy instruments would not be sufficient, and fiscal policy had to be exercised (Midthjell, 2011). The ZLB can amplify the effects of fiscal policy, as the interest rate may not respond to changes in fiscal policy in an offsetting manner. In this case, Central Banks cannot cut policy interest rates to offset the negative short-term effects of a fiscal consolidation on economic activity. Monetary policy is said to accommodate the expansionary effects of fiscal stimulus (Christiano, Eichenbaum & Rebelo, 2011).

When investigating the effects of fiscal policy on the economy, the findings vary widely. Often, it is assumed that "*an increase in public expenditure will not have any marked effect on GDP over time, due to a crowding-out effect on private consumption and investment*" (Taylor, 1993; Cwik & Wieland, 2009; Cogan, Cwik, Taylor & Wieland, 2009, referred in Midthjell, 2011, p. 27)[2]. The argument is that a rise in government spending leads to pressure on prices and increased interest rates. This gives lower private consumption and investment and thus dampens the positive effect on GDP of increased government spending. As during the financial crisis, the key interest rate was kept close to zero and the monetary policy became passive. "*The effect of fiscal policy may be stronger than under normal conditions when the interest rate is close to zero, as the leeway of the central bank is limited*" (Midthjell, 2011, p. 37; Woodford, 2011, p. 15-16). An increase in government spending when the ZLB is strictly binding could lead to a

[2] Crowding-out effects implicates that government spending reduces private investment and consumption (Şen & Kaya, 2014).

rise in output, marginal cost and expected inflation. This expected inflation can drive down the interest rate, and consequently private spending can increase. This increase can possibly lead to a further rise in output, marginal cost, and expected inflation, and a further decline in interest rate. The net results can therefore be a large rise in output and a large fall in the rate of deflation. The extensive use of fiscal policy both during and after the financial crisis, has shown that an increased understanding of the actual effects of fiscal policy is necessary (Christiano et al., 2011, p. 80). As seen in Norway today, the interest rate has reached ZLB and the effects of fiscal policy might have increased.

2.2 Norwegian fiscal policy

The Norwegian economy grew dramatically after one of the largest offshore oil fields was discovered in 1969 and should be taken into consideration when analysing the Norwegian economy. The oil wealth was intended to serve both current and future generations. In order to avoid imbalances in the economy, it was decided that revenues from oil and gas should be used cautiously. To embrace this, the Government Pension Fund Global (GPFG) was created in 1996. For the fund to function as a benefit for as many generations as possible, a spending rule was agreed upon only allowing to spend four percent of the expected return (Norges Bank, n.d). In 2017, this was adjusted to three percent (SNL, 2019).

Even if oil revenue spending is set to three percent over time, an important aim of the spending rule is to flatten economic fluctuations to ensure capacity utilization and low unemployment. The last years, less than three percent has been spent. As a result of the economic packages introduced to help companies sustain their business through the corona crisis, the spending of oil revenues was expected to increase (Statistics Norway, 2020). The revised budget for 2020 (presented in May 2020), revealed the spending to be NOK 419.6 billion (measured by the size of the structural non-oil deficit). This is accounted to be 4.2 percent of the estimated value of the GPFG at the beginning of the year, and 13.1 percent of trend GDP of mainland Norway. The spending is amounted to NOK 242.2 billion in 2019, and 8 percent of trend GDP of mainland Norway (Government, 2020). Compared to Norway's trading partners, the Norwegian economy will most likely recover faster as there is room for larger and faster actions in Norwegian fiscal policy (Statistics Norway, 2020).

Furthermore, the spending rule has allowed the Norwegian Government to consistently conduct an expansionary fiscal policy, especially since 2012[3]. The International Monetary Fund (IMF) describes fiscal policy as expansionary when aggregate demand is increased directly through an increase in government spending. If aggregate demand is decreased through lower government spending, fiscal policy is often considered to be contractionary (International Monetary Fund, 2020).

Norway's economy is affected by not only the amount of oil revenues spent, but also by how these are spent. The spending should be focused on measures likely to improve the productivity and the growth capacity for the rest of the economy. Even before the start of the corona crisis, the Norwegian productivity would probably have to increase more rapidly than in the last 10-12 years to maintain somewhat the same growth in the living standard (Borgås, 2018). To dampen the consequences of COVID-19, the Norwegian government and parliament spend oil revenues by imposing several economic measures, e.g. crisis packages for workers. Looking at the budget indicator, all the measures together stimulates the economy with almost five percentage points[4]. In the financial crisis, the budget indicator was calculated to 2.4 percentage points (Statistics Norway, 2020).

[3] This paragraph relies on the lecture by professor Knut Anton Mørk (3rd of April 2020) in Macroeconomic Policy.
[4] The aim of the indicator is to give a picture of the structure of fiscal policy, meaning if it works expansionary or contractionary when the budget for example is corrected for the effects caused by cyclical conditions in the economy (Finans -og tolldepartementet, n.d).

Chapter 3 - Literature Review

This chapter presents a literature review on fiscal policy, giving special attention to spending multipliers with related findings from quantified models. We introduce four different identification approaches using a VAR framework, with the associated empirical findings.

3.1 Spending multipliers

Spilimbergo et al. (2009, p. 2) define a spending multiplier as "*the ratio of a change in output (ΔY) to an exogenous change in the fiscal deficit with respect to their respective baselines*". The fiscal deficit is government expenditure, Δ*G,* or net taxes -Δ*T*. Ilzetzki, Mendoza and Vegh (2013, p. 244) give an example of how the spending multiplier can be interpreted; if a one dollar increase in government consumption causes a 50 cent increase in the output, a multiplier has a size of 0.5. The most common multipliers are shown in Table 3.1 (Spilimbergo et al., 2009, p. 2).

Spending multipliers
The *impact* multiplier $\left(\equiv \frac{\Delta Y(t)}{\Delta G(t)}\right)$.
The multiplier, defined as $\left(\equiv \frac{\Delta Y(t+N)}{\Delta G(t)}\right)$ over any N horizon.
The *peak* multiplier, defined as the largest $\left(\equiv \max_N \frac{\Delta Y(t+N)}{\Delta G(t)}\right)$ over any N horizon.
The *cumulative* multiplier, defined as the cumulative change in output over the cumulative change in government spending at some horizon N $\left(\equiv \frac{\sum_{j=0}^{N} \Delta Y(t+j)}{\sum_{j=0}^{N} \Delta G(t+j)}\right)$.

Table 3.1. Source: Spilimbergo et al. (2009, p. 2). The table shows how spending multipliers are calculated. Y = output and G = government spending.

On the debate of spending multipliers, a central issue is the substantial disagreement regarding how to go about identifying fiscal shocks. Different methodologies and a large range of estimates lead to disagreements in the profession on the reliability of the multipliers. The main challenge is simultaneity bias. A relating example is when multipliers inappropriately are concluded as low. To reduce the risk of simultaneity bias, higher frequency data can be used, in the presence of implementation lags in fiscal policy with respect to the output gap. VAR models can be applied to calculate the fiscal multipliers, in which it is crucial to correctly identify exogenous movements in government spending (Spilimbergo et al., 2009, p. 5). Hall (2009, p. 11-12) argues that using a VAR is a more powerful approach than a simple regression, as it catches much of the noise by associating it with other causal factors. The precision of the estimates can therefore be higher.

3.1.1 Spending multipliers in different theoretical frameworks

This subsection interprets the theoretical frameworks that may lead to different sizes of a spending multiplier, as seen in Table 3.2.

Macroeconomic theory	**The size of a multiplier**
Keynesian	$\frac{dY}{dg} > 1$ Very likely
Neoclassical	$\frac{dY}{dg} < 1$ Unless very strong assumptions
New Keynesian	$\frac{dY}{dg} \frac{>}{<} 1$ Dependent on monetary policy accommodation

Table 3.2. The table illustrates sizes of a spending multiplier in the three different theoretical frameworks; Keynesian, Neoclassical and New Keynesian. Y = output and g = government spending.

Keynesian multiplier

Box 1- Keynesian theory

The Keynesian theory "*attempts to build the microeconomic foundations of wage and price stickiness*" (Gordon, 1990, p. 1115). The key assumption of Keynesian models is based on the view that aggregate demand shock affects employment but has no effect on real wages (Blanchard & Fischer, 1989, referred by Christiano & Eichenbaum, 1992, p. 431). In addition, the model is based on theory "*of the effects of aggregate demand on real output and inflation*". The Keynesian view implies that aggregate demand is affected by both private and public economic decisions. A change in aggregate demand can have the greatest short-term impact on real output and employment, and not on prices (Blinder, 1988, p. 110-111). A government spending shock can have a positive effect on output and private consumption. Gordon (1990, p. 1135-1136) states that "*The essential feature of Keynesian macroeconomics is the absence of continuous market clearing*". In other words, the Keynesian model is a non-market-clearing model, where prices can fail to adjust rapidly enough in order to clear markets within a relatively short period.

$$\frac{dY}{dG} = \frac{1}{1 - c_1(1 - t_1) + i_1 r_1 + m} > 1$$

Equation 3.1. An illustrative Keynesian spending multiplier. Y = output, G = government spending, c_1 = marginal propensity to consume out of current income, t_1 = income tax rate, i_1 = the sensitivity of investment to changes in the interest rate, r_1 = the interest rate (endogenous response of monetary policy), and m = sensitivity of imports to GDP. None of the variables are time dependent.

The investment-savings curve (IS curve) in the Keynesian theory can be combined by different equations for output, consumption, investment, tax and net export, as seen from the equations in A3.1 (in Appendix)[5]. Combining these equations leads to an illustrative Keynesian spending multiplier in small open economies, as seen in Equation 3.1. In the Keynesian theory, a government spending increase may

[5] This paragraph relies on lectures by professor Gisle J. Natvik (28th of March 2019) in Business Cycles.

have a positive effect on output through the demand side and multiplier mechanism (Ramey, 2011a). A Keynesian multiplier depends heavily on the households’ marginal propensity to consume (c_1), and these types of Keynesian models predict positive multipliers (Ramey & Shapiro, 1998). From Equation 3.1, spending multiplier increases when households’ marginal propensity to consume out of the current income (c_1) rise. A rise in government spending might increase disposable income ($1-t_1$) and a rise in consumption, leading to a possible increase in output and income.

The multiplier decreases as the sensitivity of imports to GDP (m) increase. The increased amount of income is used on imports rather than domestically. The domestic multiplier effect is less when import increases (resulting in a decrease in net exports). An increase in demand could result in a higher interest rate due to higher demand for money (Ramey, 2011a). This rise in the interest rate (r_1) can lead to a decrease in the spending multiplier, as it leads to a decrease in investment sensitivity to change in the interest rate (i_1) (investments are crowded out). In a liquidity trap, the government may not respond with an increase in interest rate, which most likely will result in a high spending multiplier (> 1 as shown in Table 3.2 above).

Neoclassical multiplier

Box 2 - Neoclassical theory

The Neoclassical models imply a positive effect of government spending on output and predict a negative effect on private consumption (Blanchard & Perotti, 2002, p. 1360-1361). A permanent increase in government spending will lead to a negative wealth effect for the representative household. Decreased consumption and increased labor supply can in turn result in a raise of output. In the case of a temporary increase in government spending, there can be less impact on output because of negative wealth effects. In the short-term, hours should increase, and consumption should decrease (Ramey, 2011, p. 2). Choices about output are made by competitive price-taking firms. A key ingredient of the models is not rational expectations, as in the New Keynesian model, but the assumption of continuous market clearing (Gordon, 1990, p. 1116). Hall (2009, p. 4) argues that in the Neoclassical general-equilibrium model (excluding unemployment), a raise in government spending is often caused by investment and consumption, but it does not increase the total output substantially.

$$\frac{dy}{dg} = \frac{\alpha}{\alpha + \sigma\,(1-\bar{g})\,(1 + 1/\psi - \alpha)} < 1$$

Equation 3.2. A prototypical Neoclassical spending multiplier. Source: Hall (2009, p. 17). y = output, g = government spending, α = the labor elasticity of production, σ = the utility of consumption, $\bar{g}$ = government spending in steady state, and ψ = the labor supply elasticity. None of the variables are time dependent.

The spending multiplier can differ in a general equilibrium when the markets clear, in contrast to the Keynesian model[6]. A3.2 in the Appendix lists the equations for a static model. The equations lead to a prototypical Neoclassical spending multiplier, as seen in Equation 3.2. Neoclassical models predict positive and negative multipliers depending on, amongst other things, changes in government spending. This is due to consumers' lifetime budget constraint determining their level of consumption (Ramey, 2011a).

A permanent increase in government spending could be caused by resource constraints and has a negative wealth effect on the consumers. As seen in Equation 3.2, the consumers will decrease their consumption and leisure, leading to a rise in the labour supply (α) (Baxter & King, 1993; Bouakez & Rebei, 2007, p. 955). The spending multiplier can decrease when the linearity of utility of consumption (σ) becomes steeper. Consequently, the size of a multiplier can be < 1, as $\alpha \leq 1$ and $\psi > 0$. A rise in government spending, can increase hours worked as there is a higher marginal utility of consumption. Also, wages can decrease and output can increase (Bouakez & Rebei, 2007, p. 955). The spending multiplier can increase when the labor elasticity of production (α) and labor supply elasticity (ψ) increase.

[6] This paragraph relies on lectures by professor Gisle J. Natvik (28th of March 2019) in Business Cycles.

New Keynesian multiplier

Box 3 - New Keynesian theory

According to Ball, Mankiw and Romer (1988), referred by Roberts (1995, p. 975), an important part of the New Keynesian view is the consensus around the micro-foundations of sticky price models. As prices are sticky, future prices must be considered when setting prices (Roberts, 1995, p. 975). Unlike the Keynesian models, where households follow “rule of thumb” and rational expectations are not included, the New Keynesian models assume that all households are assumed to be forward-looking and they are optimizing spending decisions. The models assume sticky prices by introducing staggered price and wage setting (Cogan et al., 2009, p. 282-286). The New Keynesian approach seeks to explain an increase in consumption, real wage and productivity (Ramey, 2011, p. 2). This theory can also explain why changes in the aggregate price level are sticky, which means why changes in prices are different from changes in nominal GNP. Monopolistically competitive firms set individual prices and they accept the constraint of real sales. This view is in contrast with the Neoclassical model, in which choices about output are made by the competitive price-taking firms (Gordon, 1990, p. 1116).

The reaction of the nominal interest rate to government spending can be of large interest in the New Keynesian spending multiplier, as the Central Bank can to a large extent determine the size of the multiplier[7]. When there are sticky prices, a change in the real interest rate by the Central Bank can lead to a change in the nominal interest rate. Hence, the amount spent in different time periods can be affected. This mechanism gives the Central Bank the opportunity to choose between a very large or a very small multiplier.

One of the alternative explanations of the size of the multiplier, state that a strict inflation targeting ($\pi - \pi^* = 0$) would make the economy act as if there were flexible prices. This could lead to a multiplier of the same size as in the

[7] This paragraph relies on lectures by professor Gisle J. Natvik (28th of March 2019) in Business Cycles.

Neoclassical model. A second alternative is when there is an interest rate rule, which can result in a multiplier between the Neoclassical -and the New Keynesian models. Lastly, when there is a ZLB, the Central Bank cannot reduce the real interest rate any further. Government spending can in this case act as a substitute for monetary policy, by stimulating inflation and decreasing the short-term real interest rate (nominal interest rate is constant). Accordingly, consumption can increase today relative to the future leading to large spending multipliers. On the contrary, if the government spending is continued into the future, the Central Bank can respond by increasing the real interest rate. As a result, consumption can decrease and the multipliers may be smaller again.

3.1.2 Multipliers from quantified models

Besides estimations from regressions, Hall (2009, p. 1, 4-6) make calibrations that rely on models derived from the New Keynesian models. The New Keynesian multipliers are found in the range of 0.7-1. On the other hand, the Neoclassical models have lower multiplier results. This is reasoned with a predicted fall in consumption when purchases rise. Hall (2009) states that there are two key features of a model that delivers a higher multiplier. Firstly, when output rises in the Keynesian models, the decline in the mark-up ratio of price over cost occurs. The second feature is the elastic response of employment to an increase in demand. This is complementary to another feature associated with Keynes; the link of consumption to current income. When monetary policy becomes passive, a multiplier can rise to as high as 1.7.

Galí et al. (2007, p. 228-229) provide some empirical evidence using VAR models (elaborated later), but their main contribution is the evidence from a simple dynamic general equilibrium model. Galí et al. (2007), referenced in Hall (2009, p. 34), describe how a multiplier may differ, as it depends on consumption behaviour. When consumption is subject to rule-of-thumb behaviour, a multiplier can be as high as 1.9, and as low as 0.75 if the consumption is subject to life-cycle consumption behaviour.

Ramey (2019, p. 90-92) estimates the effects of fiscal policies through three different approaches, where two of them are: 1) aggregate time series or panel estimates at national level, and 2) estimated or calibrated New Keynesian dynamic stochastic general equilibrium (DSGE) models. The bulk of the estimates across the leading methods of estimation and samples lie in a rather narrow range of 0.6-1. During periods in which monetary policy is very accommodative (such as a situation of ZLB) estimated and calibrated New Keynesian models for the U.S and Europe imply higher multipliers.

Fatas and Mihov (2001, p. 4-6) use a semi-structural VAR, where they compare the empirical results (elaborated later) with a Neoclassical model[8]. Two conditional moments in the data are in conflict with the theoretical predictions of the Neoclassical model; (1) the response of consumption and the correlation between consumption and (2) employment responses. Their findings suggest an increase in government spending can result in a multiplier larger than one. According to the authors, there are several dimensions in which the data can fail to be consistent with the Neoclassical model. The largest discrepancy between the model and the empirical results is the response of consumption, as it should decrease as a response to an expansion in government spending.

3.2 The importance of timing

To identify the effects of fiscal shocks, the timing of the shocks plays a critical role (Auerbach & Gorodnichenko, 2012, p. 14-18). Before we discuss the different VAR frameworks, the timing of the shock needs special attention. Ramey (2011, p. 3) compares two main empirical approaches (the BP approach and the Ramey-Shapiro narrative approach) for estimating the effects of government spending. A key difference in the empirical results of the two approaches was the timing. More precisely, it was the failure of accounting for the anticipation effects in the BP approach. In the Ramey-Shapiro narrative approach, an increase in non-defence government spending is anticipated several quarters before it actually occurs. Leeper, Walker and Yang (2009), referenced in Ramey (2011, p. 23), demonstrate how fiscal foresight can result in potentially serious econometric problems. When future changes in government spending are foreseen by agents, the resulting time series can have non-fundamental representation.

[8] When only a subset of the structural shocks is identified, it can be referred to as semi-structural VAR models (Inoue & Kilian, 2013, p. 2).

They found that one of the key problems is the econometrician have smaller information sets than the agents, leading to a conclusion of standard VAR techniques not correctly identifying shocks to government spending.

Governments may not be able to react within the same quarter to changes of the macroeconomic environment. This could be caused by a rather long process in fiscal policy decision-making, which involves many agents in parliament, government, and civil society. Reactions of fiscal policy due to current developments is only resulting from what is called ‘‘automatic” responses, which are defined by existing laws and regulations. All fiscal policy developments in a given quarter, which do not reflect automatic responses, are basically seen as structural fiscal policy shocks, which are exogenous to the macroeconomy (Blanchard & Perotti, 2002, referred in Tenhofen et al., 2010, p. 331).

The key to Blanchard and Perotti´s (2002, p. 1333-1351) identification procedure, is to recognize that the use of quarterly data almost eliminates the second channel. The second channel is when discretionary adjustment is made to fiscal policy as a consequence of unexpected events within the quarter. They state that it takes more than a quarter to (1) learn about a shock to the GDP, (2) decide what fiscal measures (if any) to take in response, (3) pass the measures through the legislature and lastly (4) actually implementing them. Therefore, they divide lags into decision lags and implementation lags in fiscal policy. Decision lags helped them achieve identification in their research, and implies that it takes some time for policy to be changed in response to shocks. Implementation lags imply that the execution of policy changes can take time, which can cause a problem that is usually identified as fiscal shocks. This may be the result of earlier policy changes, and thus be anticipated by the private sector.

3.3 Fiscal policy in the VAR framework

VAR models have been used to assess both fiscal -and monetary policy shocks in the past. Although there are differences in the specification of the reduced-form VAR model, including sample period, set of endogenous variables, deterministic terms and lag length. Most of the recent findings on the responses to fiscal policy shocks are based on SVAR models. The main differences of the existing papers are the alternative approaches applied to identify the fiscal policy shocks (Fernández & de Cos, 2006, p. 8). The four identification approaches are; the BP approach proposed by Blanchard and Perotti (2002), the recursive approach introduced by Sims (1980), the sign restrictions approach developed by Uhlig (2005) and lastly, the narrative approach, also known as the event-study approach, used by Ramey and Shapiro (1998) (Perotti, 2002, p. 8-10; Caldara & Kamps, 2008, p. 6-7). Empirical findings of these approaches are presented in more detail in the following subsections.

