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The effects of terms of trade shocks in Norway: an SVAR analysis

Master's thesis in Economics (2-year program)

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"Few countries are benefiting as much as Norway - and losing as little - in the current environment of freer trade and increased cross-border labour mobility. Prices for goods we import are falling in relation to prices for goods we export. Norway's terms of trade are improving. The Norwegian economy has experienced a strong positive income shock."

Svein Gjedrem (2006), the former governor of Norges Bank (1999-2010).
Extract from speech held in Bergen, June 2006.

Preface

Over the past year, I have been fortunate to be working at Norges Bank. This gave me the opportunity to write a thesis on the subjects in economics I cherish the most: empirical macroeconomics and monetary policy. The thesis is part of a broader project at Norges Bank that deals with Norway's dependence on developments abroad. The views expressed in this thesis are mine, and do not necessarily reflect those of Norges Bank.

Several people have made the process of writing this thesis a truly inspiring and learning experience.

First and foremost, I thank my extraordinary supervisor, Nina Larsson Midthjell, for her detailed and constructive feedback, flexibility and enthusiasm.

From the staff at Norges Bank, I would like to thank Kjetil Olsen for inviting me to write my thesis at the Bank. Leif Brubakk deserves special thanks for helping me with singling out the subject of the thesis, and for guiding me on readings, method and fruitful discussion of the results. Thanks to Francesco Furlanetto for introducing me to his own work on terms of trade shocks to the Norwegian economy, which he is doing together with Francesco Ravazzolo and Samad Sarferaz, and for being available for questions of all sorts over the past six months. Last but certainly not least, I am very grateful to Andrew Binning for helping me with writing the MatLab code that made the empirical analysis in this thesis possible. Andrew has been extremely helpful, also when it comes to making sense out of formal language. Any remaining errors are my own.

This thesis is the finalization of my many years as a student. During all these years, my dearest Rebekka has been by my side, supporting me and challenging me. She has also given me Oda, whose smiles and laughs, talks and temper shift the focus from work and studies over to more important things. This thesis is dedicated to you both.

Magnus Gulbrandsen.
Bergen, May 29, 2013

Summary

Norway is a small and open economy. Consequently, the economy is dependent on developments beyond its borders and influence. The focus in this thesis is on developments in the global economy that affect the terms of trade for Norway, and in effect key macroeconomic variables in the Norwegian economy.

Norway's terms of trade have been improving significantly over the past twenty years. This thesis argues that three foreign shocks – "terms of trade shocks" – have been especially important drivers behind this improvement: a world demand shock, an oil price shock, and a globalization shock. The goal of this thesis is to evaluate the broader macroeconomic effects and relative importance of these shocks compared to domestic shocks in the Norwegian economy.

Specifically, the empirical analysis in this thesis investigates how these shocks originating in the global economy affect domestic output, inflation, the real exchange rate and interest rates in Norway. Furthermore, to evaluate the relative importance of these shocks compared to domestic factors, the analysis also estimates the effect of three conventional domestic shocks, namely a domestic demand shock, a domestic supply shock, and, a monetary policy shock.

In order to do so, a structural vector autoregressive model (SVAR) for Norway is developed and estimated. The model contains a foreign block and a domestic block. The foreign block consists of growth in the world price of imported consumption goods, oil price growth, and output growth in Norway's main trading partners, and the three terms of trade shocks. A world demand shock is characterized by higher growth in all three variables. An oil price shock entails a higher oil price and lower foreign output growth, but an uncertain aggregate effect on import prices. Finally, a globalization shock captures the influx of developing economies into the global economy, leading to lower price on imports, a higher price of oil, and higher output growth abroad. The domestic block contains quarterly output growth in mainland Norway, the annualized inflation rate, quarterly growth in the real exchange rate and the short term money market interest rate (NIBOR). To evaluate the relative importance of specific foreign and domestic shocks, three shocks originating in

the domestic economy are introduced and identified: a domestic demand shock, a domestic supply shock, and a monetary policy shock. In line with the small, open economy assumption, fluctuations in, and shocks to, foreign variables are allowed to affect domestic variables, but not vice versa.