3.3.1 The Blanchard and Perotti approach

To identify the automatic responses of tax and government spending, the BP identification approach relies on institutional information of both tax and transfers, and the timing of tax collections. The first step of the identification is to estimate cyclically adjusted taxes and government expenditures by using the institutional information. In the second step, the estimates of fiscal policy shocks are obtained (Caldara & Kamps, 2008, p. 14).

The main results of Blanchard and Perotti (2002, p. 1331) show that positive government spending shocks have a positive effect on output and private consumption. This result is consistent with the Keynesian and the New Keynesian model. They found that an increase in government spending generate a strong negative effect on investment spending, which is in accordance with the Neoclassical model.

In order to analyse the effects of fiscal policy, Perotti (2004a, p. 1-2, 19-23) have extended the SVAR analysis executed by Blanchard and Perotti (2002) by adding inflation and interest rate. He investigates the effect in five different OECD countries. The effects of fiscal policy are studied in two different subsamples, pre-1980 and post-1980. The main results of the post-1980 subsample imply small effects of fiscal policy on GDP. He found no evidence that reduction in taxes is more efficient than increasing spending. Weaker effects of government spending shocks on GDP is found in the pre-1980 subsample. The cumulative multipliers are quite similar across countries. In the post-1980 subsample, the cumulative multiplier is zero in the fourth quarter and negative in the 12th quarter (except for the U.S). In the pre-1980 subsample, the multiplier is slightly below or above one in quarter four and 12 (except for the U.S and UK). Investigating the whole sample, he found a significant positive response of GDP to the spending shocks in all the countries except for Australia. The results from the subsamples suggest the response of GDP is much stronger in the pre-1980 period.

There are also other papers investigating the effects of government spending using BP approach. Galí et al. (2007, p. 231-233) apply an identification strategy similar to both Blanchard and Perotti (2002) and Fatas and Mihov (2001), using U.S data. They find that the government spending shock itself is persistent and significant. The impact spending multiplier is 0.78, and the multiplier has increased to 1.74 at the end of year two. This is similar to the multipliers reported by Blanchard and Perotti (2002). Also, they observe a positive effect on private consumption, and the rise remains persistently above zero. Tenhofen et al. (2010, p. 330) study the effects in Germany, and use the BP approach. As a response to government spending shock, they also find that GDP increases, private consumption increases weakly on impact, while private investment increases strongly. Note that in this study, GDP, inflation and interest rate are ordered before government spending. Fernández and de Cos (2006, p. 17-19) present results of a government spending shock in Spain. The major findings indicate that the spending shock is very persistent. Moreover, the results suggest GDP reacts positively in the short-run. In the long-run, GDP is lower and inflation is higher. The interest rate responds positively and persistently according to the authors. The cumulative spending multipliers are found to be around 1.3 in the first two years, which is rather large compared to multipliers in other OECD countries

Burriel et al. (2009, p. 16-27) look at the effects of a government spending shock in both the U.S and the Euro area. Their key findings suggest that the shock seems to be more persistent in the U.S. In both areas, GDP increases and stays significant for five quarters. These findings are similar to what is found in other countries previously. Generally, many papers have found that a shock to government spending has a positive effect on GDP in the short-run. Still, both the size and the persistence vary across studies. The cumulative multipliers are slightly below one after four quarters. The shock leads to a rise in prices, resulting in a hump-shaped effect on inflation. Also, the resulting effect of the long-term interest rate rises in response to the shock. It is worth noting the long-term interest rate is ordered before inflation in the VAR model. Private consumption appears to be positively affected, which is in accordance with both the Keynesian and the New Keynesian model.

3.3.1.1 Two components of government spending

Burriel et al. (2009, p. 27-28) extend their analysis by assessing at the responses of a public consumption and a public investment shock. Note that they study the "pure" effect of each shock. They find that the effects of these two shocks are qualitatively similar, with a small and short, positive effect on GDP, and rise in inflation. In another paper by Perotti (2004b, p. 9-17), the effects in Australia, Canada, West Germany, UK, and the U.S are studied. The key findings imply that for all countries, GDP is positively affected by a public consumption shock. Public investment shock appears to generate a positive and significant effect in the U.S, Germany and Canada after two quarter. When reaching the second year, Germany is the only country with a positive and significant effect on GDP. Comparing the two shocks, the public investment shock generates a larger effect on GDP than the public consumption shock in Germany. When investigating the effects of switching places of the fiscal variables, the resulting effect seem to differ minimally. Following Perotti's (2004b) study, there is no evidence that public investment shocks have stronger impact than public consumption shocks regarding the effect on GDP. This result holds both in the short -and long-run. Public investment appears to crowd out private investment, and no evidence is found for government investment "paying for itself" when looking at the long-run. Additionally, limited positive effects of public consumption are observed.

Ilzetzki et al. (2010, p. 11, 22) also follow the BP approach, and study government spending effects in 44 countries. They observe that a positive public consumption shock will decrease GDP, while a positive public investment shock generates a rise in GDP. Fernández and de Cos (2006, p. 20-21) also look at the effect of public consumption and investment shocks, finding that neither of the two shocks are persistent. In both cases, they find that GDP reacts positively and peaks in the third quarter. Lastly, they found that the prices are affected positively by both shocks.

3.3.2 The recursive approach

The recursive approach relies on Cholesky ordering to identify fiscal shocks (Perotti, 2002, p.10). Fatas and Mihov (2001, p. 2-3) use data from the U.S in a semi-structural VAR model. They focus only on the conditional correlation of consumption and employment, which requires identifying only the spending shock. The findings of Fatas and Mihov (2001) suggest that private consumption raises. They find an expansionary increase in government spending with a multiplier larger than one (i.e., the output increases more than one-to-one), which is largely driven by an increase in private consumption (Fatas & Mihov, 2001, p. 10, 21).

The study of Caldara and Kamps (2008, p. 19-20) is based on data from the U.S. In their paper, the findings using the recursive approach are similar to what they find applying the BP approach. This is reasoned with a government spending shock being identified in the same way for both approaches, by ordering it first. The main findings for the non-fiscal variables include a persistent increase in GDP and private consumption, followed by a hump-shaped pattern. The spending multiplier peaks after three to four years with a value of around two. The inflation and short-term interest rate increase with a lag of around two years.

3.3.3 Sign restrictions

Sign restrictions was first introduced by Uhlig (2005) and later extended by Mountford and Uhlig (2009) (referred in Mountford and Uhlig (2009, p. 960)). On the contrary to the BP -and the recursive approach, the sign restrictions approach does not require that number of shocks must equal number of variables. Also, "*it does not impose linear restrictions on the contemporaneous relation between reduced-form and structural disturbances*". Instead, Mountford and Uhlig (2005), referred in Caldara and Kamps (2008, p. 16), impose restrictions directly on the shape of the impulse responses and identify four shocks (business cycle shock, monetary policy shock, government spending shock and tax shock).

In the study of Mountford and Uhlig (2009), data on the U.S are used. Private consumption is found to not fall in response to an unexpected raise in government spending. This is in line with Blanchard and Perotti (2002), and Galí et al. (2007), referred in Mountford and Uhlig (2009, p. 962). Nevertheless, while these studies find that private consumption has a strong increase, Mountford and Uhlig (2009) find a small and significant effect different from zero on impact. Thus, the response of private consumption to a government spending shock might be difficult to reconcile with the standard Keynesian model. Besides, GDP is weakly stimulated for the first four quarters, and the GDP deflator falls. The negative relationship between prices and government spending is also found in other studies (Fatas & Mihov, 2001; Canova & Pappa, 2007, referred in Mountford & Uhlig, 2009, p. 962).

Dungey and Fry (2009, p. 1154-1155) apply the sign restriction approach using data on New Zealand. Their results imply that a raise in GDP is followed by a government spending shock, which is in line with previous findings (Blanchard & Perotti, 2002; Perotti, 2004a). Mountford and Uhlig (2009) find that the inflation falls in response to the shock, and that the interest rate rises initially when the shock is delayed for a year. On the other hand, Dungey and Fry (2009) observe that the interest rate raises initially related to the higher GDP, but only in the short-run.

3.3.4 The narrative approach

Following the work of Ramey and Shapiro (1998), parts of the literature have tried to avoid the identification problem in VAR analysis and instead looked for fiscal episodes, which can be seen as exogenous with respect to state of the economy (for example the large increase in military spending, associated with the onset of different wars (Ramey & Shapiro, 1998, referenced in Caldara & Kamps, 2008, p. 17)). The findings of Ramey and Shapiro (1998) imply that government spending raises GDP and lowers private consumption. The same findings were also found by Edelberg et al. (1999) and Burnside et al. (2004), by using the narrative approach on Ramey and Shapiro “war dates”.

Ramey (2011b, p. 3-4, 43) constructed two new measures of government spending shocks. One of the measures builds on Romer and Romer (2010), in which narrative evidence is used to construct a new, richer variable of defence shocks. This relies on news sources rather than legislative records (as Romer and Romer (2010) used). When using the narrative approach, they find GDP to rise more, and private consumption is lower. As narrative approach shocks capture the timing of the news about future increase in government spending much better and faster, it could also capture the initial decline in private consumption (as explained in section 3.2).

Compared to the findings discussed above, Caldara and Kamp (2008, p. 17-19) present somewhat different results when applying the narrative approach. They created a dummy variable that captures fiscal episodes, including the different war periods excluding the Korean war. Their findings involve a persistent increase in GDP, following a hump-shaped pattern. Note that in this study, private consumption increases, although the response is statistically significant only for one to three years.

3.3.5 Summary of empirical findings

The four different approaches discussed above imply how the responses of the key macroeconomic variables vary, even if all of them are using VAR models to assess the effects of fiscal policy shocks. When comparing the narrative approach (not including Caldara and Kamps, 2008) and the three other approaches, it is worth noting that the main difference in the results seem to be the response of private consumption. In BP, recursive -and sign restrictions approach, private consumption is found to react positively, while the narrative approach indicates a fall in private consumption. This can also be seen from Table 3.3, which illustrates a summary of the studies discussed above. The table focuses on the effects of government spending, public consumption, public investment, GDP, private consumption, inflation and interest rate. In our thesis, we apply the recursive approach to identify government spending shocks.

Study	Approach	Sample	VAR specification	Findings
Blanchard and Perotti (2002)	BP	U.S. Quarterly, 1947:1-1997:4	T G Y	G↑: Y↑, C↑, I↓ T↑: Y↓, I↓
Perotti (2004a)	BP	U.S, Germany, UK, Canada and Australia. Quarterly. Two periods: 1960:1-1979:4 and 1980:1-2001:4	G T Y π r	G↑: Y↑ (in all countries except for Australia)
Galí et al. (2007)	BP	U.S. Quarterly, full postwar: 1948:1-2003:4, post–Korean war: 1956:1-2003:4, and post-1960:1960:1-2003:4	G Y h C I w d i	G↑: C↑, I↓
Tenhofen et al. (2010)	BP	Germany. Quarterly, 1974:1–2008:4	Y π r G T	G↑: Y↑, C↑, I↑
Fernández and de Cos (2006)	BP	Spain. Quarterly, 1980:1-2004:4	G T Y π r Y PC PI π	G↑: Y↑, π↑, r↑ PC↑: Y↑, π↑ PI↑: Y↑, π↑
Burriel et al. (2009)	BP	U.S and Euro area. Quarterly, 1981:1-2007:4	G T Y r π PC Y r π PI Y r π	G↑: Y↑, π↑, r↑, C↑ (in both areas) G↑: I↓ (US), I↑ (Euro area) PC↑: Y↑, π↑ (in both areas) PI↑: Y↑, π↑ (in both areas)
Perotti (2004b)	BP	Australia (1960:1-2001:2), Canada (1961:1-2001:4), West Germany (1960:1-1989:4), UK (1963:1-2001:2), and U.S (1960:1-2001:4), Quarterly.	PI PC T G Y π r	PC↑: Y↑ (all countries) PI↑: Y↑ (U.S, Germany and Canada)
Ilzetzki et al. (2010)	BP	44 countries. Quarterly, 1960:1-2007:4	PI PC Y	PC↑: Y↓ PI↑: Y↑
Fatas and Mihov (2001)	Recursive	U.S. Quarterly, 1960-1996	G C I Y T r	G↑: Y↑, C↑, π↓
Caldara and Kamps (2008)	Recursive	U.S. Quarterly,1955-2006	G Y π T r	G↑: Y↑, C↑, π↑, r↑

Mountford and Uhlig (2009)	Sign restrictions	U.S. Quarterly, 1955-2000	Y C G T I r π	G↑: Y↑, I↓, C↑, r↑, π↓
Dungey and Fry (2009)	Sign restrictions	New Zealand. Quarterly, 1983:2-2006:4	G T d Y π r	G↑: Y↑, r↑
Ramey and Shapiro (1998), Edelberg et al. (1999), Burnside et al. (2004)	Narrative	U.S. Quarterly, 1947-late 1990s or 2000s	G Y w pr p r I	G↑: Y↑, C↓
Ramey (2011)	Narrative	U.S. Quarterly, 1939-2008	G Y h C I T	G↑: Y↑, C↓
Caldara and Kamps (2008)	Narrative	U.S. Quarterly,1955-2006	G Y π T r dv	G↑: Y↑, C↑

Table 3.3. Summary of the findings using the four approaches. G = government spending, Y = output/GDP, C = private consumption, I = private investment, π = inflation, r = interest rate, PC = public consumption, PI = public investment, T = Tax, h = hours worked, i = income, d = deficit, w = wage, e = private employment, pr = productivity, p = prices, dv = dummy variable .

Chapter 4 - Methodology and estimations

The first half of this chapter elaborates the methodology to the recursive identification approach. The second half of the chapter presents the data, the ordering, the assumptions and the resulting estimations of our baseline model.

4.1 Stationarity and lag selection

4.1.1 Are the time series stationary?

A time series is stationary when the mean and the variance of a time series are constant over time, and if the covariance between two values from the series depend only on the length of the time separating the two values (not depending on the actual time the variables are observed) (Hill, Griffiths & Judge, 2001). The specification of the drift, also called the trend of the series, is important when we formally want to test for non-stationarity because trends often make the data non-stationary (Bjørnland & Thorsrud, 2015)[9].

Most macroeconomic time series are non-stationary and will often inhabit trends and drift upwards over time. These time series have a deterministic trend. When a deterministic time trend (the time index t and a slope parameter α) is added to a moving average representation, the time series will be non-stationary, as the first- and second-order moments will depend on the time index. An important observation is that the deviations of the time series process (y_t) from its mean, are stationary (Bjørnland & Thorsrud, 2015, p. 113). Following a shock, the time series will therefore always return to the trend. This is called a trend-stationary process. Times series that do not drift systematically in any direction, are said to have a stochastic trend. A random walk model is the simplest model of a variable with a stochastic trend[10].

4.1.2 Cointegration

Bjørnland and Thorsrud (2015, p. 249-254) argue that information may be lost when making a times series stationary by e.g. differencing the data. In other words, level information may be lost. In order to avoid this, there are conditions and methods that will allow us to directly work with non-stationary data in levels, known as cointegration. If there exists non-stationary I(1) variables, a linear combination of these variables will also be non-stationary. However, there is a possibility for the linear combinations to be stationary. If two or more time series share the same common trend component, which will cancel each other out through a linear combination of the variables, they are said to be cointegrated.

In a multivariate setting, we work with a VAR model, in which there can exist non-stationary I(1) variables. The VAR model is said to be covariance-stationary if the effects of the shocks eventually die out. This is true if all the eigenvalues of the companion form matrix are less than one in absolute value. When the VAR is

[9] In a non-stationary time series either the first-or second-order moments depend on the time index. By visual inspection of time series, it can be interpreted whether a time series is stationary or not (Bjørnland & Thorsrud, 2015).

[10] A random walk is defined as "*a time series process that only depends on past values of itself and a Gaussian white noise errors".* The IRFs will remain at the initial shock at all horizons, meaning the effect of the shock never dies out (Bjørnland & Thorsrud, 2015, p. 115).

stable, it is also stationary by definition, i.e. the analysis can be performed in normal way if there exists cointegration (Bjørnland & Thorsrud, 2015, p. 249-254).

4.1.3 Lag length selection

When choosing the lag length, one can either use economic theory, or some sort of statistical information criterion such as the Akaike and the Baynes information criterion test (AIC and BIC test). The main difference between the two tests is that the BIC will suggest models with fewer lags than the AIC criterion. A method often used is to choose a rather large length a priori, and then preforming a robustness test by re-estimating using a shorter lag length. One should also be careful with including too short lag length because that can lead to a mis-specified model, and the OLS estimates will be biased. Consequently, spurious significance of the parameters is induced since unexplained information is left in the disturbance term. On the other side, a large lag length relative to the number of observations will often lead to a poor and inefficient estimation of the parameters. (Bjørnland & Thorsrud, 2015, p. 199-200).

4.2 Vector autoregressive (VAR) models

VAR models are commonly used to estimate the effects of fiscal policy shocks on economic activity (Boiciuc, 2015). The VAR(p) model can be written as:

$$y_t = \mu + A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + e_t\,, \tag{4.1}$$

where A is a (n x n) coefficient matrix, μ is a (n x 1) vector of intercept terms, and e_t is a (n x 1) dimension vector of error terms which we assume are white noise, with the following properties:

$$\mathrm{E}[e_t] = 0 \tag{4.2}$$

$$\mathrm{E}[e_t, \quad e_s'] = \begin{cases} \Sigma_e & for\ t = s \\ 0 & otherwise \end{cases}$$

This VAR model of order p is called a reduced-form representation, making it different from SVAR (will be introduced later in this chapter).

VAR is a multivariate generalization of the univariate AR(p) model, and is used to analyse multiple variables at the same time (Bjørnland & Thorsrud, 2015, p. 189-191). Statistical tests are frequently used in determining inter-dependencies and dynamic relationships between different variables. Therefore, non-statistical a priori information was incorporated into this methodology (Pfaff, 2008, p. 1). An argument for including many variables at the same time is that a given variable does not only depend on past values of itself, but also on past values of other variables. Including lags of all endogenous variables in the VAR is therefore typical.

The stability of a VAR(p)-process is an important characteristic, meaning that "*it generates stationary time series with time invariant means, variances and covariance structure, given sufficient starting values*". In practice, the stability of an empirical VAR(p)-process can be analysed through the companion form, and by calculating the eigenvalues of the coefficient matrix (Pfaff, 2008, p. 2). For the VAR model to be covariance-stationary, the effect of the shocks must eventually die out. This is true if all the eigenvalues of the companion form matrix are less than one in absolute value. If the process is stable, the series fluctuate around a constant mean, and their variability does not change as they develop. When the VAR model is stable, the autocorrelation functions die out as the number of lags increase (Bjørnland & Thorsrud, 2015, p. 192, 197).

Using ordinary least squares (OLS), the VAR system can be estimated equation by equation. This will be consistent and also efficient under the assumption of normality of the errors. We can assume a given sample size of T with the endogenous variables $y_1, \dots y_T$, for each of the n variables in the VAR model. In addition, we have sufficient pre-sample values for each of the n variables, $y_{-p+1}, \dots,$ y_0 (Bjørnland & Thorsrud, 2015, p. 199). The coefficients of a VAR(p)-process can be estimated efficiently by least-squares applied separately to each of the n equations. Once a VAR(p) model has been estimated, structural analysis can be performed (Pfaff, 2008, p. 3).

4.3 Structural vector autoregressive (SVAR) models

As mentioned earlier, VAR(p) can be interpreted as a reduced-form model (Pfaff, 2008, p. 4). Foroni (2014) pointed out that reduced-form VARs are not sufficient when it comes to the structure of the economy[11]. The reduced-form error terms (e_t) cannot be interpreted as structural shocks. According to Foroni (2014), orthogonal shocks with economic interpretation are needed to be able to perform policy analysis, and therefore we need a structural representation. In contrast to VAR, SVAR models in general allow the explicit modelling of contemporaneous interdependence between the left-hand side variables. These types of models try to bypass the shortcomings of VAR models.

In the following section, we will solve the estimation problem by starting from a structural representation, and recover the structural shocks by using a reduced-form representation of VAR. The following technical presentation of the SVAR method together with the identification, will be based on notes by Cross (2019), combined with Bjørnland and Thorsrud (2015, p. 215-224)[12].

The structural representation of a VAR model, or the general SVAR(p) model, with n variables and p lags, is the following:

$$B_0 y_t = b + \sum_{j=1}^{p} B_j y_{t-j} + \varepsilon_t, \qquad \varepsilon_t \sim N(0,1), \text{ where} \tag{4.3}$$

y_t is a n x 1 vector of variables of interest, b is a n x 1 vector of constants, B_j, with j = 1,…,p, are n x n matrices of autoregressive coefficients, ε_t is a n x 1 vector of white noise errors, each with unit variance, and B_0 is a n x n matrix that shows how the variables of interest respond to shocks at the current date t, called the *impact matrix*.