The six shocks are identified through sign restrictions, and the model is estimated over the period 1994Q1-2012Q4. The statistical tool used to estimate the model is MATLAB. The main results are as follows: All three foreign shocks contribute significantly to explaining movements in the oil price and the price of imported consumption goods, and thus Norwegian terms of trade. Furthermore, each shock explains variation in foreign GDP growth, and thereby foreign demand for domestic goods. There is strong evidence to suggest that terms of trade shocks not only affect terms of trade differently, but also the domestic economy.

More specifically, a world demand shock is expansionary: domestic output gap, inflation and interest rates increase. The exchange rate appreciates, thus acting as a buffer against the effects of higher import and export prices. An oil price shock dampens activity in mainland Norway and inflationary pressure. This effect can be traced in a sharp fall in foreign output, and thus foreign demand for goods produced in mainland Norway. According to the results, the interest rate falls. The real exchange rate appears to appreciate, but this effect is uncertain. A globalization shock, entailing lower import prices and a higher oil price, is expansionary, but in the short run not inflationary. However, in the longer run, inflation picks up, and interest rates are increased in order to dampen activity in the domestic economy. The exchange rate response is uncertain, but seems to appreciate following the shock.

The three domestic shocks affect the domestic economy largely as expected and in line with previous empirical findings. By increasing activity and inflationary pressure in the domestic economy, a demand shock is met by contractionary monetary policy, and in turn a stronger Krone exchange rate. A supply shock is identified by imposing a positive output effect, but a lower inflation rate.In response, the interest rate is pushed down, and the real exchange rate depreciates. Finally, the output growth effect of a monetary policy shock is negative, but short-lived and

highly uncertain. Inflation and the exchange rate where restricted to respond by increasing and appreciating, respectively.

On average, the three foreign shocks together explain roughly $\frac{1}{3}$ of variation in domestic variables. Variation in mainland output growth and the real exchange rate growth, lie close to this average with 31 percent and 34 percent, respectively. Domestic inflation is less dependent on foreign factors: only 14 percent of variation is due to terms of trade shocks. Among domestic variables, movements in interest rates is most dependent on foreign factors (45 percent). Fluctuations in domestic output growth, inflation and the interest rate is predominantly determined by domestic demand and supply side shocks, with contributions ranging from 17 to 46 percent. Monetary policy shocks contribute with only a marginal share in these three variables, but is the single most important domestic factor in explaining variation in the real exchange rate. A significant share of variation in the real exchange rate (30 percent) is unaccounted for in the model, due to a choice of not trying to identify any exchange rate shock.

Thus, I find that terms of trade shocks are important for the Norwegian economy, but clearly less important than domestic factors. All foreign shocks contribute with sizable shares, but at the same time they affect the economy differently. While all positive shocks improve Norwegian terms of trade, they induce different response of monetary policy, both in the immediate aftermath of the shock, and in the longer run. Thus, the findings in this thesis highlight the importance of disentangling the source of the terms of trade shock, in order for economic policy to respond correctly.

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1 Introduction

In small open economies foreign factors play a crucial role for domestic business cycles. One such factor is the terms of trade, i.e. the export and import prices an economy faces. Over the past twenty years, Norway has experienced a radical improvement in its terms of trade: the price of Norwegian exports have been soaring while import prices have been more or less constant, see figure 1.1. However, the macroeconomic effects, and the relative importance of this development are uncertain and have until recently remained largely unexplored within the Norwegian context.