To illustrate this general form, we can show an example of a bivariate SVAR (2) model (with no constant):

$$\begin{bmatrix} B_{11,0} & B_{12,0} \\ B_{21,0} & B_{22,0} \end{bmatrix} \begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} = \begin{bmatrix} B_{11,1} & B_{12,1} \\ B_{21,1} & B_{22,1} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} \tag{4.4}$$

[11] Claudia Foroni (10th of November 2014), Norges Bank. "*A primer on Structural VARs*'.
[12] Lecture notes by Jamie Cross (14th of March 2019) in Research Methodology.

By looking at this equation, we can tell that a unit increase in $\varepsilon_{1,t}$ will cause $y_{1,t}$ to immediately increase by $B_{11,0}$, and $y_{2,t}$ to immediately increase $B_{21,0}$.
A problem with the SVAR is that it suffers from simultaneity, which means that "*changes in the endogenous variables at date t generate changes in other endogenous variables at date t*" (Cross, 2019). The OLS estimator becomes inconsistent with these results. To solve the estimation problem, we first write the SVAR as a reduced-form VAR and estimate it using OLS. Lastly, we recover the SVAR for the structural analysis.

To get to the reduced-form VAR, we multiply equation (4.3) by B_0^{-1}, where we assume that B_0 is invertible. Then, the SVAR can be written as:

$$y_t = B_0^{-1}b + \sum_{j=1}^{p} B_0^{-1}B_j y_{t-j} + B_0^{-1}\varepsilon_t$$

$$= a + \sum_{j=1}^{p} A_j y_{t-j} + e_t, \qquad e_t \sim N(0,1) \qquad (4.5)$$

↓

$A(L)y_t = e_t$, where

$B_0 = I$, $a = B_0^{-1}b$ is a n x 1 vector of constants, $A_j = B_0^{-1}B_j$, with j=1,…,p, are n x n matrices, $A(L) = (I - A_j L)$, and importantly;

$e_t = B_0^{-1}\varepsilon_t$ is a n x 1 vector of error terms. (4.6)

The reduced-form errors, e_t, are therefore linear combinations of the structural errors, ε_t, with the covariance matrix:

$E[e_t, \quad e_t'] = B_0^{-1}(B_0^{-1})' = \sum$, where (4.7)

$\sum$ is the covariance matrix of the reduced-form errors. Note that equation (4.7) is the same as equation (4.2).

4.4 Identification

In this section, we will recover the SVAR from the reduced-form using equation (4.7). One problem is that the SVAR model has more parameters than the estimated reduced-form VAR has. As mentioned earlier in the section of VAR, all parameters of the reduced-form model can be estimated by OLS, equation by equation. The covariance matrix (4.7) will generally not be a diagonal matrix, and the reduced-form errors are typically correlated (Bjørnland & Thorsrud, 2015, p. 218). Consequently, the structural parameters of the model (the SVAR parameters in equation (4.3)) are not identified. This is called the *identification problem*. Assume SVAR has: k = n (np + 1) autoregressive parameters, and n^2 contemporaneous parameters. While reduced-form VAR has: k = n (np + 1) autoregressive parameters, and $\frac{n\,(n+1)}{2}$ unique parameters in the covariance matrix. To identify the structural model, it is necessary to impose restrictions.

With one of the structural parameters set to zero, the system could be identified. This means that we would have a system with the same number of known and unknown values. One way to solve this problem is by using the *order condition*: since B_0 (SVAR) has n^2 unique elements, while reduced-form VAR has $\frac{n\,(n+1)}{2}$, we can achieve exact identification by restricting n^2 - $\frac{n\,(n+1)}{2}$ = $\frac{n\,(n-1)}{2}$ elements of B_0 to be zero.

When adding n additional variables to the VAR, it is not always possible to add $\frac{n\,(n-1)}{2}$ additional restrictions to identify the SVAR. To solve this identification problem, we use the Cholesky Decomposition. An issue with the order condition is that it does not state which elements in the SVAR that needs to be restricted. Any $\frac{n\,(n-1)}{2}$ elements will do. However, it is common for people to assume a *recursive system*. That is, restricting elements of B_0 that are above the main diagonal to be zero. One natural reason for doing that is because there are exactly $\frac{n\,(n-1)}{2}$ such elements. Another natural reason is to use Cholesky Decomposition.

From equation (4.5) we already showed that the reduced-form VAR(p) can be written as:

$A(L)y_t = e_t$, where (4.8)

A(L) is the lag polynomial, y_t is a vector of variables and e_t are Gaussian white noise errors, i.e., $e_t \sim$ i.i.d. N (0, ∑). Assuming that the VAR(p) is stable, then

A(L) is invertible. To get the MA (∞) representation of the reduced-form VAR, we multiply equation (4.8) by the inverse $A(L)^{-1}$:

$y_t = C(L)e_t$

$$= \sum_{j=0}^{\infty} C_j e_{t-j}, \tag{4.9}$$

$= e_t + C_1 e_{t-1} + C_2 e_{t-2} + \ldots$, where $C(L) = A(L)^{-1}$, $A_0 = I$ and $C_0 = I$.

The reduced-form errors are likely correlated, meaning the matrix, ∑, is likely not a diagonal matrix. Having a shock in one variable is likely to be caused by a shock in another variable. To be able to perform a structural analysis, one has to make the shocks uncorrelated. This means that the analysis will be performed through the MA representation, where residuals are orthogonal, i.e. they are uncorrelated. To perform this, we use the Cholesky decomposition, where any positive definite symmetric matrix can be factorized as the product:

$$\sum{}' = PP', \text{ where} \tag{4.10}$$

P is a lower triangular matrix with positive elements on the main diagonal, called the (lower) Cholesky factor of ∑', and P´ is its conjugate transpose. Note that every covariance matrix is a positive definite symmetric matrix implying that they each have a unique Cholesky factor. Using the fact that $I = PP^{-1}$, we can get the MA representation of SVAR by rewriting the equation (4.9):

$y_t = \sum_{j=0}^{\infty} C_j P P^{-1} e_{t-j},$

$$= \sum_{j=0}^{\infty} \Theta_j \varepsilon_{t-j}, \tag{4.11}$$

$= P\varepsilon_t + \Theta_1\varepsilon_{t-1} + \Theta_2\varepsilon_{t-2} + \ldots$, where $\varepsilon_t = P^{-1}e_t$ and $\Theta_j = C_jP$.

Given that P is a lower triangular matrix, the components of ε_t will be uncorrelated, although the components of e_t may not be uncorrelated.

Going back to our previous example of the bivariate SVAR model (equation 4.4) using the MA (∞) representation, we get:

$$\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix} y_t = \begin{bmatrix} P_{11} & 0 \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} + \Theta_1\varepsilon_{t-1} + \Theta_2\varepsilon_{t-2} + \ldots$$

Note that under this identification strategy, the restriction only applies to the transmission process at time t.

This means that the Cholesky decomposition implies that the second shock, ε_2, does not affect the first variable contemporaneously (that is, at time t), while both shocks, ε_1 and ε_2, can affect the second variable contemporaneously. After one period, there are no further restrictions, since there is a chance that Θj have non-zero elements above the diagonal, meaning both shocks potentially can affect both variables. Now, the question is if these restrictions make sense in an economical interpretation. To show this, an example is presented in section A4.1 (in Appendix), in which the order is decided based on economic theory.

The construction and interpretation of the IRF is central in the SVAR literature. An IRF describes how a given (structural) shock affects a variable in the y_t-vector over time. In the setting of a structural model, the impulse can be seen as the cause and its propagation as the effect over time. By using IRFs, we can investigate how shocks impact the variables in the SVAR system.

4.5 Limitations to the methodology

Bjørnland and Thorsrud (2015) argue there is a major limitation of the VAR approach, namely the approach must be estimated using low order systems. The residuals will include all effects of omitted variables, leading to major distortions in the impulse responses. This will further make them of little use for structural interpretations. Interpreting the impulse response are difficult due to unexplained information left in the disturbance terms induced by all measurement errors or mis-specifications. A conclusion from this argument is that a careful empirical analysis should be applied when specifying the VAR. Although there should be a caution against overinterpreting the evidence from the VAR models.

Stock and Watson (2001, p. 110-112) also mention a limitation of VAR. There is a possibility of getting misleading responses when computing the standard errors for impulse responses if the variables are highly persistent. Without modification, standard VARs loose conditional heteroskedasticity, nonlinearities and drifts or breaks in parameters. Also, timing conventions in VARs do not necessarily reflect real-time data availability, leading to undercutting the method of identifying restrictions based on timing assumptions.

Another concern is the use of informal restrictions in the SVAR approach, which are indeed widespread. Many researchers have an idea of how the IRFs to a given structural innovation should look like. An example is with regards to fiscal policy shock, which should trigger a positive output response. After imposing the formal identifying restrictions, many SVAR modelers check if the estimated IRFs are in accordance with their a priori views. In the case of implausible responses, the researcher returns to the specification of the model and examine if it is possible to produce a more plausible model. By this procedure, there are indications of the SVAR analysis being prone to undisciplined data mining. The issue of informal restrictions also raises the question of whether the SVAR methodology is a suitable tool to establish stylized facts, in order to discriminate between different theoretical models (Gottschalk, 2001).

4.6 Data

The sample of all the variables used in our SVAR models (both baseline and the extensions) cover the period from 1991:1 to 2019:3. Quarterly data are used because this is essential for identifying fiscal shocks (Blanchard & Perotti, 2002). Government spending data is the sum of public consumption and public investment. We use mainland Gross Domestic Product (GDP) (in market value) because this is the natural benchmark. The data of government spending and GDP is seasonally adjusted, in volume and collected from Statistics Norway (2020). To see the percentage change, we take the log of both variables. In order to get the variables on the same scale, they are multiplied by 100.

As a measure for inflation, we use the mainland GDP deflator, collected from FRED (2020). The data was quarterly and seasonally adjusted, with an index 2015=100. The variable is log-differenced to see the percentage change. For the same reason as above, we multiplied the index by 100. The GDP deflator is calculated by dividing nominal GDP by real GDP and then multiplied by 100. It is a measure of the price level of all new, domestically produced, final goods and services in an economy. Further, it is a price index that measures price inflation or deflation.

Data of the 3-month Norwegian InterBank Offered Rate (NIBOR) is used as a measure for the nominal interest rate[13]. The 3-month NIBOR can be defined as the sum of 3-month policy rate expectations plus risk premium (which vary across banks) (Sparebanken Vest, 2015)[14]. The data from period 1991:1 to 2013:4 is collected from Norges Bank (2020), while the data from period 2014:1 to 2019:3 is collected from Oslo Stock Exchange (2020). As the data from both references were monthly, the last month in each quarter is collected in order to get quarterly frequency data.

For our extensions we have used quarterly data on public investment, public consumption and private consumption, all collected from SSB. The data on public investments consists of mainland-Norway. Public consumption includes consumption in both state -and local government. Private consumption involves consumption by households and non-profit organizations. The data is seasonally adjusted and in volume, and as above, all these variables are multiplied by 100. Except for interest rate, all variables are logged, however inflation is log-differenced.

4.7 Baseline model

4.7.1 Ordering of the variables

The structural model consists of government spending (G_t), GDP (Y_t), inflation (π_t) and interest rate (r_t). We assume the variables are driven by related structural shocks $\varepsilon_{G,t}$, $\varepsilon_{Y,t}$, $\varepsilon_{\pi,t}$ and $\varepsilon_{r,t}$ (with a constant term included). To be able to identify the structural shocks, $\frac{4\,(4-1)}{2} = 6$ restrictions have to be made, and we obtain the structural model:

[13] The 3-month NIBOR is a collective term for Norwegian money market rates, running with different maturities. "*Nibor is intended to reflect the interest rate level a bank require for unsecured money market lending in NOK to another bank*" (Finans Norge, n.d).

[14] The policy rate is another candidate for the Norwegian interest rate, which is Norges Bank's main instrument in stabilizing inflation and developments in the Norwegian economy (Norges Bank, n.d). However, by comparing the two interest rates in the robustness test (section 6.4), we see that the trends in the time series are quite similar.

$B_{11}G_t = \alpha_1 + B_{11}G_{t-1} + B_{12}Y_{t-1} + B_{13}\pi_{t-1} + B_{14}r_{t-1} + \varepsilon_{g,t}$

$B_{22}Y_t = \alpha_2 - B_{21}G_t + B_{21}G_{t-1} + B_{22}Y_{t-1} + B_{23}\pi_{t-1} + B_{24}r_{t-1} + \varepsilon_{y,t}$

$B_{33}\pi_t = \alpha_3 - B_{31}G_t - B_{32}Y_t + B_{31}G_{t-1} + B_{32}Y_{t-1} + B_{33}\pi_{t-1} + B_{34}r_{t-1} + \varepsilon_{\pi,t}$

$B_{44}r_t = \alpha_4 - B_{41}G_t - B_{42}Y_t - B_{43}\pi_t + B_{41}G_{t-1} + B_{42}Y_{t-1} + B_{43}\pi_{t-1} + B_{44}r_{t-1} + \varepsilon_{r,t}$

Using the recursive system, we restrict the elements of B_0 that are above the main diagonal to be zero. Recall that P is a lower triangular matrix with positive elements on the main diagonal, and therefore, ε_t will be uncorrelated.

$$\begin{bmatrix} G_t \\ Y_t \\ \pi_t \\ r_t \end{bmatrix} = \begin{bmatrix} \theta_{11,0} & 0 & 0 & 0 \\ \theta_{21,0} & \theta_{22,0} & 0 & 0 \\ \theta_{31,0} & \theta_{32,0} & \theta_{33,0} & 0 \\ \theta_{41,0} & \theta_{42,0} & \theta_{43,0} & \theta_{44,0} \end{bmatrix} \begin{bmatrix} \varepsilon_{g,t} \\ \varepsilon_{y,t} \\ \varepsilon_{\pi,t} \\ \varepsilon_{r,t} \end{bmatrix} + \Theta_1\varepsilon_{t-1} + \Theta_2\varepsilon_{t-2} + \ldots,$$

The particular ordering of the variables has the following implications:

1. Government spending does not react contemporaneously to shocks to any of the variables in our system.
2. GDP does not react contemporaneously to inflation and interest rate shocks, but is affected contemporaneously by shocks to government spending.
3. Inflation does not react contemporaneously to interest rate shocks, but is affected contemporaneously by government spending and GDP shocks.
4. Interest rate is affected contemporaneously by shocks to all variables in the system.

It is worth noting that after the initial period, all the variables in the system can interact freely. This means that for example, inflation shocks can affect GDP in all periods after the one in which the shock occurred. The following discussion will justify the assumptions based on both economic theory, and previous empirical findings on the contemporaneous relations between the variables.

As explained earlier, ordering government spending first, means we assume that all elasticities of government spending to GDP, inflation and interest rate are set equal to zero. In monetary policy VARs with monthly data, it is more common to order GDP before the policy instrument. This is the case because the effect of the

Federal Fund rate (FFR) on GDP can take more than a month. It is highly questionable to extend this assumption to fiscal policy VARs. The reason is that government spending is a component of GDP. This assumption imposes an implicit assumption of exactly 100 percent crowding out contemporaneously on private GDP (Perotti, 2004a, p. 6). Furthermore, government spending does not seem to respond to GDP contemporaneously (Blanchard & Perotti, 2002). Also, the movements in government spending are largely unrelated to the business cycle. This indicates that it is plausible to assume that government spending is not affected contemporaneously by shocks coming from the private sector (Caldara & Kamps, 2008, p. 14). Therefore, government spending is ordered before other variables when Cholesky decomposition is used (Fatas & Mihov, 2001; Galí et al., 2007; Ilzetzki et al., 2013).

As discussed in chapter 3, Blanchard and Perotti (2002, p. 1334) argue that in fiscal policy, it can take more than a quarter for policymakers and legislatures to (1) learn about a shock to GDP, (2) decide on what fiscal measures to take (if any) in response, (3) pass the measures through the legislature and then (4) finally implementing them. Hence, these arguments underline why government spending is ordered before GDP.

Ordering interest rate last (after inflation) can be justified by; (1) *"on the grounds of a central bank reaction function implying that the interest rate is set as a function of the output gap and inflation"* and (2) *"given that government spending is not sensitive to interest rate changes*" (Caldara & Kamps, 2008).

When the announcement of fiscal policy is omitted, there can be consequences for the estimated effects of fiscal policy. The effects on interest rate following a government spending shock prevails almost immediately because fiscal policy is announced in advance. As a consequence, the response of interest rate will catch the effects of the anticipated component of fiscal policy. In other words, it will catch the effects of changes in fiscal policy that are expected to occur in the future based on the information at time t, and the information available to the public (Perotti, 2004a, p. 12).

4.7.2 Estimations

The following subsection presents our results and estimations from the tests introduced above. The specification of our baseline model will thereby be justified.

Stationarity

The time series that appeared to be non-stationary by visual inspection were logged, as an attempt to make them stationary (see the plots in Appendix, Figures A4.1-A4.7). Government spending, public consumption, public investment and GDP appear to have a deterministic trend, as they are drifting upwards. The time series of inflation seem to have a stochastic trend, as it does not have a clear trend (neither drifting upwards nor downwards), i.e. it looks stationary and has a non-zero mean. The time series of the interest rate does not have a clear deterministic or stochastic trend. To estimate our VAR model, we include both a constant and a linear trend, which is also used in the literature (Asche & Kristiansson, 2019).

Lag selection

We run a BIC and AIC test to decide upon the lag length. The BIC test gives one lag and the AIC test gives ten lags (the test results are shown in Table A4.1, in Appendix). As the results are not in line with economic theory, we have not chosen the number of lags provided by these tests. Kilian and Lutkepohl (2017) argue that we have to allow for delays in the response to the shocks. As we are working with fiscal policy and quarterly data, it is often considered optimal to use a lag length of four to eight, which also is in line with the optimal range suggested by Blanchard and Perotti (2002, p. 1340). The main idea behind this reasoning is that there often is a wider time period between the implementation of a policy decision, and how the decisions affect other macroeconomic variables. Relying on these arguments, we have chosen four lags in our model.

Eigenvalues and Cointegration

All the computed eigenvalues are less than one in absolute value (shown in Table A4.2, in Appendix). By definition, the VAR(p)-processes are stable and thereby also stationary (Bjørnland & Thorsrud, 2015, p. 192). Additionally, the results from the Johansen trace test indicate existence of cointegration between the variables, meaning we can reject the null hypothesis for r < 6 (shown in Table A4.3, in Appendix)[15]. Resting on these results, we conclude that the VAR model is both stable and stationary (Bjørnland & Thorsrud, 2015, p. 249-254). Because of this, the Augmented Dickey-Fuller (ADF) test was not performed[16].

Chapter 5 - Results and analysis

This chapter presents results obtained by using MatLab R2019b. Common for all subsections, is that all the functions illustrate the impulse responses of all endogenous variables to a one percent shock to government expenditure at time zero. The shock is normalized to one, indicating how one percent increase in government spending will affect the other variables in the model. All figures display a horizon of 20 quarters as this is common in fiscal policy literature after a one-period government spending shock.

5.1 Baseline model

The results below present how a one percent shock to government spending affects the Norwegian economy in our baseline model, consisting of government spending, GDP, inflation and interest rate. This is interesting to investigate because the strength of the effect of government spending is disputed, and many of the existing evidence refers to the U.S or other European countries.

[15] The Johansen test, which are likelihood-ratio tests, can test for cointegration. The test can be seen as a multivariate generalization of the ADF test, the generalization being the examination of linear combinations of variables for unit roots. If there are n variables with unit roots, there can be at most n-1 cointegrating vectors. The Johansen test is a test of the null hypothesis of no cointegration against the alternative of cointegration. The number of cointegrating vectors, is referred to as *r*. In the trace test, the null hypothesis states that there are no cointegrating vectors, $r = 0$, and the alternative hypothesis states that $r \leq n$, where n is the maximum number of possible cointegrating vectors (Dwyer, 2015).

[16] An ADF test is performed to test for unit roots, in which it tests whether a times series is a random walk (have unit root) against the alternative that it is a trend stationary process (no unit root). A unit root is defined as "*if variable y_t can be made approximately stationary by differencing it once, we say that it is integrated of first order, I(1), or that it has a unit root. Stationary random variables, such as Δy_t are called integrated of order zero, I (0)".* A time series with random walk is said to have a unit root, as the effects of a shock persist forever (Bjørnland & Thorsrud, 2015).

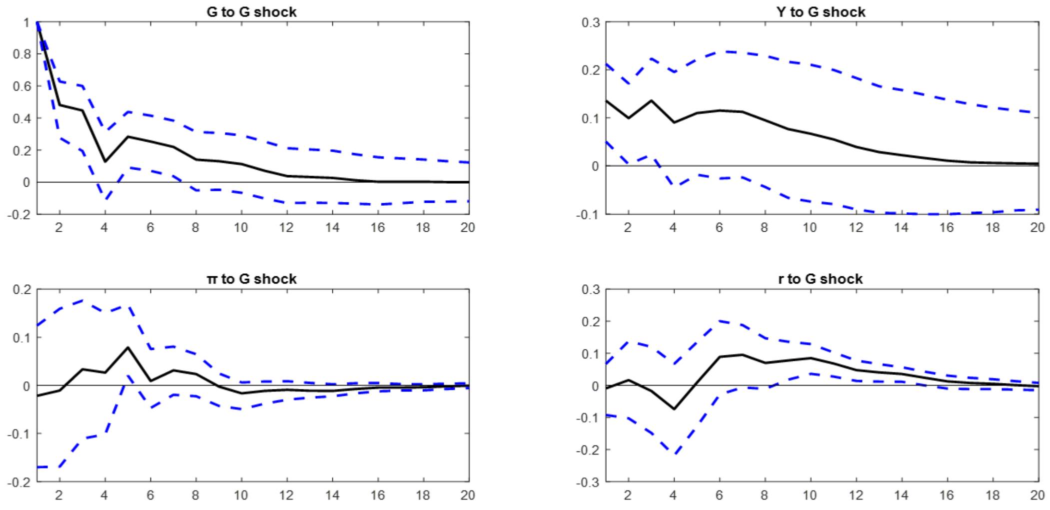

Figure 5.1. Estimated impulse responses to a government spending shock in the four-SVAR model. G = government spending, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

From Figure 5.1, we see that the spending shock turns out to be persistent, as the positive and statistically significant response lasts for almost two years. The persistency of the shock is consistent with the existing evidence from other OECD countries (Perotti, 2004a, referred in Fernández & de Cos, 2006, p. 17) and from the U.S (Galí et al., 2007; Burriel et al., 2009).

GDP has a positive and statistically significant peak effect of 0.13 percent on impact. This effect on GDP is consistent with previous findings (Ramey & Shapiro, 1998; Edelberg et al., 1999; Fatas & Mihov, 2001; Blanchard & Perotti, 2002; Perotti, 2004a; Burnside et al., 2004; Fernández & de Cos, 2006; Burriel et al., 2009; Mountford & Uhlig, 2009; Dungey & Fry, 2009; Tenhofen et al., 2010). During the first three quarters, the response of GDP has a small and statistically significant fall. After the first year, the response is not statistically significant before it returns back to trend. In general, this short-lived, positive effect on GDP is often found to be the response of government spending shock (Burriel et al., 2009). Our results indicate that higher government spending can boost the economy, as there is a short-lived increase in GDP.

Following the shock, the response of inflation is statistically insignificant, except for the increase in the fifth quarter with a peak effect of 0.09 percent. Higher inflation as a response to higher government spending is also consistent with other empirical findings (Fernández & de Cos, 2006; Burriel et al., 2009). In the robustness test, we replace the GDP deflator with CPI, which is another measure of inflation. Figure 6.1 in the robustness test illustrates how the trend of these two measures differ. However, in Figure A6.4 (in Appendix), the different trends of the GDP deflator and CPI seem to have a minor affect looking at the IRFs of the baseline model.

The response of the interest rate is statistically insignificant until the ninth quarter. Here, the response is shown to be positive and statistically significant. This effect lasts until it returns back to trend. An increase in the interest rate is in line with other studies discussed earlier (Fernández & de Cos, 2006; Burriel et al., 2009; Mountford & Uhlig, 2009; Dungey & Fry, 2009). In the New Keynesian model, monetary policy can be used actively to prevent a further increase in inflation following a fiscal stimulus. Norway has an inflation target of two percent, and use the Taylor rule as a reference to set the interest rate. In this case, monetary policy should react less to changes in fiscal policy. In the New Keynesian model, fiscal stimulus allows inflation to rise a little before the Central Bank reacts. In Norway, the monetary policy is expected to react stronger when the output is above or below the trend, as the Taylor rule is used (Woodford, 2011). Furthermore, Woodford (2011) attributes this effect to sticky prices, making the real interest rate rise more than under flexible prices. Following a government spending shock, our results show that the interest rate is increasing when inflation is increasing, indicating monetary policy may have been used actively. Pressure on prices and increased interest rates might lead to a fall in consumption and investment, which can dampen the positive effect on GDP (Taylor, 1993; Cwik & Wieland, 2009; Cogan et al., 2009, referred in Midthjell, 2011, p. 27).

In the robustness test, we replace NIBOR interest rate with the policy rate to investigate if the results differ. Figure 6.2 in the robustness test shows that the trend of NIBOR and the policy rate are similar, with NIBOR being at a higher level than the policy rate. However, the difference is minimal and therefore our results does not seem to be altered (see comparison of the IRFs in Figure A6.6 in Appendix).

By economic theory, we can expect that a positive government spending shock is likely to increase the aggregate demand, resulting in higher growth in the short-run, and higher inflation. This is in line with our findings. Looking at the supply-side of the economy, an increase to different components of government spending will determine the impact. An increase in government spending could improve infrastructure, which could lead to a rise in productivity and growth in the aggregate demand looking at the long-run perspective.

The size of the effect of a government spending shock can also be illustrated by multipliers[17]. A reminder of the definitions is shown in Table 5.1:

Impact multiplier	*Multiplier*	*Peak multiplier*	*Cumulative multiplier*
$\left(\equiv \frac{\Delta Y(t)}{\Delta G(t)}\right)$	$\left(\equiv \frac{\Delta Y(t+N)}{\Delta G(t)}\right)$	$\left(\equiv \max_{N} \frac{\Delta Y(t+N)}{\Delta G(t)}\right)$	$\left(\equiv \frac{\sum_{j=0}^{N} \Delta Y(t+j)}{\sum_{j=0}^{N} \Delta G(t+j)}\right)$

Table 5.1. Source: Spilimbergo et al. (2009, p. 2). The table shows how multipliers are calculated. Y = output and G = government spending. (Note that this table is the same as Table 3.1).

When using logged values, the impulse responses will show the elasticities, making it impossible to read multipliers directly from the graph (Ramey, 2019, p. 96). For the purpose of calculating spending multipliers, the IRFs are transformed from logs to levels. Hence, we present the NOK response of GDP to a positive government spending shock of one NOK (Asche & Kristiansson, 2019, p. 17).

Horizon	1^{st} quarter	4^{th} quarter	8^{th} quarter	12^{th} quarter	20^{th} quarter	peak
Multiplier	0.25	0.25	0.25	0.25	0.24	0.49(2)
Cumulative Multiplier	0.25	0.32	0.33	0.33	0.32	0.33

Table 5.2. Multipliers and cumulative spending multipliers after a positive government spending shock in sample period 1991:1 - 2019:3. These are calculated by the definitions shown in Table 5.1. In parentheses, the quarter of the peak response is shown.

Table 5.2 shows an impact multiplier of 0.25, meaning one additional NOK of government spending delivers NOK 0.25 of additional output. This can imply that

[17] All multipliers are calculated using the IRFs values of GDP and government spending.

output has risen less than an increase in government spending on impact, indicating there may be some crowding out of output by government spending (Ilzetski et al., 2013). Our findings are consistent with the findings of Spilimbergo et al. (2009), as they found a multiplier to be 0.5 or less in small open economies. The small size indicates there may have been larger leakages, as a greater part of the stimulus may have been spent on imports. Other reasons behind the small size may be a lower marginal propensity to consume, or that the stimulus measures may have been targeted towards consumers who are liquidity constrained. According to our results in year one, the estimated multiplier for Norway is still 0.25. This seems to be in a lower range compared to other studies for other countries in the SVAR literature, in which a multiplier above one is found (Blanchard & Perotti, 2002; Galí et al., 2007; Burriel et al., 2009). This is also the case compared to Mineshima, Poplawski-Ribeiro and Weber (2014) (referenced in Asche and Kristiansson, 2019, p. 19-20), who found a multiplier between 0.5-0.9, based on a survey of the literature on spending multipliers. On the other side, our multiplier is close to the Norwegian findings of Asche and Kristiansson (2019), as they found it to be 0.43 on impact. However, our multiplier appears to be stable for 20 quarters.

The peak multiplier with a size of 0.49 is reached in quarter two. This is inconsistent with the findings of Caldara and Kamps (2008), where the peak is reached after three years when using the different identification approaches (except for the narrative approach). As seen in Table 5.2, the size of the multiplier seems to be persistent except for the increase from the impact to the peak in quarter two. This may be a result of the one-period shock to government spending, in contrast to a long-lasting shock (Asche & Kristiansson, 2019; Ramey, 2019, p. 91). The interest rate might have risen as a response to the fiscal stimulus in our results, leading to larger crowding out effects of domestic investment and/or consumption. Consequently, small multipliers below one can occur (Spilimbergo et al. 2009).

In the New Keynesian benchmark, where we find sticky prices or wages, monetary policy can affect the real activity. Suitably, the responses of an increase in government spending can depend on the monetary policy response (Woodford, 2011). A possible reasoning for our rather low multiplier could be the rise in interest rate around the tenth quarter, possibly leading to lower marginal propensity to consume. If monetary policy is constrained by the ZLB on the short-term nominal interest rate, the Central Bank cannot tighten policy in response to an increase in government spending (Woodford, 2011). In the case of ZLB, we can find deviations from the standard Taylor rule (higher interest rate when inflation is high, and lower interest rate when unemployment is high). Our results are in the lower range also compared to the calibrated New Keynesian models, where multipliers in a range of 0.6-1 are found (Hall, 2009; Ramey, 2019). A consistent size of our multipliers can be explained by the persistent response of government spending and GDP, as seen in Figure 5.1.

Ilzetksi et al. (2013) argue that it can be misleading to focus only on an impact multiplier as fiscal stimulus packages can only be implemented over time and the possibility of lags in the economy's response. The cumulative spending multiplier in Table 5.2 is less than one for the whole period. Burriel et al. (2009) also find it to be below one but after four quarters. Asche and Kristiansson (2019) found a positive cumulative multiplier in Norway using the BP approach. However, they found it to increase steadily over time from 0.42 on impact to 1.10 at quarter 20. In contrast, our results show that the cumulative multiplier is very steady throughout the whole period.

The FEVD is a standard VAR tool, which shows what "*proportion in the variance of the next period certain shocks have"*. In our case, it imply how much of the forecast error variance is, due to variability in the structural shocks to the variables in the baseline model at different horizons, given information at time *t* (Ravnik & Zilic, 2011, p. 41; Bjørnland & Thorsrud, 2015, p. 225).

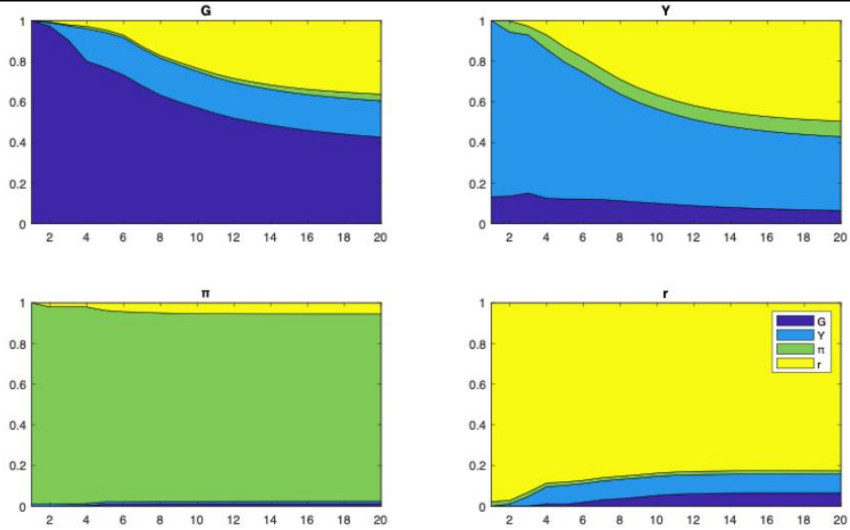

Figure 5.2f. G = government spending, Y = GDP, π = inflation, r = interest rate. An illustration of the FEVD of the baseline model, indicating how much of the variation in each variable is caused by a shock to the other variables.

	Shock to government spending	
Horizon	4th quarter	8th quarter
Government spending	0.80	0.63
GDP	0.12	0.11
Inflation	0.00	0.02
Interest rate	0.01	0.04

Table 5.3. FEVD of the variables in the baseline model, illustrate the amount of variation in percentage, as a result of a government spending shock after both one and two years.

Figure 5.2 illustrates the FEVD for the variables used in the baseline model, indicating that shocks in the variables themselves has the greatest impact on their variation for the whole period. Table 5.3 illustrates how much of the variation in the variables are caused by a shock to government spending. Note that a structural interpretation is only given for the government spending shock, and not for the other shocks (e.g. monetary policy shock) as they are just residuals. Investigating one year after the government spending shock, it is responsible for 12 percent of the variation in GDP. Looking at the variation in inflation and interest rate, they are affected minimally or not at all. After two years, the shock still has the largest effect on the variation in GDP (11 percent), and minor effects on inflation and interest rate. These results are consistent with the results found in the IRFs, as the government spending shock appears to have larger impact on GDP, compared to the other variables.

5.2 Extensions

In the first extension, we divide government spending into its two components, public investment and public consumption. In the second extension, we add private consumption to the baseline model. The motivation for these extensions will be elaborated below. In both extensions, we still estimate our VAR model with a lag length of four and include both a constant and linear time trend. The eigenvalues of the extended VAR models are all less than one and thus, still stable.

5.2.1 Two components of government spending

There is little existing comparative evidence on the macroeconomic properties of public consumption and investment. Our motivation for this extension is to investigate the effect on Norwegian GDP, inflation and interest rate of a shock to each of the two components. By this we want to assess if one of the components has larger impact than the other, or if they have equal effects on the variables.

Keeping in line with other papers, we order public consumption before public investment (Blanchard & Perotti, 2002, p. 1362-1363; Galí et al., 2007, p. 231; Burriel et al., 2009, p. 25; Tenhofen et al., 2010, p. 332). It is reasonable to believe there can be a delay from the investment shock occurs, until the return is received. Perotti (2004b, p. 17) postulates that public investment shocks might have longer decision and implementation lags, compared to public consumption shock. This is also the reason behind our expectations of how the variables are affected differently by the two shocks. We expect public consumption to have the largest impact in the short-run, and public investment to have a greater effect in the long-run. We have the following VAR model, henceforth referred to as Model X: [public consumption, public investment, GDP, inflation, interest rate]. This ordering implies that GDP, inflation and interest rate will react contemporaneously to both the shocks, independent of which one of them is ordered first. Whether public investment reacts contemporaneously to public consumption or public consumption reacts contemporaneously to public investment, will be dependent on the ordering of the two components. However, in the robustness test we find that the ordering of the two components do not alter our results. This is also in accordance with previous findings (Perotti, 2004b; Burriel et al., 2009; Iltzeski et al., 2010).

In the following subsections, we study how a shock to public consumption affects GDP, inflation and interest rate (see Figure 5.3). Then, we investigate the effect of a public investment shock to the same variables (see Figure 5.4). Lastly, the two shocks are compared.

Shock to public consumption

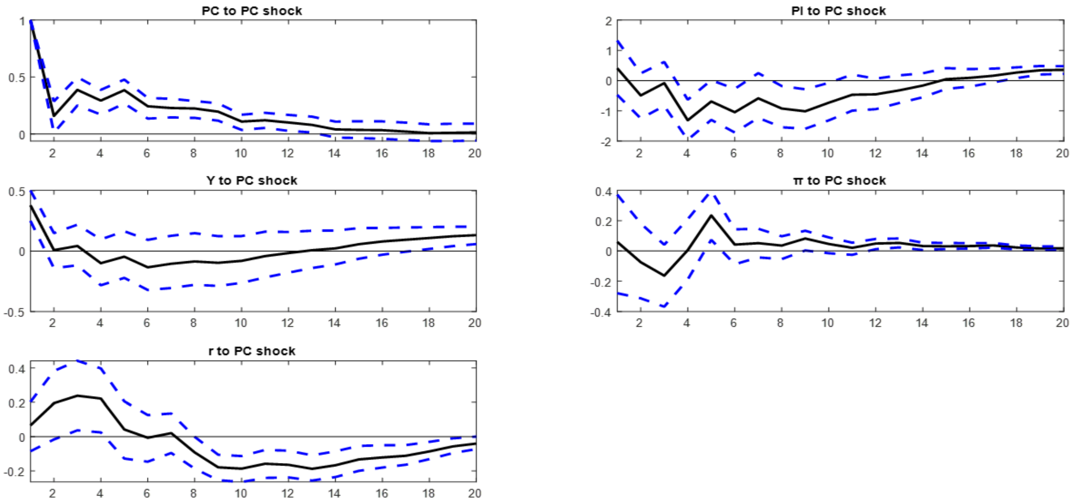

Figure 5.3. Estimated impulse responses to a public consumption shock in the five-SVAR model. PC = public consumption, PI = public investment, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

A public consumption shock affects GDP with an initial positive and statistically significant response of 0.38 percent. Before reaching the second quarter, the response has become statistically insignificant but becomes statically significant again around the 18th quarter. In the fifth year, the response is positive and statistically significant with a response of 0.13 percent. Inflation has a positive statistically significant response around the fifth quarter, with a peak effect of 0.23 percent. The response becomes positive and statistically significant again around the 12th quarter, before it slowly returns back to trend. Looking at the interest rate, the response is positive and statistically significant around the third quarter, with a peak effect of 0.24 percent. After two years, the response becomes negative and statistically significant, before it increases towards trend, still having a negative response in the fifth year. It is worth noting that after around two years, we have both a negative response in the interest rate and a positive response in inflation. The falling interest rate could possibly lead to a higher GDP than what it could have been without the fall.

Shock to public investment

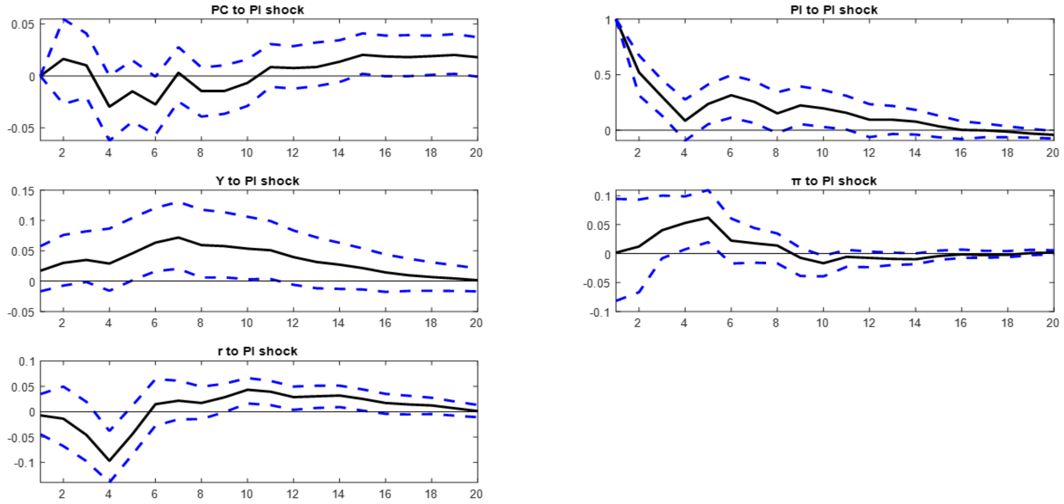

Figure 5.4. Estimated impulse responses to a positive public investment shock in a five-SVAR model. PC = public consumption, PI = public investment, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

A public investment shock leads to a statistically significant increase in GDP in the seventh quarter, where it reaches its peak effect of 0.07 percent. After the peak, the positive and significant effect slowly falls until the 12th quarter (where the effect becomes insignificant). The response of inflation is positive and significant in the fifth quarter, with a peak effect of 0.06 percent. The interest rate response is significant and affected negatively in the fourth quarter. By the IRFs, we see that as the investment shock decreases, the interest rate is reduced further. A reduction of the interest rate by the Central Bank could also be used as a tool to stimulate the economy. However, the fall in interest rate might lead to less credibility of the public investment shock. This discussion is elaborated below.

Around the tenth quarter, the interest rate becomes positive and significant before slowly falling towards trend.

Comparison

A comparison of the two shocks indicate that the positive response of GDP caused by a public investment shock is more persistent, having its peak effect in the seventh quarter. This effect lasts for around one year. Following a public consumption shock, the initial GDP response is the peak effect, only lasting for one quarter. According to our results, public investment has the largest impact. The two shocks affect inflation similarly in the fifth quarter, with a positive and significant response. However, the peak effect of 0.06 percent caused by a public investment shock is considerably lower, compared to the response of 0.23 percent by a public consumption shock.

Comparing the interest rate response in the fourth quarter, a public investment shock leads to a negative effect, whereas a public consumption shock generates a positive effect. On the other side, after around two years, the responses caused by the shocks show opposite effects. The reason why public investment has a greater impact on GDP could possibly be due to a fall in the interest rate. In addition to the public investment shock, the reduced interest rate could possibly make it more attractive to consume and produce, and might give another boost to GDP. If the interest rate instead had increased (as with the case of public consumption in the fourth quarter), the higher levels of consumption and production may be less attractive. Accordingly, this could possibly inhabit the same level of increase in GDP. In other words, the fall in interest rate might stimulate the economy further, making the responses of a public investment shock look larger than what they actually are. For this reason, the credibility of the public investment shock might also be reduced.