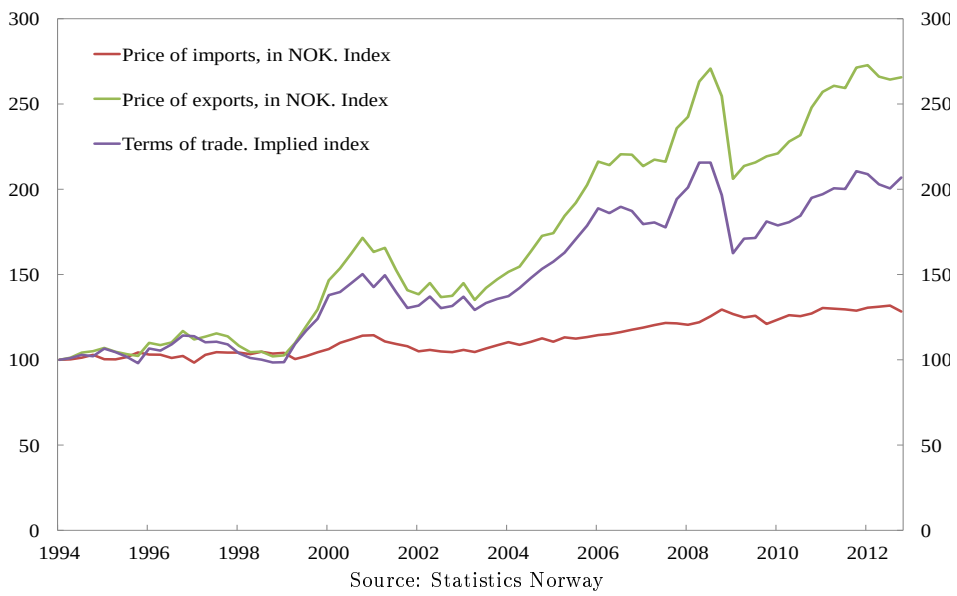

Figure 1.1: Price of Norwegian exports and imports in Norwegian Kroner, and implied terms of trade. Index, 1994Q1=100.

The goal of this thesis is to empirically investigate the sources of this improvement in terms of trade over the past twenty years, and the macroeconomic effects on the domestic economy. Furthermore, the thesis seeks to evaluate the importance of these foreign developments, relative to domestic factors, such as domestic demand and supply, and monetary policy measures. This thesis asks:

1. *How do Norwegian output, inflation, exchange rate and interest rate respond to foreign shocks that alter the terms of trade in a small, open, oil-exporting economy, like Norway? And;*
2. *What is the relative importance of these terms of trade shocks compared to domestic shocks?*

The rationale behind these research questions is threefold. First, to date, terms of trade effects in Norway has not been the explicit focus of empirical research, which leaves a gap in the literature.[1] Second, while research have been carried out on small, open economies before, the macroeconomic effects of changes in terms of trade in Norway might differ significantly from these, due to Norway's dependence on its petroleum industry. Third, the real world relevance of the question is important. If terms of trade shocks affect the real economy, then it also affects peoples' lives. Furthermore, while terms of trade must be taken as exogenous, the response of fiscal and monetary policy should certainly not. Hence, disentangling the expected short- and long run effects of different types of terms of trade shocks provides a more sound foundation for policy decisions and in extension a good policy response.

To achieve this goal, the thesis develops a structural VAR (SVAR) model, based on a small, open economy assumption. Norway is a small, open economy in that it is trade dependent, i.e. exporting some of domestic production in exchange for importing foreign produced goods (open); but at the same time the share of total traded goods in the world is so small that it cannot affect the prices of its imports and exports (small). In short, while on the one hand being dependent on trade, it cannot affect its terms of trade. Thus it is assumed that export- and import prices are exogenous and altered by foreign shocks. The thesis focuses on three foreign shocks that are arguably the main drivers behind the increase in Norwegian terms of trade; a world demand shock; an oil price shock, and; a globalization (supply) shock. These shocks in turn are important not only because they alter Norwegian terms of trade, but also because they are transmitted to the Norwegian economy.

[1] In an ongoing project at Norges Bank, Francesco Furlanetto, Francesco Ravazzolo and Samad Sarferaz investigate the effect of terms of trade shocks in Norway, with a similar approach as in this thesis. I am grateful to these scholars for letting me into their project.

Furthermore, in order to evaluate the relative importance of these shocks compared to domestic shocks, three domestic shocks are analyzed; a demand shock, a supply shock, and a monetary policy shock. All shocks are identified by imposing sign restrictions on the response of variables in the period following a shock.[2]

The thesis is structured as follows. Chapter 2 provides an overview of the empirical literature on the effects of foreign shocks to a small, open economy, with as special focus on the literature on Norway. The focus is on the SVAR model literature. Chapter 3 develops an SVAR model for Norway, and presents the identification scheme utilized in this thesis. Chapter 4 is dedicated to describing the data utilized in the empirical analysis. Chapter 5 presents the results. Chapter 6 summarizes and concludes.

[2]The statistical tool used to estimate the model is MATLAB. Andrew Binning at Norges Bank has been most helpful with writing the MATLAB code.