According to Murphy and Walsh (2018, p. 2), macroeconomic models predict that during normal times (e.g. no ZLB) interest rate can rise as a response to government spending. This can potentially crowd out investment and lower future economic output, as government spending can lead to excess demand for resources. For markets to clear, a rise in interest rate can delay households' consumption or firms' investment. If there had been a decrease in demand, a reduced interest rate would be reasonable to stimulate demand. Therefore, our empirical findings regarding the public investment shock, fail to support the strong theoretical prediction that government spending causes interest rate to rise.

The results of the two shocks differ in the empirical findings and might indicate little consensus of the effects of the two shocks. Still, we find our results to be in accordance with some of the previous studies. Burriel et al. (2009) state that the two shocks are qualitatively similar, with a small and short-lived increase in GDP. Ilzetzki et al. (2010), however, found that a shock to public consumption will decrease GDP, and a public investment shock will increase GDP. Perotti (2004b) finds that the public investment shock generates a larger effect on GDP (only in Germany). In the other OECD countries, public consumption seems to have a greater impact. The findings of Germany are in accordance with our results. Perotti (2004b) also switches places of the fiscal variables and the results are minimally affected. Based on these findings, he argues that there is no evidence of public investment shocks having larger impact on GDP than public consumption. In our robustness test we also find minor changes in the responses, when changing order of the two components. Fernández and de Cos (2006) find that both shocks have a positive effect on GDP, but only the effect by public investment is positive after the fourth quarter. This is in line with our findings. The authors also find that inflation is increasing in response to both shocks, which is also consistent with our results.

We have found different effects of the two shocks in this extension. Public investment seems to lead to larger GDP response. This large effect could possibly be influenced by other mechanisms than the public investment shock itself, as interpreted from the FEVD in Table A6.1 (in Appendix). Three and seven percent of the variation in GDP in quarter four and eight, respectively, is caused be a shock to public investment. The public consumption shock appears to have less impact. The response of GDP might be dampened because of the rise in interest rate. The variation in GDP caused by a consumption shock, is larger in the fourth quarter (eight percent) and lower in the eighth quarter (four percent). This seem to be in line with the responses we expected; the response of public consumption shock has larger effect on the Norwegian economy in the short-run, whereas the response of public investment is larger in the long-run. Note that the public investment shock has larger effect on the variation in the interest rate than the public consumption shock, both in the fourth and eighth quarter (referring to Table A6.1 in Appendix), which might lead to reduced credibility of the investment shock, as discussed above.

5.2.2 Adding private consumption to the baseline model

The motivation behind investigating the response of private consumption is because it stands out in how it reacts in the different theoretical frameworks. According to the Neoclassical theory, private consumption decreases, while Keynesian theory states that it increases. In the New Keynesian model, private consumption is to a large extent dependent on the actions of the Central Bank. Suitably, the responses of private consumption to a shock in government spending will differ, leading to variations in the spending multipliers.

Blanchard and Perotti (2002) and Galí et al. (2007) have ordered private consumption after government spending and GDP in a VAR model. Tenhofen et al. (2010) ordered it before inflation and interest rate. Our decision of the ordering is resting on these papers. In addition, we justify the assumptions on the contemporaneous relations between the variables as follows; it is reasonable to expect that a rise in government spending is meant to stimulate the growth in the economy, consequently households' consumption can increase. The demand for goods and services will increase when households receive additional capital. The VAR model is thereby: [government spending, GDP, private consumption, inflation, interest rate]. The particular ordering of the variables has the same implications as the baseline model (described in section 4.7.1).

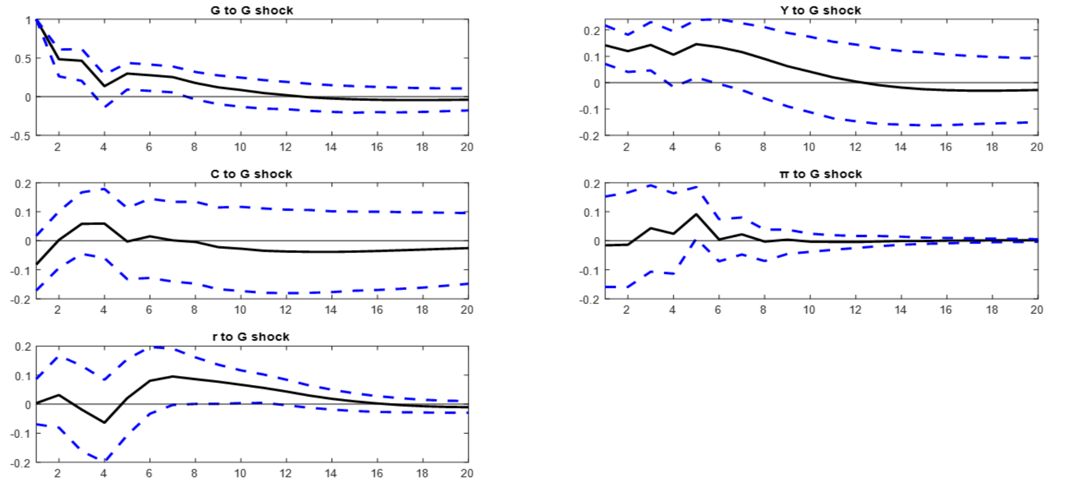

Figure 5.5. Estimated impulse responses to a government spending shock in the five-SVAR model. G = government spending, Y = GDP, C = private consumption, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

Figure 5.5 shows the IRFs of a government spending shock, and the responding effects of GDP, private consumption, inflation and interest rate. The shock has a positive and significant initial effect on GDP for around one year. None of the other responses are statistically significant, neither initially nor until the responses return back to trend. The statistically insignificant response of private consumption does not rise, although it does not have a clear fall either. The response is negative both on impact and from the second year, while it is positive only for a short period of time. On impact, the negative response implies that there have been negative wealth effects brought about a rise in government spending by extracting resources from the private sector. We can therefore interpret private consumption as having a crowding out effect in the Neoclassical model (Bouakez & Rebei, 2007, p. 955). As there is a negative wealth effect in the Neoclassical model, households work more, which might lead to an increase in GDP (Ramey, 2019, p. 92). This is the case also in our results (see Figure 5.5). The negative effect around year two in private consumption may be caused by the increase in interest rate, which is in accordance with the New Keynesian model. Because there is inconsistency in the estimated response of private consumption, it is not clear if our results support one specific theoretical model. Nevertheless, the increase in interest rate can explain why private consumption is not rising. Resting on these findings, our results are leaning more towards the New Keynesian model.

Different responses of private consumption are found in previous literature. Empirical findings show an initial fall in private consumption when using the narrative approach (Ramey & Shapiro, 1998; Edelberg et al., 1999; Burnside et al., 2004). Increased private consumption is in line with previous results based on BP, recursive -and sign restriction approach (Fatas & Mihov, 2001; Blanchard & Perotti, 2002; Galí et al., 2007; Caldara & Kamps, 2008; Burriel et al., 2009; Tenhofen et al., 2010).

Horizon	1st quarter	4th quarter	8th quarter	12th quarter	20th quarter	peak
Multiplier	0.26	0.57	0.26	0.26	0.24	0.57(4)
Cumulative Multiplier	0.26	0.30	0.30	0.30	0.28	0.30

Table 5.4. Multipliers and cumulative spending multipliers after a positive government spending shock in sample period 1991:1 - 2019:3 (private consumption is added to the baseline model). These are calculated by the definitions shown in Table 5.1. In parentheses, the quarter of the peak response is shown.

Table 5.4 illustrates spending multipliers when private consumption is included. As the impact multiplier is below one (0.26), GDP has risen less than government spending. The multipliers in all horizons are smaller than one, indicating that our data can support the Neoclassical model. The key channels through which fiscal policy affects the private economy are amongst others wealth effects and intertemporal substitution effects. Private consumption is said to fall less when there is a temporary increase, compared to a permanent increase. This also indicates that labor supply increases less. Accordingly, intertemporal substitution effects may be less effective in this case (Ramey, 2011a, p. 674). Our small multipliers are also consistent with the findings of Baxter and King (1993) referenced in Ramey (2011a, p. 674). The authors found it to be 0.56 when there is a temporary increase in government spending, which is close to ours.

A peak multiplier of 0.57 in quarter four indicates that the effect of government spending is larger after one year. The IRFs show that private consumption has an insignificant positive response in the fourth quarter, as well as a negative response in the interest rate. A positive private consumption response may indicate that the households' marginal propensity to consume is higher, than marginal propensity to save (households increase their consumption, receive higher real wage and save less). Thus, these findings are pulling towards the New Keynesian model. In this case, a spending multiplier would also be smaller than one.

As the cumulative multipliers and the belonging discussion in the baseline model and this extension model deviate minimally, we will not repeat the whole analysis here. Our findings of the cumulative multiplier in this extension model are not consistent with other countries (where it is found to be slightly below one after four quarters). In quarter 20, our results show a value of 0.28, whereas it is found to be 0.02 and 0.19 in the Euro area and U.S, respectively (Burriel et al., 2009, p. 27).

Chapter 6 - Robustness tests

This chapter presents the analysis of the robustness tests. The tests include changing the number of lags, confidence intervals and compare the time series for different measures of inflation and interest rate. In addition, we test the ordering of variables in the VAR models, both in the baseline model and one extended model.

6.1 Changing the lag length

We use a lag length of four in the baseline model, but it would be interesting to investigate if the results change when applying either a lower or a higher lag length. First, we test the baseline model with a lag length of one as this is the result of our BIC test, where we also want to check if valuable information actually disappears (referring to subsection 4.1.3). Second, we test if the baseline model is robust when including six lags. According to Caldara and Kamps (2008, p. 11), using a higher lag order than four (e.g., Mountford and Uhlig (2005)), does not affect the results. Still, Blanchard and Perotti (2002) argue that the optimal range is within four to eight lags.

Figure A6.1 (in Appendix) illustrates the IRFs when using one lag length. The response of GDP is now continually significant and positive for the whole period.

In contrast, when using four lags, the response of GDP is significant only for the first year. The pattern of significance is also seen in the responses of inflation and interest rate, where the responses are more significant with one lag rather than four lags. The reason for having more significant results when using one lag length, might be that less information is taken into account. This could possibly lead to loss of valuable information, which can give poor and inefficient estimations. Based on this, it does not seem reasonable to use one lag.

Figure A6.2 (in Appendix) illustrates the IRFs when using a lag length of six. The responses seem to be significant for a shorter period of time, especially the response of inflation shows no significant results at all. However, in the baseline model, the inflation response was only significant for one quarter, and both GDP and interest rate have minimal changes. Using a lag length of six seems reasonable as our robustness test shows there are only minor quantitative deviations. These findings are in line with Caldara and Kamps (2008, p. 26), who also tested for six lags and also got robust results. Hence, our baseline model is robust to a lag length of six. As including several lags seem to result in more uncertainty of the responses, we rather keep the lag length of four.

6.2 Confidence bands of 68%

We use 68 percent confidence bands instead of 95 percent in this robustness test. With smaller sample size, the mean is not as precise as with larger samples, and therefore tend to have wider confidence bands. Because we have a rather small sample size, confidence bands of 95 percent are chosen. However, we test confidence bands of 68 percent because we want to investigate if our sample size could have been large enough to have a narrower confidence band. Also, some literature apply confidence bands of 68 percent, which often can be seen as common practice in the government spending literature (Blanchard & Perotti, 2002; Ramey, 2011, p. 11). However, Ilzetski et al. (2010, p. 11) used 90 percent confidence bands.

Figure A6.3 (in Appendix) shows IRFs in the baseline model when using 68 percent confidence bands. Here, the confidence bands are narrower and the requirements for what is accepted as significant results is lower. The response of

GDP to a government spending shock is now continuously significant until around year two, indicating a more persistent response of GDP. A significant deflation is shown after the tenth quarter, and the interest rate appears to have a more long-lasting positive and significant response, compared to before. Therefore, using 68 percent confidence bands would differ the responses, but only to a certain degree. Additionally, Ramey (2011, p. 11) states there is no theoretical justification for using 68 percent confidence bands in a VAR model.

6.3 Comparing two measures of inflation

In this robustness test we apply CPI as a measure of inflation, in order to investigate if our results change or not[18]. The price index is collected from Statistics Norway, where the data was quarterly and seasonally adjusted, with an index 2017=100[19]. To transform the CPI into inflation, we have to take the log-difference of the index. To make sure that all variables are on the same scale, we multiply it by 100. Figure 6.1 shows that the trend of the GDP deflator and the CPI are not similar. Figure A6.4 (in Appendix) shows the baseline model with the GDP deflator at the top, and the baseline model with the CPI at the bottom. The analysis of these results is presented in section 5.1.

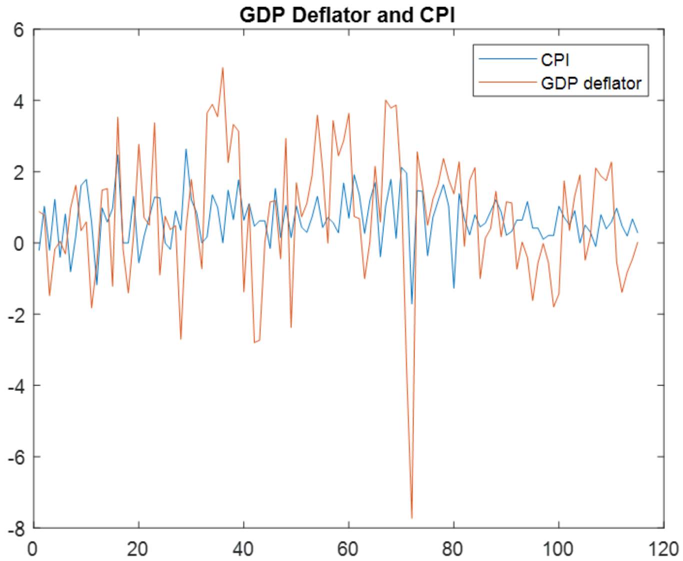

Figure 6.1. The orange line represents the trend of the GDP Deflator. The blue line represents the trend of the CPI. Both measures are log-differenced and multiplied by 100.

[18] CPI is another well-known measure of inflation, which involves the prices of only the goods and services bought by consumers. We chose to use the GDP deflator because it includes all goods and services produced domestically.

[19] Note that the GDP deflator has index 2015=100.

6.4 Comparing two measures of interest rate

In this subsection, a robustness test of the short-term interest rate is elaborated. We replace a three-month NIBOR with the policy rate. The policy rate is collected from Norges Bank as monthly data. To transform it into quarterly data we sorted out the last month in every quarter. Figure 6.2 shows the trends of the two different measures of interest rate. The NIBOR lies somewhat above the policy rate, still the trends are very similar. Norges Bank (2019, p. 10) also present these two interest rates in a figure in their Monetary Policy Report, in which they find similar results (see Figure A6.5 in the Appendix). Resting on the similarity of our results, changing the interest rate data should not alter our previous results significantly. Figure A6.6 (in Appendix) shows the two IRFs. The baseline model with the NIBOR interest rate is at the top, the baseline model with the policy rate is at the bottom. Comments on the comparison of these IRFs have already been given in section 5.1.

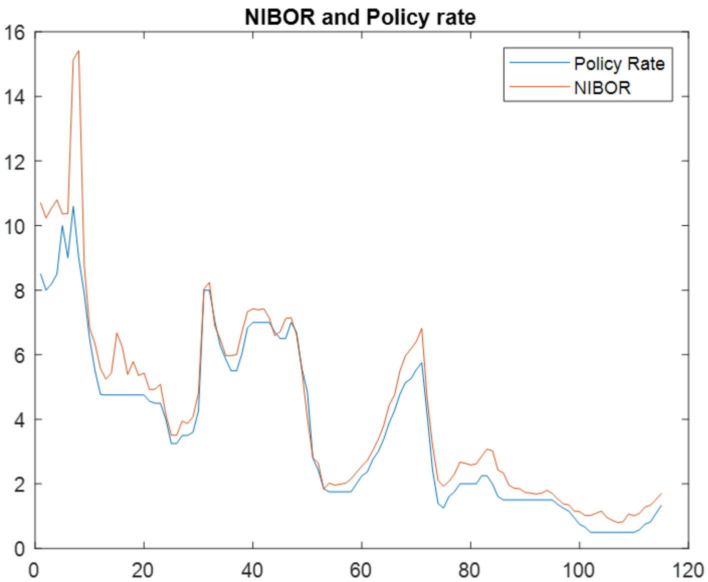

Figure 6.2 The orange line represents the trend of the 3-month NIBOR interest rate. The blue line represents the trend of the policy rate. Both interest rates are transformed from monthly to quarterly data.

6.5 Changing ordering of government spending and GDP

There are disagreements on how one should identify fiscal shocks. This identification problem arises because there are two possible directions of causation; either government spending affects GDP, or GDP affects government spending. The latter causation could be related to automatic stabilisers and implicit or explicit policy rules (Ilzetzki et al., 2010, p. 4). Additionally, when ordering government spending before GDP, the possibility of discretionary adjustment of fiscal policy in response to unexpected movements in GDP, will virtually be eliminated (Jemec, Kastelec & Delakorda, 2011, p. 10).

Relying on these arguments we apply a robustness test, ordering GDP first. The VAR model now has the following order (henceforth referred to as Model Z): [GDP, government spending, inflation, interest rate]. The implications are that GDP can affect all the other variables contemporaneously, while government spending can only affect inflation and interest rate contemporaneously. Other papers also order GDP before government spending (Favero, 2002, referred in Perotti, 2004a, p. 10; Tenhofen et al., 2010, p. 331-332). Further, governments cannot react contemporaneously to changes of the macroeconomic environment. This is reasoned with fiscal policy decision-making being time consuming, in the way that is involves many agents in parliament, government and civil society (referring to section 3.2) (Blanchard & Perotti, 2002, referred in Tenhofen et al., 2010, p. 331-332).

In Figure A6.7 (in Appendix), we compare the IRFs of the baseline model (at the top) and Model Z (at the bottom). The impact effect of GDP is different as expected. This is the case because GDP reacts contemporaneously to the shock in the baseline model, but it only reacts after the initial period in Model Z. In the baseline model, the response of GDP after the initial period is positive and significant for three quarters. In Model Z, the response is never statistically significant.

As noted in subsection 4.7.1, it is more common to order GDP before the policy instrument in monetary policy. Extending this to fiscal policy is highly questionable. The reason is that government spending is a component of GDP. This assumption imposes an implicit assumption of exactly 100 percent crowding out contemporaneously on private GDP (Perotti, 2004a). We therefore consider it more reasonable to order government spending before GDP.

6.6 Changing ordering of public consumption and public investment

Other empirical findings state that there are no significant differences if the ordering of public investment and public consumption is reversed. In this robustness test, we therefore follow Perotti (2004b) and Ilzetski et al. (2012) in ordering public investment before public consumption. The five-variable VAR model (henceforth referred to as Model Y) have the following ordering: [public investment, public consumption, GDP, inflation, interest rate]. First, we compare a public investment shock in Model X and Y, then we compare a public consumption shock in the same two models.

Figure A6.8 (in Appendix) illustrates a comparison of the responses of GDP, inflation and interest rate following a public investment shock in Model X (at the top) and Model Y (at the bottom), respectively. As expected, there are minimal differences in the two models. The IRFs in Figure A6.9 (in Appendix) also illustrate a comparison of the responses of GDP, inflation and interest rate, but here the variables are followed by a public consumption shock in Model X (at the top) and Model Y (at the bottom). In this case, the differences are also minor in the two models.

Table A6.1 and A6.2 (in Appendix) (also seen in Figure A6.10 and A6.11) display the FEVD of Model X and Y. When comparing the public consumption shock in the two tables, there is almost no change in the degree of explanation in the variation of GDP, inflation and interest rate. A comparison of the public investment shock in the two tables show that the result has either minor or no changes in the degree of explanation in the variation of the same variables. Hence, our results in this robustness test indicate that the ordering of public consumption and public investment in the VAR model is independent of the resulting variation of the variables. Our results are therefore robust.

Chapter 7 - Conclusion

In this thesis, we investigate the impact of government spending on the Norwegian economy using a SVAR framework. To identify the structural shocks, a recursive approach relying on the Cholesky ordering is applied. The main findings in our baseline model followed by a one percent government spending shock, leads to a positive significant response of 0.13 percent on impact in GDP. The response is short-lived, significant and positive for only around one year. The response of inflation is statistically significant only in quarter five, which is also found to be the peak effect (0.09 percent). Interest rate shows a positive and significant response in quarter nine, which lasts until it returns back to trend. Our results show that the interest rate is increasing when inflation is increasing, indicating monetary policy may have been used actively. Pressure on prices and increased interest rates might lead to a fall in consumption and investment, which can dampen the positive effect on GDP. Further, the analysis yields an impact spending multiplier of 0.26, and a peak multiplier of 0.49 in quarter two. For all 20 quarters, the multiplier appears to be steady with a value of 0.26. Our resulting multipliers seem to be on a lower range compared to other studies, relying on both empirical and quantified findings. The cumulative spending multiplier is found to be around 0.33 for all horizons. Cumulative multipliers less than one are also consistent with other studies.