2 Literature review

A prominent view in the current literature on macroeconomics is that price shocks to globally traded goods are not all alike and identification of different types of shocks, depending on their sources, therefore becomes crucial.[3] This "multiple-sources" approach is parallel to that of standard theory of price formation and general equilibrium effects: since prices of goods (here: imports and exports) are driven by demand and supply side factors, the response of macroeconomic variables depends on the source of the shock. Several papers have supported this hypothesis empirically. Kilian (2009), and succeeding papers, argue theoretically and show empirically that the source of an oil price shock is of crucial importance to how US domestic variables respond. Similarly, Peersman and Van Robays (2009) use SVAR to show a parallel trend for the Euro area. footnoteA standard approach to estimating the effects of exogenous shocks has become structural autoregressive models (SVAR). Unless explicitly stated otherwise, all literature presented in this chapter utilize the SVAR methodology. A more in-depth presentation of the SVAR method is provided in chapter 3. For now, it suffices to note that SVAR departs from standard vector auto regression models (VARs) in that shocks are identified in order to give them an economically meaningful interpretation.

Jääskela and Smith (2011) adopts the "multiple-sources" approach to terms of trade shocks for the Australian economy. Like Norway, Australia is a small, open economy in the sense that prices on imports and exports are exogenously determined. Thus, they identify three types of foreign shocks that affect the Australian economy and its terms of trade: a world demand shock, a commodity-market specific shock, and a globalization shock.[4] Domestic shocks are not identified. The estimation results in Jääskelä and Smith (2011) show that all three shocks explain parts of the variation in domestic variables. For instance, output tends to increase following all positive shocks in terms of trade. The response of inflation, on the other

[3] The strongest advocate of this view, with special reference to oil price shocks, is probably Lutz Kilian (see for instance Kilian 2009). For a conflicting view, see Hamilton (2003).

[4] All three shocks are likely to affect an economy not just through terms of trade. However, Jääskelä and Smith (2011) identify these shocks based on a priori (theoretical-based) assumptions of the response of export- and import prices, as well as world demand, hence the term "terms of trade" shocks.

hand, depends on the nature of the shock and the response of monetary policy. The authors highlight the (flexible) exchange rate as an important buffer against foreign shocks. Furthermore, interest rate movements following shocks suggest a monetary policy that aims at hindering the transmission of shocks to the domestic economy. It should, however, be noted that, except from the exchange rate, all variables is predominantly determined by the unidentified domestic shocks.

With broadly similar shock characteristics as that of Jääskelä and Smith (2011), Karagedikli and Price (2012) estimates terms of trade effects for New Zealand.[5] The results, however, are quite different. First, New Zealand's output is estimated to decrease following a benign world supply shock that promotes better terms of trade. Second, integration of emerging economies in the world economy (i.e. a globalization shock) had little effect on New Zealand GDP. Variance decomposition analysis on the other hand shows largely the same picture as what Jääskelä and Smith (2011) find for Australia, although the New Zealand dollar exchange rate seems less sensitive to foreign shocks than its Australian counterpart.

These two studies suggest that foreign factors are important in small, open economies, although less important than domestic ones, which are not identified in neither of the two studies. It also seems clear that terms of trade effects differ depending on the origins of the shock. However, the two papers highlight the fact that the response of domestic variables depends on the structure of the economy under investigation.

Empirical analyses on the effect of terms of trade shocks in Norway are scarce. As a rare exception, Otto (2003) investigates the effect of terms of trade in Norway among several other small, open economies. That paper focuses on the effect on the trade balance (the Harberger-Laursen-Metzler effect) and output, where the latter was found to increase following a positive terms of trade shock.[6] Importantly, however, and in contrast to the more recent literature, all terms of trade shocks were equal, i.e. not depending on the source of the shock.

[5] The difference is largely semantic. Karagdekli and Price (2012) focus on shocks to commodity prices, whereas Jääskelä and Smith (2011) consider the same shocks as terms of trade shocks.

[6] The Harberger-Laursen-Metzler effect predicts that an adverse terms of trade shock will cause an improvement in the current account balance (see Otto 2003, Harberger 1950 and Laursen and Metzler 1950).

While Otto does not touch the discussion of the role of oil for terms of trade effects, Spatafora and Warner (1995) argue that: "...an examination of the data for oil exporters leads to a different picture of terms-of-trade effects than can be obtained from an unbiased sample of terms-of-trade articles in the literature" (Spatafora and Warner 1995: 2).[7] While this seems as an important result with respect to the Norwegian case, it is important to notice that Norway is not among the 18 oil exporting countries analyzed in the paper.

If the structure of the economy is important, as the papers above suggest, oil (and the broader petroleum sector) must necessarily become a crucial part in the portrayal of the Norwegian economy. Accordingly, the effects of foreign factors on the Norwegian economy have typically focused on oil price shocks, not terms of trade per se (see for instance Bjørnland 2008, Akram 2004, Jiménez-Rodriguez and Sanchez 2005, and Solheim 2008).

The broad description of oil shocks offered in the literature shares important characteristics with that of the commodity specific shock described in Jääskelä and Smith (2011) and Karagdekli and Price (2012). Following a commodity/oil price hike, one should expect a falling global demand and higher export prices from the net exporter (see Kilian 2009, Hamilton 2003, Peersman and Stevens 2010, Peersman and Van Robays 2009, and Akram and Winje 2008). Yet, the literature also highlights that empirically, oil price shocks often differ significantly from other types of commodity shocks (Hamilton 2003, Karagdikli and Price 2012, Kilian 2009).

Consequently, there is a vast empirical literature on the effects of oil price shocks. Intuitively, the net oil importer suffers from an oil price hike, and (all else equal) the world economy as a whole will therefore experience a drop in demand.[8] For the net oil exporter the picture is more divided. Jiménez-Rodriguez and Sanchez (2005) compare the response of GDP to oil price hikes in OECD countries. Interestingly, the two oil exporting countries in the sample, Norway and United

[7] Spatafora and Warner (1995) employ OLS fixed effects estimation on a panel of 18 oil exporting countries to study terms of trade effects.

[8] Note, however, that the observed net response of net importer are likely to depend on whether supply- or demand side factors drive the oil price hike (Kilian 2009).

Kingdom, experience opposite effects of oil price hikes. Whereas Norway's economy is boosted, UK output falls. The authors trace the diverging response by a considerably sharper appreciation of the sterling exchange rate than the Norwegian krone exchange rate following the price rise.

Likewise, Bjørnland (2008) finds that all variables of interest (i.e. output, inflation, interest rates and exchange rates) rise as a response to an oil price shock. At the same time, an oil price rise will, seen in isolation, entail a lowering of global economic activity (Jiménez-Rodriguez and Sanchez 2004, Hamilton 1983, and Bjørnland 2008).

Oil price shocks, therefore, share the features of Jääskela and Smiths "commodity-specific" shock. Seen from a world point of view, both an oil price shock and a commodity shock is associated with a lowering of world demand and a higher import price on oil/commodities (i.e. a higher world price on the exports of the net exporter). Comparing the findings in Jääskelä and Smith (2011) and Bjørnland (2008), however, the effect of these two shocks on the domestic economy look less uniform. In Jääskelä and Smith (2011), the exchange rate is an important buffer against foreign shocks. For instance, following a commodity specific shock the exchange rate appreciation offset the inflationary pressure, and in the medium run actually lowers the inflation rate. In Bjørnland's (2008) analysis of oil price shocks, the economy reacts by increased output, as in Jääskelä and Smith (2011), but this increased activity also leads to a higher inflation rate. The difference can partly be explained by a small and fluctuating (and in the end; insignificant) response of exchange rates in Norway (Bjørnland 2008: 20). The latter finding contrasts a conventional and widely held view that oil exporting countries will experience a real appreciation of the exchange rate following oil price hikes. Several papers have shown that to be the case also for Norway (Haldane 1997, Solheim 2008, Bjørnland 2008, and Akram 2004).

In sum, while an oil price shock is an important component of the exogenously determined foreign factors, the research on responses of oil shocks highlight the importance of exchange rates in the response of inflation and output.