In the first extension, we decompose government spending into public consumption and public investment, and investigate the effects of the two shocks. When comparing the responses, we find that a shock to public investment has the strongest effect, as it gives the most persistent and positive significant effect on GDP. The two shocks have similar effect on inflation, both positive and significant. However, a public consumption shock generates a larger effect on inflation (0.23 percent) than a public investment shock (0.06 percent). A public consumption shock leads to an increase in the interest rate (quarter three), whereas a public investment shock affects the interest rate negatively (quarter four). We have discussed that this negative effect might stimulate the economy further, making the responses of a public investment shock appear to be larger than what they actually are. This might reduce the credibility of the public investment shock. Resting on these findings, our results indicate that the two components of government spending have some differences in how Norwegian GDP, inflation and interest rate react to the two shocks.

In the second extension, we include private consumption. The estimated response of private consumption is insignificant for the whole period. The response does not rise, although it does not have a clear fall either. Due to the inconsistency in the response, it is not clear if our results support one specific theoretical model. Nevertheless, the increase in the interest rate can explain why private consumption is not rising. Based on these findings, our results are leaning more towards the New Keynesian model. Moreover, the analysis yields an impact multiplier of 0.26 and is consistent during the whole period, except for a peak multiplier of 0.57 in quarter four. The cumulative multiplier has a somewhat steady size of 0.30 for all horizons, also found to be in accordance with other studies, as in the baseline model.

For future research, different suggestions can be considered in order to investigate fiscal policy in Norway. One suggestion is to include other variables in the model, such as oil prices, tax, private investment, public and private employment or net exports. If tax is included, a model could be built to identify the effects of both a tax- and spending shock. Another suggestion is using identification schemes other than the recursive approach. This could be interesting because previous findings show lack of consensus regarding private consumption when using the narrative approach.

References

Asche, A. & Kristiansson, A. (2019). The Effects of Fiscal Policy in Norway – A SVAR approach. Arbeidsnotat 2019/1 Finansdepartementet. Collected from https://www.regjeringen.no/contentassets/4555aa40fc5247de9473e99a5452fdfd/arbnotat_1_2019.pdf

Auerbach, A. & Gorodnichenko, Y. (2012). Measuring the Output Responses to Fiscal Policy. American Economic Journal: Economic Policy, 4(2), 1-27.

Baxter, M. & and King, R. G. (1993). Fiscal Policy in General Equilibrium. The American Economic Review, 83(3), 315-334.

Bjørnland, H., Thorsrud, L. (2015). Applied Time Series for Macroecnomics (2nd. Edt.). Oslo: Gyldendal Akademisk.

Blanchard, O. & Perotti, R. (2002). An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. The Quarterly Journal Of Economics, 117(4), 1329-1368.

Blinder, A. S. (1988). The fall and rise of Keynesian economics Economic Record. In Snowdon, B. & Vane, H. R. (Ed.), A Macroeconomics Reader (p. 278–94). London: Routledge.

Boiciuc, I. (2015). The effects of fiscal policy shocks in Romania. A SVAR Approach. Procedia Economics and Finance, 32, 1131-1139.

Borgås, F. (2018). Utgiftene øker sakte, men sikkert. Collected from https://www.ssb.no/offentlig-sektor/artikler-og-publikasjoner/utgiftene-oker-sakte-men-sikkert

Bouakez, H. & Rebei, N. (2007). Why does private consumption rise after a government spending shock? Canadian Journal Of Economics/Revue Canadienne D'économique, 40(3), 954-979.

Burnside, C., Eichenbaum, M. & Fisher, J. (2004). Fiscal shocks and their consequences. Journal Of Economic Theory, 115(1), 89-117.

Burriel, P., De Castro, F., Garrote, D., Gordo, E., Paredes, J. & Perez, J. (2009). Fiscal policy shocks in the euro area and the US: an empirical assessment. The Journal of Applied Public Economics, 31(2), 251-285.

Caldara, D. & Kamps, C. (2008). What are the effects of fiscal policy shocks? A VAR-based comparative analysis. (Working Paper Series NO 877 / March 2008). Collected from https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp877.pdf

Christiano, L. J. & Eichenbaum, M. (1992). Current Real-Business-Cycle Theories and Aggregate Labor-Market Fluctuations. The American Economic Review, 82(3), 430-450.

Christiano, L., Eichenbaum, M. & Rebelo, S. (2011). When Is the Government Spending Multiplier Large? Journal Of Political Economy, 119(1), 78-121.

Cogan, J. F., Cwik, T., Taylor, J. B. & Wieland, V. (2009). New Keynesian versus old Keynesian government spending multipliers. Journal of Economic Dynamics and Control, 34(3), 281-295.

Dungey, M. & Fry R. (2009). The identification of fiscal and monetary policy in a structural VAR. Economic Modelling 26, 1147–1160.

Dwyer, G. (2015). The Johansen Tests for Cointegration. White Paper. Collected from: http://www.jerrydwyer.com/pdf/Clemson/Cointegration.pdf

Edelberg, W., Eichenbaum, M. & Fisher, J. (1999). Understanding the Effects of a Shock to Government Purchases. Review Of Economic Dynamics, 2(1), 166-206.

Fatás, A. & Mihov, I. (2001). The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence. Mimeo, INSEAD. Collected from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.547.9291&rep=rep1&type=pdf

Favero, A. (2002). How Do European Monetary and Fiscal Authorities Behave? CEPR Discussion Paper (May 2002) No. 214. Collected from https://pdfs.semanticscholar.org/ebb3/f4426233e01e0c389ffdd34588a1c2f25495.pdf

Fernández, F. & de Cos, P. (2006). The economic effects of exogenous fiscal shocks in Spain: a SVAR approach. ECB Working Paper, No. 647, European Central Bank (ECB).

Finans Norge (N.D). Nibor – The Norwegian Interbank Offered Rate. Collected from: https://www.finansnorge.no/en/interest-rates/nibor---the-norwegian-interbank-offered-rate/

Finans -og tolldepartementet. (N.D). DEN OLJE-, RENTE- OG AKTIVITETSKORRIGERTE BUDSJETTINDIKATORER. Collected from https://www.regjeringen.no/globalassets/upload/fin/statsbudsjettet/notat---den-olje--rente--og-aktivitetskorrigerte-budsjettindikatoren.pdf

FRED. (2020). GDP implicit price deflator Norway. Collected from https://fred.stlouisfed.org/series/NORGDPDEFQISMEI

Galí, J., López-Salido, J. & Vallés, J. (2007). Understanding the Effects of Government Spending on Consumption. Journal Of The European Economic Association, 5(1), 227-270.

Giordano, R., Momigliano, S., Neri, S. & Perotti, R. (2007). The effects of fiscal policy in Italy: Evidence from a VAR model. European Journal of Political Economy, 23(3), 707-733.

Gordon, R. J. (1990). What is New-Keynesian Economics? Journal of Economic Literature, 28(3), 1115-1171.

Gottschalk, J. (2001). An Introduction into the SVAR Methodology: Identification, Interpretation and Limitations of SVAR models. Kiel Working Paper, No. 1072, Kiel Institure for the World Economy (IfW), Kiel.

Government. (2020). Revised National Budget- a budget to help us safely reclaim ordinary life. Collected from https://www.regjeringen.no/en/aktuelt/a-budget-to-help-us-safely-reclaim-ordinary-life/id2701787/

Hall, R. E. (2009). By How Much Does GDP Rise If the Government Buys More Output. NATIONAL BUREAU OF ECONOMIC RESEARCH, 40(2), 183-249.

Hill, C., Griffiths, W. & Judge, G. (2001). Undergraduate Econometrics. USA. John Viley & Sons.

Ilzetzki, E., Mendoza, E. & Végh, C. (2010). How big (small?) are fiscal multipliers? Working Paper 16479. Collected from https://www.nber.org/papers/w16479.pdf

Ilzetzki, E., Mendoza, E. & Végh, C. (2013). How big (small?) are fiscal multipliers? Journal Of Monetary Economics, 60(2), 239-254.

Inoue, A. & Kilian, L. (2013). Inference on impulse response functions in structural VAR models. Journal of Econometrics 177(1), 1–13.

International Monetary Fund. (2020). Fiscal Policy: Taking and giving away. Collected from https://www.imf.org/external/pubs/ft/fandd/basics/fiscpol.htm

Jemec, N., Kastelec, A. S. & Delakorda, A. (2011). The macroeconomic dynamics in the Slovenian economy. Collected from https://bankaslovenije.blob.core.windows.net/publication-files/PA_22011__How_do_fiscal_shocks_affect_the_macroeconomic_dynamics_in_the_Slovenian_economy.pdf

Kilian, L. & Lutkepohl, H. (2017). Structural vector autoregressive analysis. Cambridge University Press, Cambridge.

Midthjell, N. (2011). Fiscal policy and financial crises – What are the actual effects of fiscal policy? Norges Bank. Economic Bulletin, 82, 24-38. Collected from https://www.norges-bank.no/contentassets/bdccffbe63374cca96a00cdf312888ab/fiscal_policy_and_financial_crisis.pdf

Mountford, A. & Uhlig, H. (2009). What are the effects of fiscal policy shocks? Journal of applied econometrics, 24, 960-992.

Murphy, D. and Walsh, K. (2018). Government Spending and Interest Rates. Working paper. Collected from https://4f3ea0d3-a-62cb3a1a-s-sites.googlegroups.com/site/kieranjameswalsh/MWOct2018.pdf?attachauth=ANoY7cqyhrjNq99OHyiLm42X6TteIBZYEpe9X3qchoZLXWV6XpQMfjotr72taI4b4-C8qMc4VdVpxZ5uaG5O1_C7IwumQxlLS8i7gKCtOYAHfeNnzBGXlq2vPmBvVib6SAcgZDlj49n_s6X5c8E8TwUGi5bDeg5DfCZuSHfOYowhfJRX-TxOqMBS_D9NK8gpQt5tRGpYqE_3bP0IuKw_Vkp_CUqfdFWNpw%3D%3D&attredirects=0

Norges Bank. (2020). Short term interest rates. Collected from https://www.norges-bank.no/en/topics/Statistics/Historical-monetary-statistics/Short-term-interest-rates/

Norges Bank. (n.d). About the Fund. Collected from https://www.nbim.no/en/the-fund/about-the-fund/

Norges Bank (n.d). The policy rate. Collected from https://www.norges-bank.no/en/topics/Monetary-policy/Policy-rate/

Norges Bank. (2019). Monetary policy report with financial stability assessment (Second quarter). Collected from https://static.norges-bank.no/contentassets/cda000898c914e7890fa1b545d81ace4/mpr_219.pdf?v=09/12/2019095833&ft=.pdf

Oslo Stock Exchange. (2020). Nibor. Collected from https://www.oslobors.no/Oslo-Boers/Statistikk?fbclid=IwAR3e3MzC8kMQMkUZuh8-zdCHL_5QX7ttT8Pp-GcgL9J0mR49weg-QjcD4-0

Perotti, R. (2002). Estimating the effects of fiscal policy in OECD countries (European Central Bank Working Paper Series NO 168 / August 2002). Collected from https://www.econstor.eu/bitstream/10419/152602/1/ecbwp0168.pdf

Perotti, R. (2004a). Estimating the Effects of Fiscal Policy in OECD Countries. SSRN Electronic Journal.

Perotti, R. (2004b). Public Investment: Another (Different) Look. Working Paper n. 277. Collected from ftp://ftp.igier.unibocconi.it/wp/2004/277.pdf

Pfaff, B. (2008). VAR, SVAR and SVEC Models: Implementation Within R Package vars. Journal of Statistical Software, 27(4).

Ramey, V. & Shapiro, M. (1998). Costly capital reallocation and the effects of government spending. Carnegie-Rochester Conference Series On Public Policy, 48, 145-194.

Ramey, V. (2011a). Can Government Purchases Stimulate the Economy? Journal Of Economic Literature, 49(3), 673-685.

Ramey, V. (2011b). Identifying Government Spending Shocks: It's all in the Timing. The Quarterly Journal Of Economics, 126(1), 1-50.

Ramey, V. (2019). Ten Years After the Financial Crisis: What Have We Learned from the Renaissance in Fiscal Research? Journal Of Economic Perspectives, 33(2), 89-114.

Ravnik, R. & Zilic, I. (2010). The use of SVAR analysis 25 in determining the effects of fiscal shocks in Croatia. Financial theory and practice, 35(1), 25-58.

Roberts, J. M. (1995). New Keynesian Economics and the Phillips Curve. Journal of Money, Credit and Banking, 27(4), 975- 984.

Şen, H. & Kaya, A. (2014). Crowding-out or crowding-in? Analyzing the effects of government spending on private investment in Turkey. Panoeconomicus, 61(6), 631-651.

Sims, C. (1980). Macroeconomics and Reality. Economterica 48(1), 1-48.

Sparebanken Vest (2015). Forskjellen på Norges Banks styringsrente og bankenes utlånsrente. Collected from https://www.spvnyheter.no/privatokonomi/boliglaan/forskjellen-pa-norges-banks-styringsrente-og-bankenes-utlansrente/

Spilimbergo, A., Symansky, S. & Schindler, M. (2009). Fiscal Multipliers. SPN/09/11, International Monetary Fund, Research Department.

Statistics Norway. (2020). Kvartalsvis nasjonalregnskap: 1978 – (xlsx-filer). Tabell 7: Makroøkonomiske hovedstørrelser. Sesongjustert. Prosentvis volumendring fra foregående kvartal [xlsx]. Collected from: https://www.ssb.no/nasjonalregnskap-og-konjunkturer/tabeller/knr-tabeller

Stock, J. H. & Watson, M. W. (2001). Vector autoregressions. Journal of Economic perspectives 15(4), 101–115.

Store norske leksikon (SNL). (2019). Handlingsregelen. Collected from https://snl.no/handlingsregelen

Tenhofen, J, Wolff, G. B. & Heppke-Falk, K. H. (2010). The Macroeconomic Effects of Exogenous Fiscal Policy Shocks in Germany: A Disaggregated SVAR Analysis. Jahrbücher f. Nationalökonomie u. Statistik, 230(3).

Woodford, M. (2011). Simple Analytics of the Government Expenditure Multiplier. American Economic Journal: Macroeconomics, 3(1), 1-35.

Appendix

Appendix Chapter 3 - Literature Review

A3.1 IS curve in the Keynesian theory

IS curve:

$Y = C + I + G + NX$

$C = c_0 + c_1(Y – T)$

$I = i_0 – i_1R$

$T_t = t_1Y$

$NX = m_0 + m_1(Y^* - Y)$

Interest rate rule (can be derived from money market, LM)

$R = r_0 + r_1Y$

Equations A3.1. Equations to calculate a Keynesian spending multiplier. Y = aggregate output, C = aggregate consumption, I = aggregate investment, G = government spending, NX = net export, c_0 = amount of consumption that does not depend on income, c_1 = marginal propensity to consume out of current income, (Y-T) = disposable income, i_0 = exogenous level of private investment, i_1 = the sensitivity of investment to changes in the interest rate, R = interest rate, T_t = lump sum tax, t_1 = income tax rate, NX = net export, m_0 = exogenous level of import, m_1 = sensitivity of imports to output, Y^* = total output, Y = output from a small open economy, r_0 = exogenous level of interest rate, r_1 = endogenous response of monetary policy.

The IS curve in Keynesian theory is combined by different equations for output, consumption, investment, tax, net export and interest rate (see Equations A3.1)[20]. The equation for output is a function of consumption, investment, government spending and net exports. The aggregate consumption equation rest on the strong assumption that consumers choose to use a constant fraction of their net income. The investment is decreased when interest rate is increased. The tax income is a constant fraction of the output. The net exports equation is a linear function of the difference between the total output from the rest of the world, and the output from the small open economy. Lastly, the interest rate is a linear function of the output.

A3.2 Equations leading to a prototypical Neoclassical spending multiplier

A static model to display the main mechanisms:

[20] Lecture notes by Professor Gisle J. Natvik (14th of March 2019). Business Cycles.

Preferences: $U(c, h) = \frac{c^{1-1/\sigma}}{1-1/\sigma} - \gamma\frac{h^{1+1/\psi}}{1+1/\psi}$

Technology: $y = h^{\alpha}$

Market clearing: $y = c + g$

Optimal labor demand: $w = \alpha h^{-(1-\alpha)}$

Optimal labor supply (first order condition for h given w): $\frac{-U_h}{U_c} = w$

$$c^{1/\sigma}\gamma h^{1/\psi} = w$$

Equations A3.2. Source: Hall (2009, p. 16-17). Equations to calculate a Neoclassical spending multiplier. y = output, g = government spending, c = consumption, w = real wage, h = hours worked, α = the labor elasticity of production, σ = the utility of consumption, ψ = the labor supply elasticity, γ = disutility of hours worked.

Appendix Chapter 4 - Methodology and estimations

A4.1 Example of order decision using economic theory

This example shows how the order is decided based on economic theory. The following example includes a structural model consisting of government spending (G_i), as a measure of fiscal policy, and output growth (Δx_i). We assume that these variables are driven by a government spending shock ($\varepsilon_{G,t}$) and a productivity shock ($\varepsilon_{PR,t}$). Constant term is not included. The dynamic specification will be as follow:

$$B_{11,0}G_t = - B_{12,0}\Delta x_t + B_{12,1}\Delta x_{t-1} + B_{11,1}G_{t-1} + \varepsilon_{G,t}$$

$$B_{22,0}\Delta x_t = - B_{21,0}G_t + B_{21,1}G_{t-1} + B_{22,1}\Delta x_{t-1} + \varepsilon_{PR,t}, \text{ where}$$

$$\begin{pmatrix}\varepsilon_{G,t}\\ \varepsilon_{PR,t}\end{pmatrix} \sim \text{i.i.d. N}\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}1 & 0\\0 & 1\end{pmatrix}\right) \qquad \text{or, } \varepsilon_t \sim \text{i.i.d. N}(0, \Omega)$$

It is important to note that the covariance matrix of the structural shocks is assumed to be an identity matrix, in other words, have zero elements off the diagonal. Hence, the structural shocks are uncorrelated and have unit variance, $\Omega = I$.

In the following, we assume that output growth shocks cannot affect government spending contemporaneously, but will do so only with a lag. This is supported by macroeconomic theory (as discussed in chapter 3) and this restriction seems reasonable from a theoretical point of view. In addition, when only having one restriction, the structural model can be recovered based on the reduced-form representation of the model.

Recall equation (4.6) in chapter 4, where the relationship between the structural and the reduced-form VAR was presented: $e_t = B_0^{-1}\varepsilon_t$. Using this fact, we can write the reduced-form moving average representation in equation (4.9) in chapter 4 ($y_t = \sum_{j=0}^{\infty} C_j e_{t-j}$), in terms of the structural MA representation:

$$y_t = C(L)B_0^{-1}\varepsilon_t, \qquad \text{(A4.1)}$$

where ε_t are the structural shocks. Writing out this equation, we get:

$$\begin{bmatrix} G_i \\ \Delta x_i \end{bmatrix} = C(L)B_0^{-1}\varepsilon_t$$

$$= C_0 B_0^{-1}\varepsilon_t + C_1 B_0^{-1}\varepsilon_{t-1} + C_2 B_0^{-1}\varepsilon_{t-2} + \ldots \qquad \text{(A4.2)}$$

$$= \begin{bmatrix} B_{11,0} & B_{12,0} \\ B_{21,0} & B_{22,0} \end{bmatrix}^{-1} \begin{bmatrix} \varepsilon_{G,t} \\ \varepsilon_{PR,t} \end{bmatrix} + C_1 B_0^{-1}\varepsilon_{t-1} + C_2 B_0^{-1}\varepsilon_{t-2} + \ldots \text{ since } C_0 = I.$$

It can also be written more compactly:

$$\begin{bmatrix} G_i \\ \Delta x_i \end{bmatrix} = \begin{bmatrix} \theta_{11,0} & \theta_{12,0} \\ \theta_{21,0} & \theta_{22,0} \end{bmatrix} \begin{bmatrix} \varepsilon_{G,t} \\ \varepsilon_{PR,t} \end{bmatrix} + \Theta_1\varepsilon_{t-1} + \Theta_2\varepsilon_{t-2} + \ldots, \qquad \text{(A4.3)}$$

where $\Theta(L) \equiv C(L)B_0^{-1}$.
$\Theta_0 = B_0^{-1}$, and captures the initial impact of structural shocks. Also, it determines the contemporaneous correlation between G and Δx. Recall the assumption that the effect of the output growth shocks on government spending is zero. This can be found by assuming a lower triangular contemporaneous matrix Θ_0, that is $\theta_{12,0} = 0$. This also implies that B_0^{-1} also is a lower triangular, and that $B_{12,0} = 0$.