The papers cited above have one important shortcoming; they do not identify domestic shocks in order to reveal the relative importance of demand and supply shocks stemming from global vs. domestic factors. Conversely, Aastveit, Bjørnland and Thorsrud (2011) estimate a FAVAR model in order to investigate the relative importance of world and regional shocks compared to domestic shocks.[9] The results attribute a much larger share of variance in domestic variables to foreign shocks than all above-cited papers, with estimates suggesting that world and regional shocks on average account for 62 percent of variation in key macroeconomic variables in Norway. Terms of trade increase, but only temporarily, in response to a world cost-push shock as export prices rise. Similarly, a world demand shock is associated with an increase in terms of trade.However, the effect seems to crucially depend on the economy in question, as the effect is notably smaller in Norway than in the UK and Canada. By extending the model to include the oil price, the authors show that a significant share of variation can be traced to oil price shocks.[10] In contrast, Mumtaz and Surico (2009) make use of a FAVAR model to show a quite different picture when it comes to the importance of world shocks. The authors find that even though world factors do affect domestic macro variables, they explain only a small part of variation compared to domestic shocks. Thus, it is not given that world factors are as important as suggested by Aastveit et al (2011).[11]

While the above-mentioned papers do not seek to identify and estimate the effects of terms of trade shocks for Norway specifically, they give some hints as to what to expect from the analysis and provide some guidelines when it comes to building a model for Norway. In sum, three general findings have importance for the SVAR

[9] A second shortcoming, which is also the rationale for utilizing the FAVAR approach, is that the diverging estimated responses are likely to be partly due to operationalization of the variables, i.e. choice of data. The FAVAR (short for: Factor Augmented VAR) approach, first suggested by Bernanke, Boivin and Eliasz (2005), seeks to alleviate this problem by filtering out a small set of common 'factors' from a wide range of different indicators (i.e. variables). These factors are in turn included in the usual VAR model in place of traditional variables.

[10] The authors note that the identified world price shock might reflect an oil price shock, with reference to the finding that the Norwegian exchange rate appreciates significantly. To examine this suspicion, the model is extended to include the oil price. Note also that Aastveit et al. (2011) do not separate between demand and supply shocks to the oil price.

[11] Aastveit et al. (2011) explicitly address the reasons for these diverging findings, see pages 16-17.

model developed in this thesis. First, Jääskelä and Smith (2011) and Kragdekli and Price (2012) provide strong foundations for thinking of terms of trade shocks to a small, open economy as consisting of several types of shocks, not just one shock. Therefore, the model developed in this thesis builds on, and extends, the Jääskelä and Smith (2011) approach to Norway. In effect, this means identifying three shocks that capture the most important factors behind the developments in Norwegian terms of trade over the past decades. Second, while there is quite substantial evidence that foreign factors are important for small, open economies, the evidence on the relative importance of foreign factors compared to domestic shocks is divided. Thus, in order to investigate this question further, the model of Jääskelä and Smith (2011) is modified by introducing and identifying domestic shocks, as in Aastveit et al. (2011). Third, the evidence on the importance of oil shocks for Norway is large, although the findings are not uniform (see e.g. Bjørnland 2008 and Jiménez-Rodriguez and Sanchez 2004). This induces another adjustment, namely that of redefining the commodity specific shock to an oil price shock in the model for Norway developed in this thesis.

3 The model

A small, open economy is defined by two features; trade dependence, i.e. exporting some of domestic production in exchange for importing foreign produced goods (open); and share of total traded goods being so small that it cannot affect the prices of its imports and exports (small). In short, while on the one hand being dependent on trade, it cannot affect its terms of trade. Export- and import prices are exogenous and altered by foreign shocks. Consequently, the only option for economic agents and policymakers is to respond as "good" as possible. In order to do so, one must know (or at least have some idea about) how the economy responds to exogenously driven changes to terms of trade. This chapter presents a structural VAR model which seeks to do just that for Norway.