Based on this restriction, the causal ordering can be identified by performing the Cholesky decomposition. This means that $B_0^{-1} = P$, where P is the Cholesky decomposition of the reduced-form covariance matrix $\sum$. Continuing with the restriction and equation (4.6), we can now recover the structural shocks from the reduced-form residuals:

$$e_t = B_0^{-1}\varepsilon_t$$

↓ (A4.4)

$\varepsilon_t = B_0 e_t = P^{-1}e_t$.

By using the restriction that $B_{12,0} = 0$, we obtain the form of the structural model that we are investigating:

$$B_{11,0}G_t = B_{11,1}G_{t-1} + B_{12,1}\Delta x_{t-1} + \varepsilon_{G,t}$$

$$B_{22,0}\Delta x_t = - B_{21,0}G_t + B_{21,1}G_{t-1} + B_{22,1}\Delta x_{t-1} + \varepsilon_{PR,t}$$

Thus, the implications of the Cholesky decomposition is as follow:

1) The first equation in the structural model will not include contemporaneous Δx's as explanatory variables.
2) The second equation may however include contemporaneous G's, but otherwise just lagged values of the variables, and so on.

Further, the property of the Cholesky decomposition is that: "*No equation contains its own contemporaneous variables, but the contemporaneous value of the variable(s) that is (are) above itself in the system*" (Bjørnland & Thorsrud, 2015, p. 221).

Usually, we do not have the parameters $B_{11,0}$ and $B_{22,0}$ in front of the dependent variables. However, it is just a matter of normalization if we remove these. The only difference between including and excluding the parameters is the interpretation.

A4.2 Plots of time series

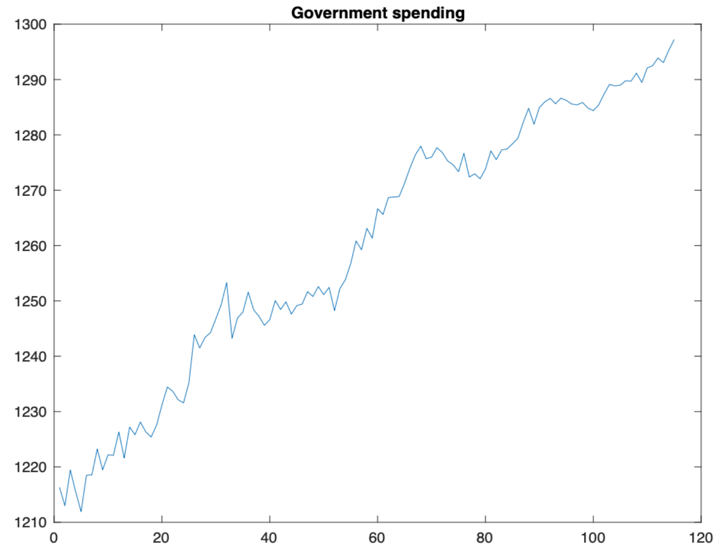

Figure A4.1. A plot of logged government spending time series.

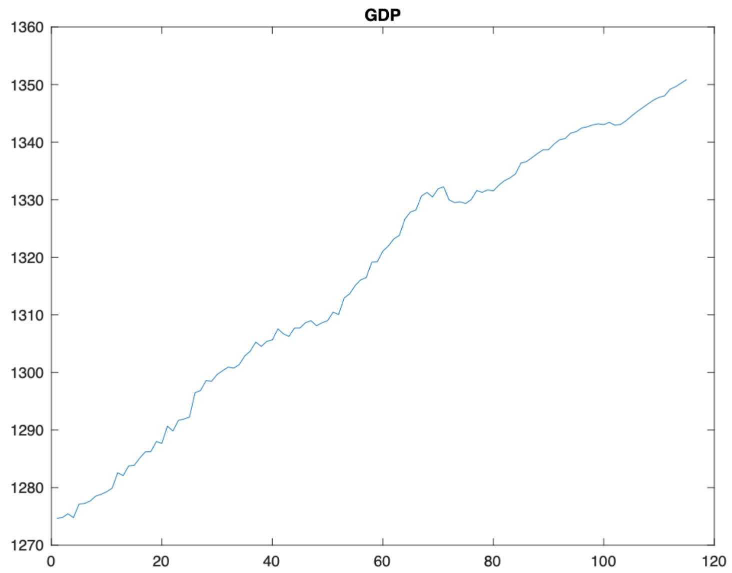

Figure A4.2. A plot of logged GDP time series.

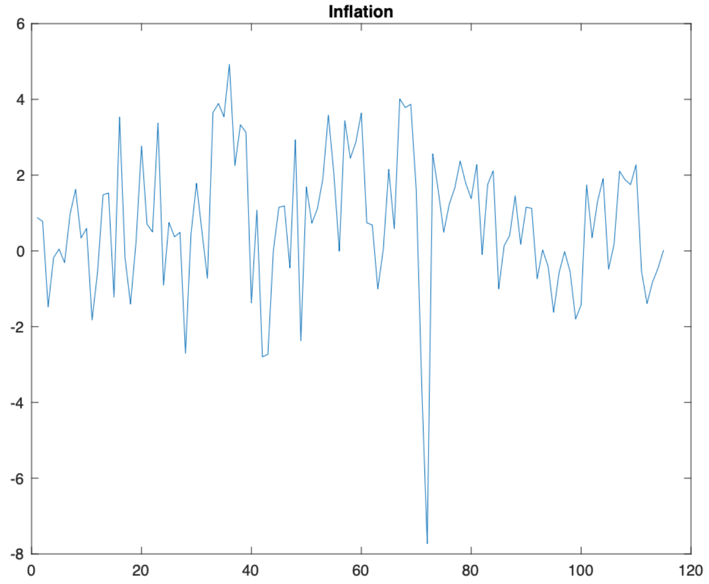

Figure A4.3. A plot of log-differenced inflation time series.

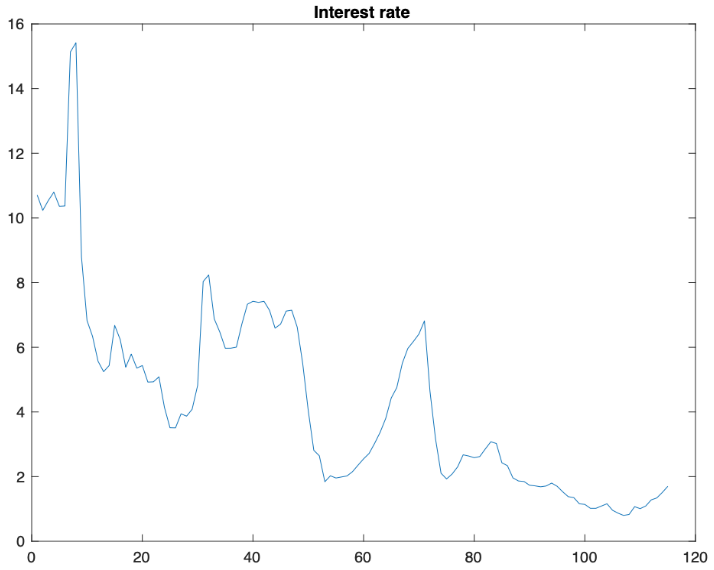

Figure A4.4. A plot of interest rate time series.

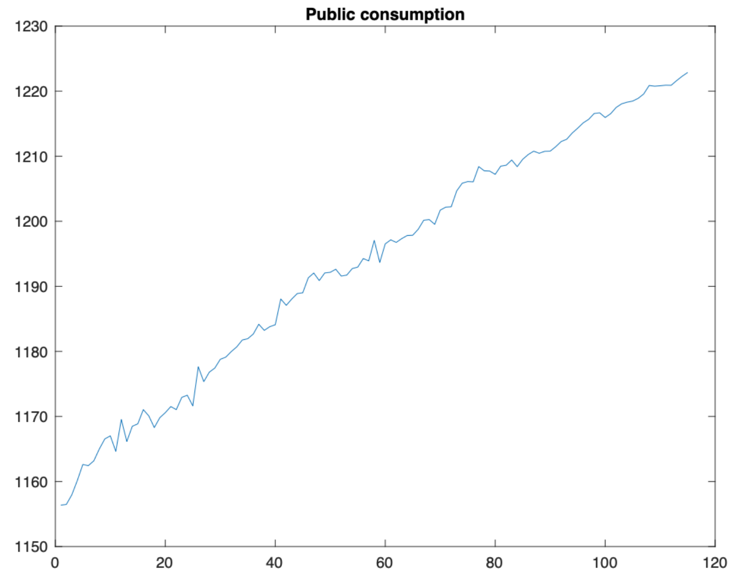

Figure A4.6. A plot of logged public consumption time series.

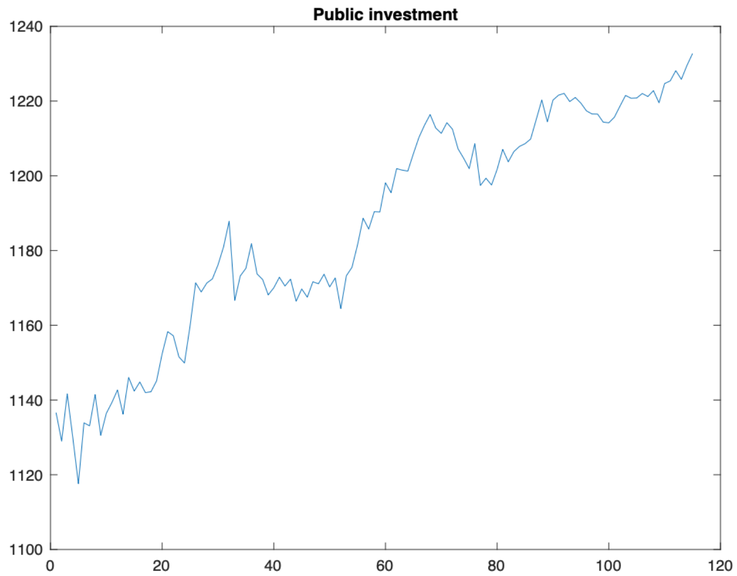

Figure A4.5. A plot of logged public investment time series.

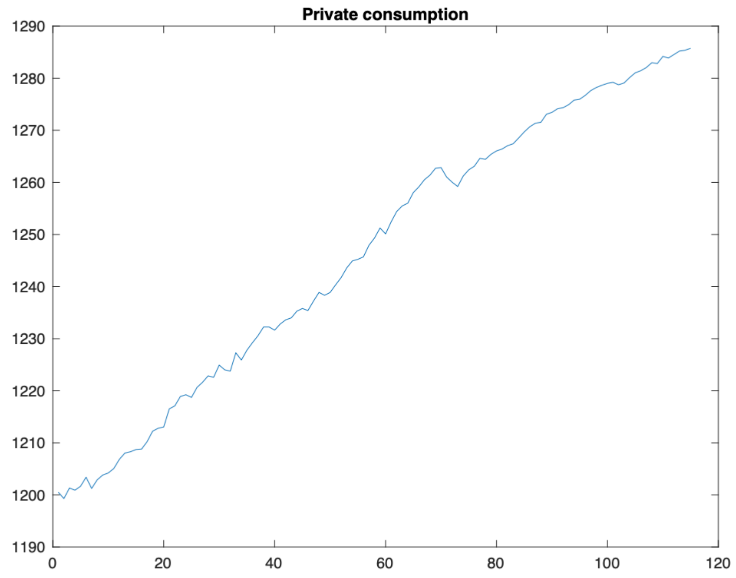

Figure A4.7. A plot of logged private consumption time series.

A4.3 AIC and BIC test of the baseline model

Lags	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
AIC	1573.13	1545.77	1536.64	1517.92	1492.69	1480.7	1401.35	1365.42	1317.49	1279.43*
BIC	1627.86*	1643.95	1678	1702.17	1719.53	1749.83	1712.48	1718.23	1711.68	1714.68

Table A4.1. Lag selection of the baseline model. * denotes the lowest value and leads to the suggested lag length.

A4.4 Eigenvalues of the baseline model

Eigenvalues of the companion form (all < 1)															
0.77	0.77	0.51	0.46	0.55	0.55	0.51	0.51	0.62	0.62	0.99	0.82	0.82	0.59	0.59	0.48

Table A4.2. Eigenvalues of the baseline model. The model is stable as all eigenvalues of the companion form are less than one.

A4.5 Johansen trace test of the baseline model

r	h	stat	c-Value	p-Value	Eigenvalues
0	1	134.5429	95.7541	0.0010	0.2969
1	1	95.0870	69.8187	0.0010	0.2833
2	1	57.7800	47.8564	0.0047	0.1555
3	1	38.8472	29.7976	0.0041	0.1488
4	1	20.8071	15.4948	0.0076	0.1119
5	1	7.5192	3.8415	0.0064	0.0649

Table A4.3. Testing for cointegration - Results from the Johansen trace test. r = the number of cointegrating vectors, h = values of h equal to 1 (true) indicate rejection of the null of cointegration rank r in favour of the alternative hypothesis[21], stat = test statistic, c-Value = critical values for right-tail probabilities, p-Values = right-tail probabilities of the test statistics.

[21] In the Johansen trace test, the null hypothesis states that there are no cointegrating vectors, $r = 0$, and the alternative hypothesis states that $r \leq$ n, where n is the maximum number of possible cointegrating vectors (Dwyer, 2015).

Appendix Chapter 6 - Robustness tests

A6.1 Changing the lag length

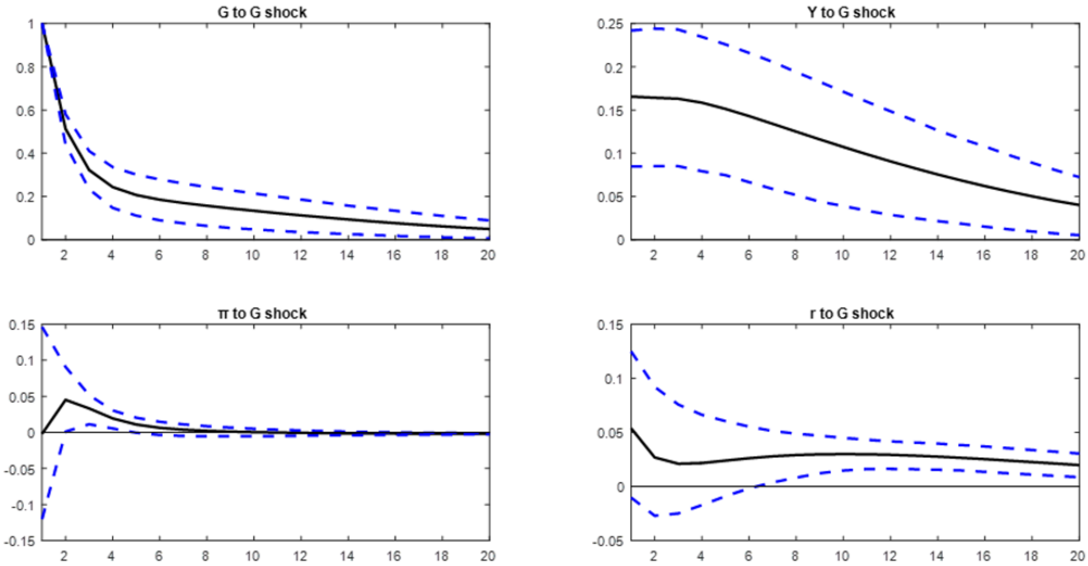

Figure A6.1. Estimated impulse responses to a government spending shock in the four-VAR model, using a lag length of one. G = government spending, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

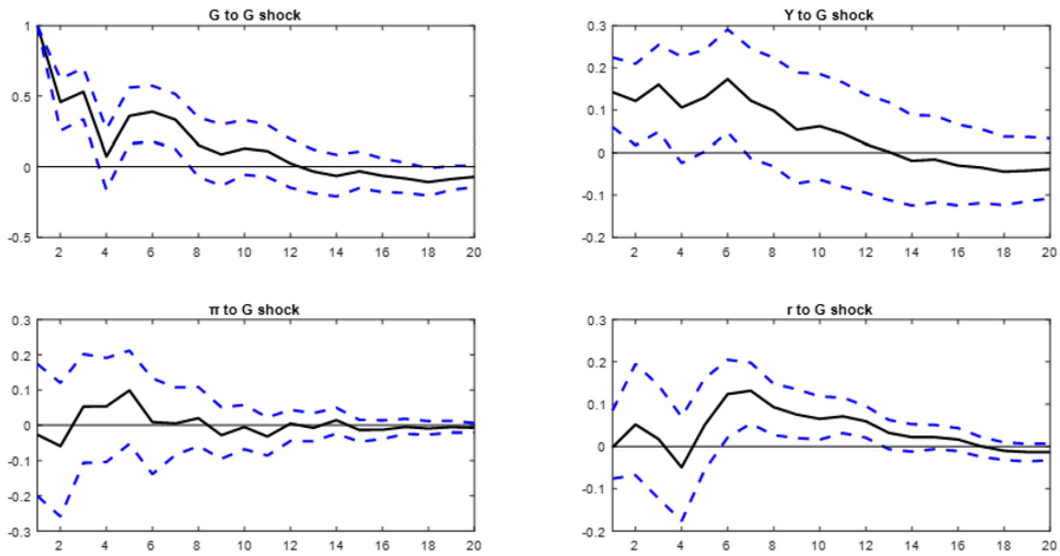

Figure A6.2. Estimated impulse responses to a government spending shock in the four-VAR model, using a lag length of six. G = government spending, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

A6.2 Confidence bands of 68%

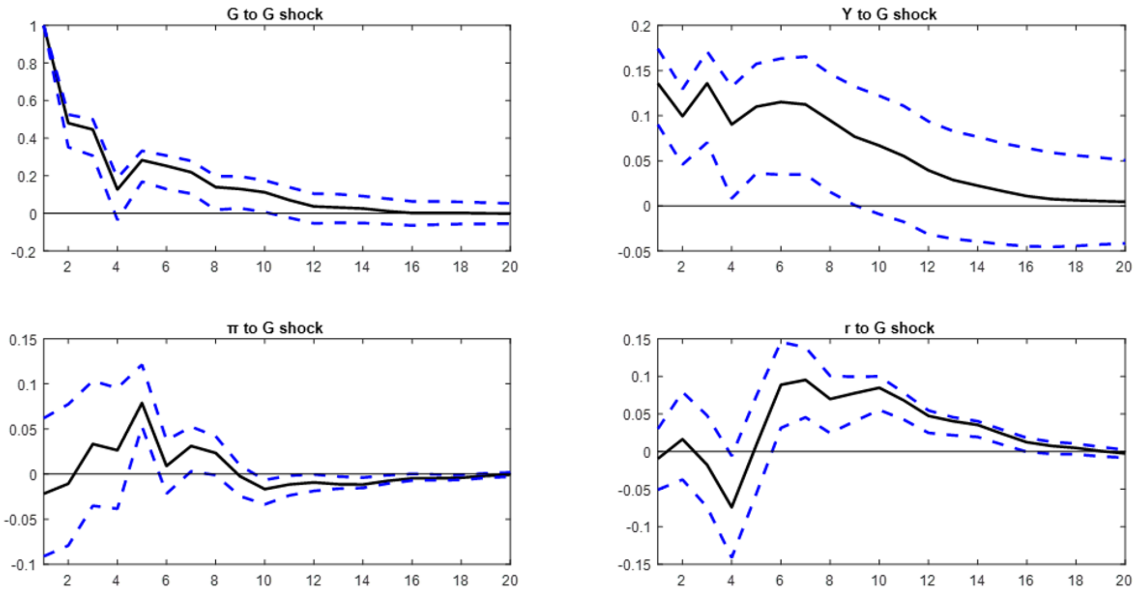

Figure A6.3. Estimated impulse responses to a government spending shock in the four-VAR model. G = government spending, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 68% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

A6.3 Comparing two measures of inflation

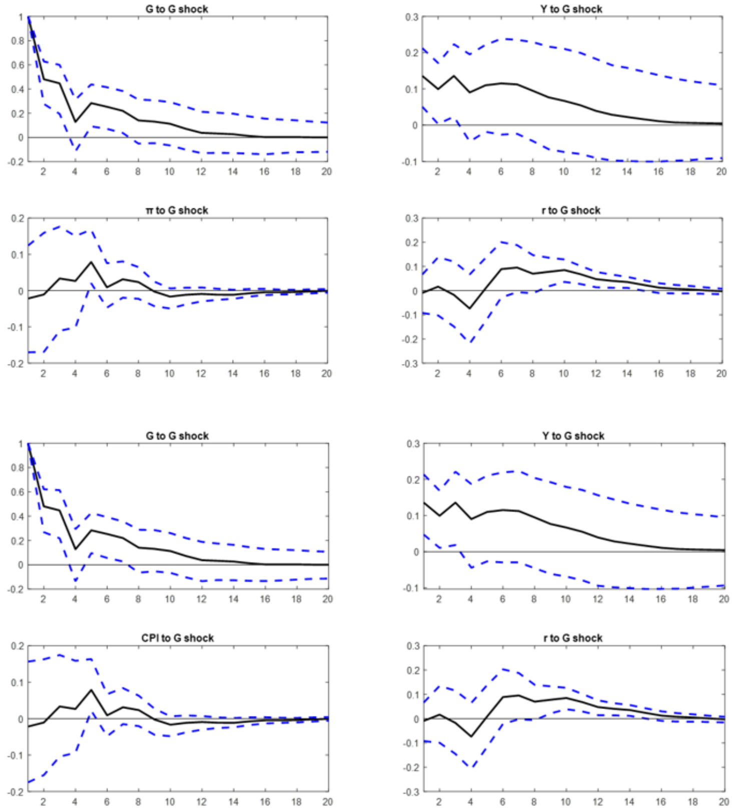

Figure A6.4. Estimated impulse responses to a government spending shock in the four-VAR model. The IRF at the top is the baseline model with GDP Deflator (π). The IRF at the bottom is the baseline model with the CPI. G = government spending, Y = GDP, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

A6.4 Comparing two measures of interest rate

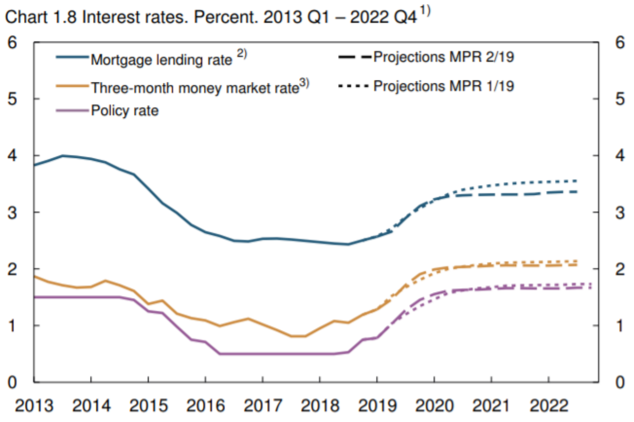

Figure A6.5. This figure is referred to in section 6.4, and in the robustness test for interest rate data. "*1) Projections for 2019 Q2 – 2022 Q3 (mortgage lending rate and three-month money market rate) (2022 Q4 (key policy rate). 2) Average interest rate on outstanding housing loans to households, for the sample of banks and mortgage companies included in Statistic Norway's monthly interest rate statistics. 3) Projections are calculated as an average of the policy rate in the current and subsequent quarter plus an estimate of the money market premium*".
Source: Norges Bank. (2019). *Monetary policy report with financial stability assessment* (Second quarter).

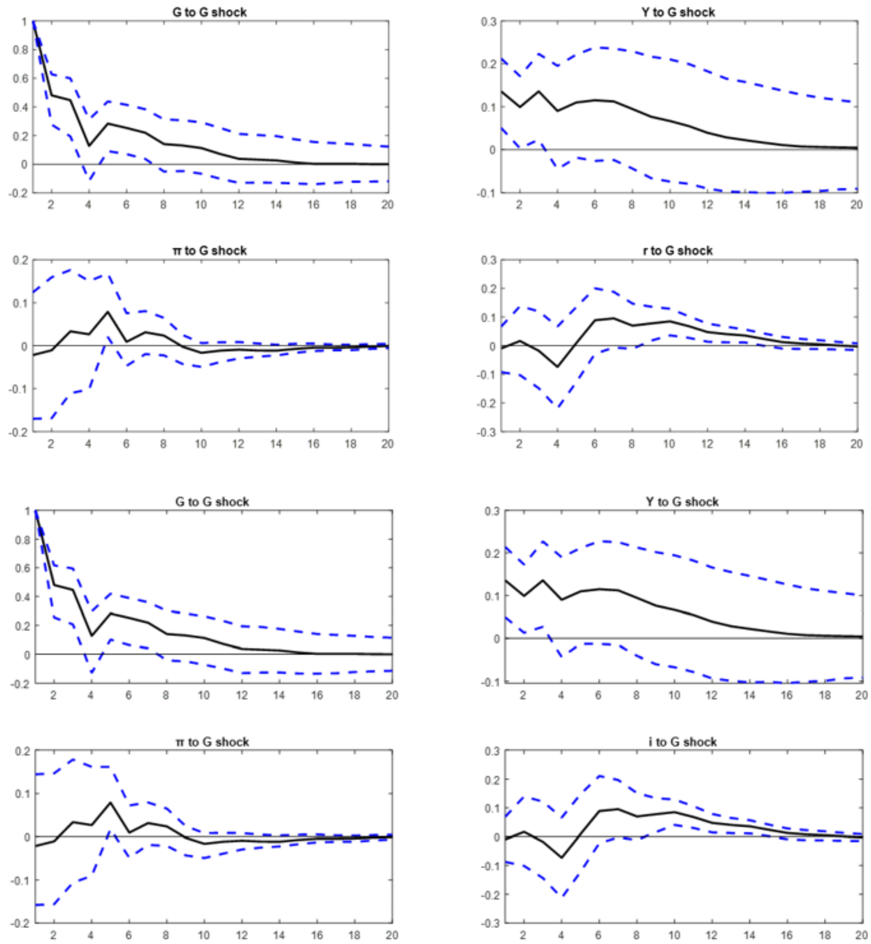

Figure A6.6. Estimated impulse responses to a government spending shock in the four-VAR model. The IRF at the top is the baseline model with 3-month NIBOR (r). The IRF at the bottom is the baseline model with the policy rate (i). G = government spending, Y = GDP, π = inflation. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

A6.5 Changing ordering of government spending and GDP

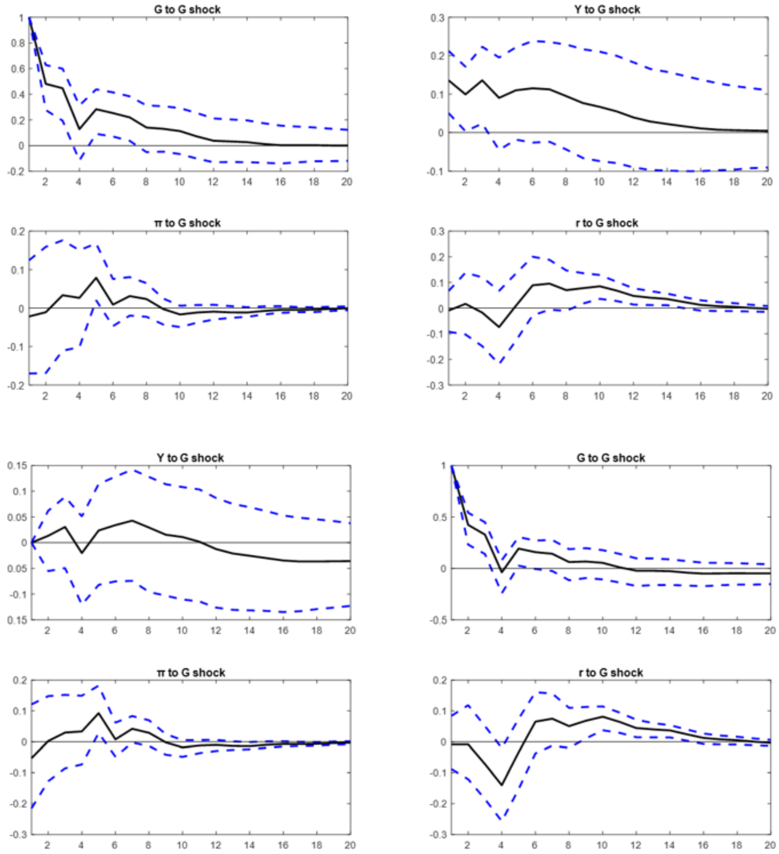

Figure A6.7. Estimated impulse responses to a government spending shock in the four-VAR model. IRFs of the baseline model at the top, and IRFs of Model Z at the bottom. G = government spending, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

A6.6 Changing ordering of public consumption and public investment

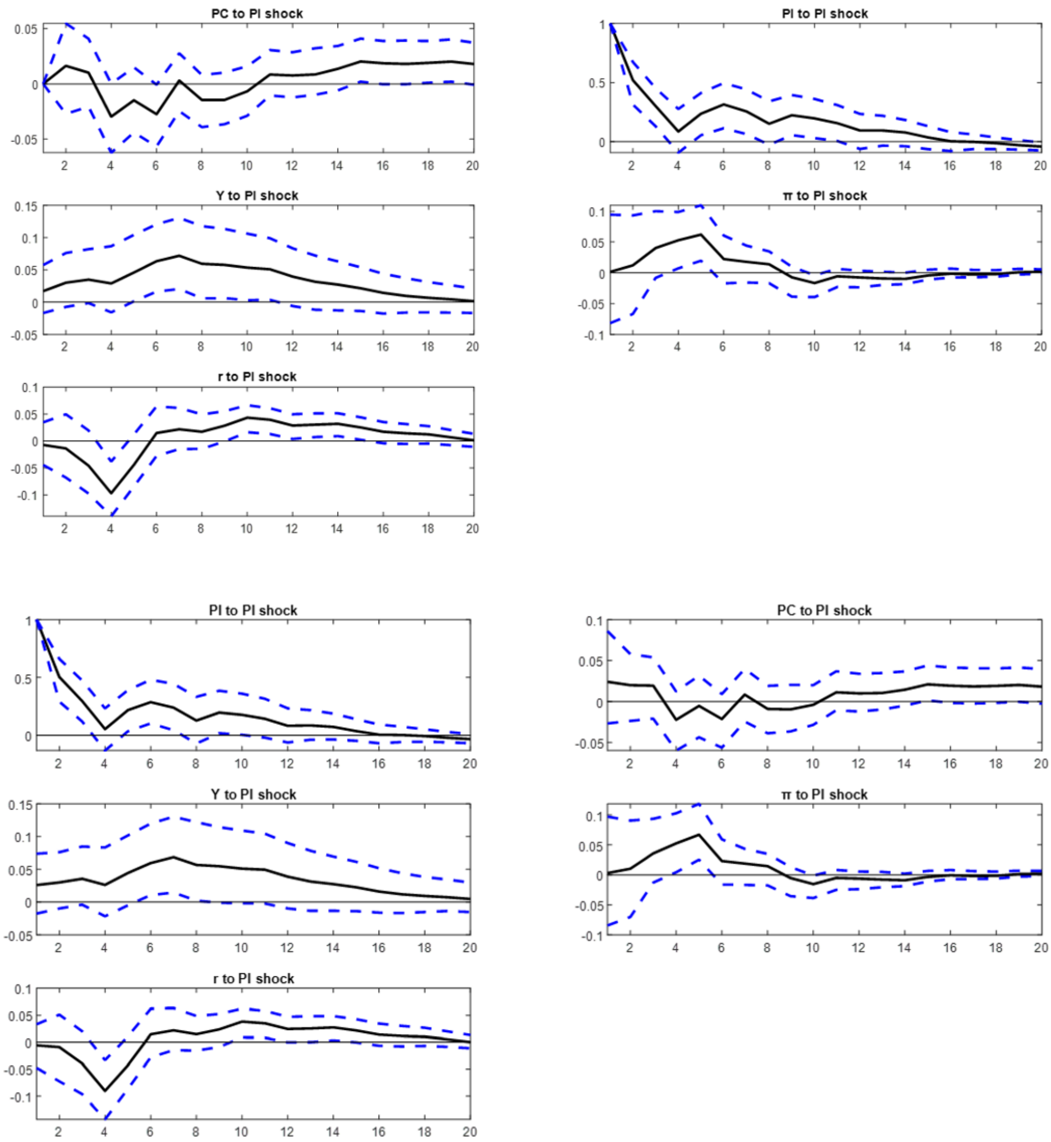

Figure A6.8. Estimated impulse responses to a public investment shock in the five-VAR model. The IRFs at the top is Model X and the IRFs at the bottom is Model Y. PC = public consumption, PI = public investment, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

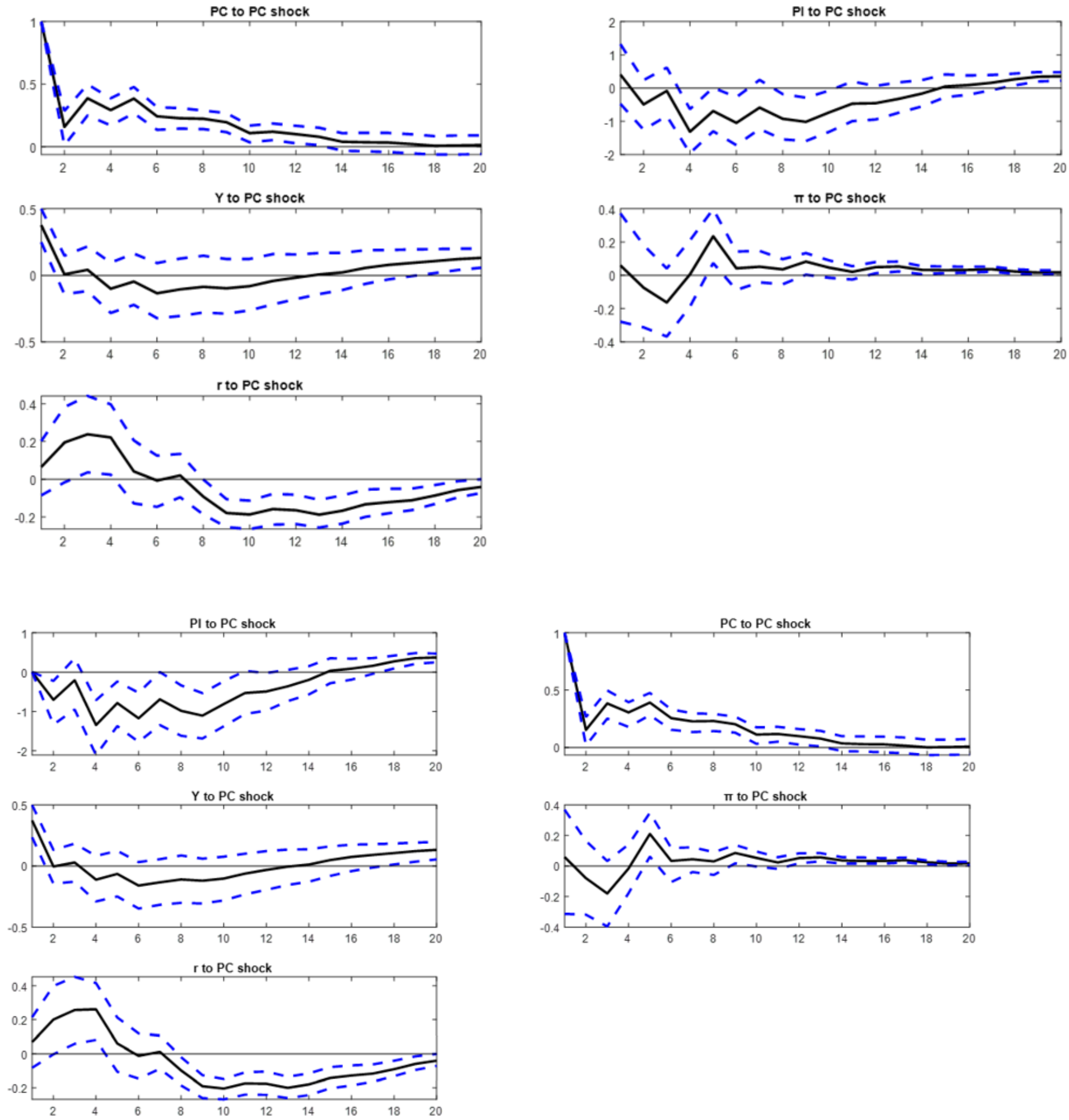

Figure A6.9. Estimated impulse responses to a public consumption shock in the five-VAR model. The IRFs at the top is Model X and the IRFs at the bottom is Model Y. PC = public consumption, PI = public investment, Y = GDP, π = inflation, r = interest rate. Sample Period 1991:1–2019:3. The horizontal axis represents quarters after the shock. The vertical axis represents the percentage impact of the shock. The dashed lines are the confidence intervals corresponding 95% standard deviations of empirical distributions, based on 1000 Monte Carlo replications. The solid line represents the impulse function.

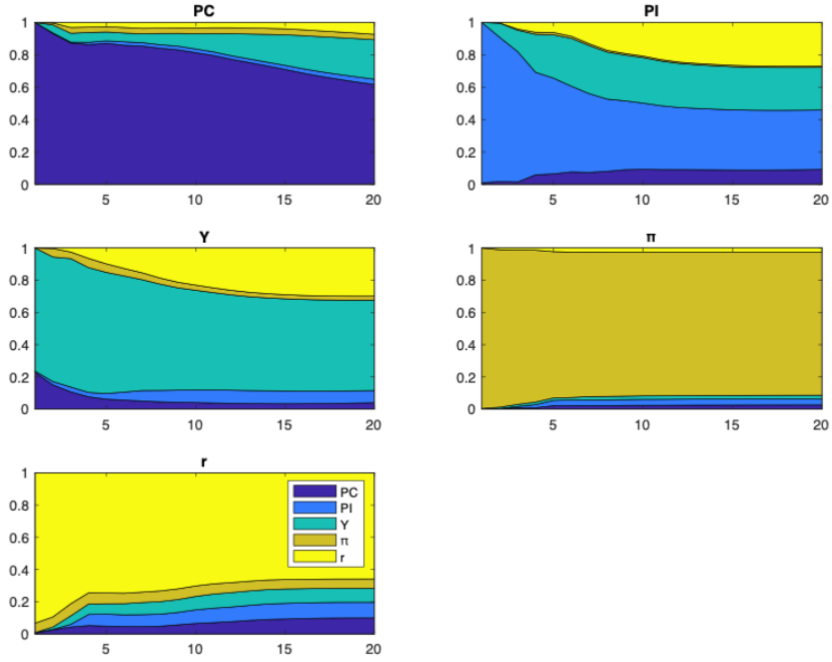

Figure A6.10. PC = public consumption, PI = public investment, Y = GDP, π = inflation, r = interest rate. An illustration of the FEVD of Model X, indicating how much of the variation in each variable is caused by a shock to the other variables.

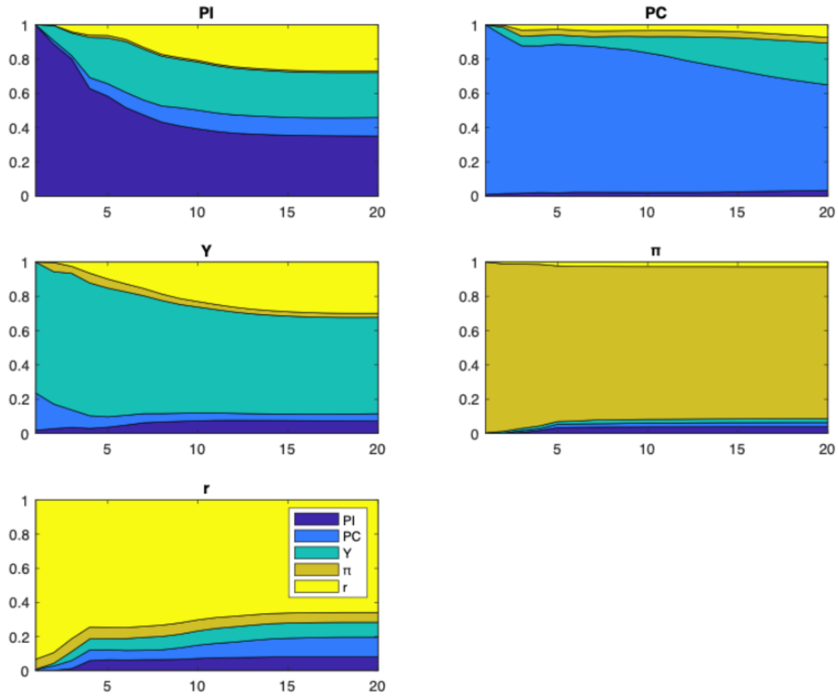

Figure A6.11. PC = public consumption, PI = public investment, Y = GDP, π = inflation, r = interest rate. An illustration of the FEVD of Model Y, indicating how much of the variation in each variable is caused by a shock to the other variables.

	Shock to public consumption	Shock to public investment
Horizon	4th quarter, 8th quarter	4th quarter, 8th quarter
Public consumption	0.86, 0.84	0.01, 0.02
Public investment	0.06, 0.08	0.63, 0.44
GDP	0.08, 0.04	0.03, 0.07
Inflation	0.01, 0.02	0.02, 0.03
Interest rate	0.05, 0.05	0.07, 0.07

Table A6.1. FEVD of the variables in Model X, illustrate the amount of variation in percentage, as a result of a public consumption and public investment shock after both one and two years.

	Shock to public investment	Shock to public consumption
Horizon	4th quarter, 8th quarter	4th quarter, 8th quarter
Public investment	0.63, 0.43	0.06, 0.09
Public consumption	0.02, 0.02	0.86, 0.84
GDP	0.03, 0.07	0.07, 0.05
Inflation	0.02, 0.04	0.02, 0.02
Interest rate	0.06, 0.06	0.06, 0.06

Table A6.2. FEVD of the variables in Model Y, illustrate the amount of variation in percentage, as a result of a public investment and public consumption shock after both one and two years.