3.1 The SVAR methodology

Vector autoregressions (VAR) have become a standard working tool in applied macroeconomics (Walsh 2010: 18-27, Christiano, Eichenbaum and Evans 1998). Because most fundamental macro-variables are endogenously determined (i.e. mutually interdependent), shocks to one variable typically sets in motion a dynamic response process in the whole system of variables. The advantage with VARs is that of being able to model this process by taking advantage of lags.[12]

A two variable VAR(2) model, where (2) signifies number of lags included, takes the following form:

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \alpha z_t + C_1 \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + C_2 \begin{bmatrix} x_{t-2} \\ y_{t-2} \end{bmatrix} + \begin{bmatrix} u_t^x \\ u_t^y \end{bmatrix}, \tag{1}$$

where the endogenous variable x_t and y_t are determined by lagged values of both variables, x_{t-i} and y_{t-i}, with $i = [1, 2]$, and some exogenous and undefined residuals, u_t^x and u_t^y, obtained after estimating the system. The matrices C_1 and C_2

[12]For a general and formal presentation of VAR/SVAR, I refer the reader to Favero (2001). In addition to this book, the presentation of SVARs and the identification problem in this thesis is based on Hamilton (1994), Christiano, Eichenbaum and Evans (1998) and Liu (2007)

contain coefficients to be estimated. Finally, the vector z_t contain a constant, and in some cases also dummies to differentiate amongst different time periods (for instance a shift in monetary policy regimes).

A VAR, like the one presented in equation (1), is a structural model in the sense that it provides estimates for the behavior and interaction among variables following exogenous (undefined) disturbances to the system. However, *structural* VARs (SVAR) have come to denote VARs in which specific shocks are pinned down in order to give them a meaningful and valid economic interpretation (Sims 2002). In other words, what distinguishes an SVAR from a classical VAR is that shocks are identified, in the statistical sense, through certain restrictions on the parameters. This is done with the intention of making valid predictions about the behavior of the endogenous system following each specific shock. These restrictions in turn amount to underlying assumptions regarding the response of certain variables to each shock. Hence, they should be based on sound theoretical and/or previous empirical evidence. Identification will be further discussed in section 3.1.1.

In the SVAR literature, equation (1) is referred to as the reduced form VAR of an underlying structural model, namely the SVAR. An SVAR(2) takes the following form:

$$A_0 \begin{bmatrix} x_t \\ y_t \end{bmatrix} = z_t + A_1 \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} x_{t-2} \\ y_{t-2} \end{bmatrix} + B \begin{bmatrix} \epsilon_t^x \\ \epsilon_t^y \end{bmatrix} \tag{2}$$

To arrive at the reduced form in equation (1), the matrices C_1 and C_2 in (1) must be defined such that $C_i = A_0^{-1} \times A_i$ for i=[1,2]. The constant term in the vector z_t is not included in a structural model, because simply ensures that estimates in the reduced from VAR are not affected by the initial level of variables, and has no economic interpretation. However, if the structural model contain structural shifts, z_t may contain a dummy that captures this shift. Furthermore, what distinguishes an SVAR from a classical VAR is the inclusion of the matrix A_0 on the left-hand side describing the contemporaneous relationship between endogenous variables x and y, and the substitution of residuals u_t^x and u_t^y with the *unobservable structural shocks* ϵ_t^x and ϵ_t^y and a contemporaneous impact (shock) matrix B.

The structural shocks are not directly observable from the data, and to evaluate each shock independently it is a necessary condition that they are orthogonal (i.e. do not correlate).[13] The estimated residuals, i.e. the u_ts in equation (1), on the other hand, have no economic interpretation, and they may be correlated. To solve this problem, the SVAR methodology assumes that innovations to u_ts are assumed to be functions of the underlying structural shocks, ϵ_ts. Thus, responses to shocks are calculated from the residuals obtained after Ordinary Least Square (OLS) estimation of the reduced form VAR, based on the following equation, derived from equations (1) and (2):

$$u_t = A^{-1}B\epsilon_t = P\epsilon_t \tag{3}$$

In sum, the key idea behind SVAR is to map the observed statistical relationship between the u-residuals, characterized by some estimated variance-covariance matrix, back into the unobserved economic relationships described by the variance-covariance matrix of the shocks, Σ. Utilizing equation (3) we have:

$$V = PE(\epsilon\epsilon')P' = P\Sigma P' \tag{4}$$

where V is the $k \times k$ (where k is the number of variables in the VAR system) observed variance-covariance matrix obtained after OLS estimation of equation (1). With equation (4), we arrive at the identification problem in SVAR analysis, which is dealt with in more detail in the next section.

3.1.1 Identification strategies

Recall that the goal is to map each unobserved shock, ϵ_t, into each respective observed residual. This is done by selecting the $k \times k$ matrix P so that equation (4) holds, while at the same time ensuring the orthogonality condition. However, because there may be many different Ps that satisfy equation (3), there is no way

[13] Formally, this entails that each element i, jin the variance-covariance matrix of the shocks, defined as $E(\epsilon\epsilon') = \Sigma$, has the property $\Sigma_{i,j} = 0$. In other words, Σ, equals the identity matrix.

to prefer one over the other without making assumptions about the form of P.[14] By formalizing these assumptions to restrictions regarding the response of certain variables to each shock, the system can be determined. Restrictions are imposed on a set of parameters in order to qualify any statements regarding a response to a specific shock. This is done in order to (at least) plausibly argue that the shocks are in fact capturing the intended concept. Hence, the restrictions are crucial and a contested theme in the SVAR literature.

To identify the shocks, there are at least three ways forward.[15] Until recent years, the most popular approach has been short-run zero restrictions, as proposed by Sims (1980). Sims (1980) suggested a so-called Choleski decomposition of matrix P and ranking of the variables according to the assumed dependence among the variables. This dependence among endogenous variables in turn is modeled by applying short-run zero restrictions, which restricts a variable from responding in the immediate period succeeding a shock.[16] The second identification approach, long-run zero restrictions, entails that, following a shock, the cumulative response of the variable in question over the entire period of analysis is zero. The third identification approach, sign restrictions, has been popularized only the past ten years (see e.g. Faust 1998, Canova and De Nicolò 2002, and Uhlig 2005). Sign restriction entails imposing a certain response of variables, either positive or negative, over a certain period following the shock. This approach has the benefit that all shocks in the system need not be identified, and thus avoids making overly strict assumptions. Furthermore, as highlighted by Uhlig (2005), sign restrictions are attractive because they make clear the analyst's selection criteria for choos-

[14] Another way to see this is by observing that V contains $k(k+1)/2$ unique elements (i.e. all elements minus the diagonal describing the covariance of each u_t with itself is necessarily equal to one), and P contains k^2 different unknown elements. Stated differently, if we seek to identify as many shocks as there are variables, there are only $k(k+1)/2$ equations to solve k^2 unknowns. In that case, the system may have many solutions and is under-determined, or unidentified.

[15] Combinations of the three types of restrictions described in the following provide additional alternatives. However, such combinations are not dealt with in this thesis.

[16] This scheme leads to a just-identified system, with a set of k(k-1)/2 zero-restrictions, i.e. the elements in the upper triangular of the $k \times k$ matrix P are set to zero (see footnote 14). In the general SVAR model described by equation (2), the ranking of x_t above y_t is essential with short-run restrictions. This amounts to restricting x_t not to respond to contemporaneous shocks to y_t, i.e. the shocks ϵ_t^y. Hence, the effect of ϵ_t^y is not transmitted to x, until the period $t+1$, and then only through the effect of y_t.

ing among competing models. Note, however, that a robust identification scheme should always *uniquely* identify each shock, that is: each shock must have a unique set of restrictions in order to avoid a multiple shock problem (Fry and Pagan 2011).

In this thesis the SVAR model for Norway will be identified using sign restrictions on the response of variables in the first period following positive shocks. Sign restrictions are chosen for the following two reasons: First, as we shall see, there are clear theoretical and empirical foundations for expecting that the foreign shocks of interest affect foreign variables in a consistent manner. Thus it provides a plausible identification scheme based solely on the foreign block, while at the same time leaving the response of domestic variables unrestricted, and entirely up to the data to decide. Second, sign restrictions have the benefit of making selection criteria for the models presented clear and precise.

3.2 The benchmark model: Jääskelä and Smiths (2011) model for Australia

The model in this thesis builds on Jääskelä and Smith's (2011) model for Australia.[17] Like Norway, Australia is a net exporter of commodities and net importer of manufactured goods and has experienced a favorable increase in its terms of trade over the past two decades. Two features in particular make the model appealing for the Norwegian setting: First, the country under investigation is a small, open economy. Second, it incorporates the widely recognized approach that price shocks to internationally traded goods may have multiple sources. These features produce an SVAR model in which terms of trade are exogenously determined, and prone to three types of shocks: a world demand shock, a commodity specific shock, and a globalization (supply) shock. These shocks in turn fit well with a description of the Norwegian development in terms of trade over the past two decades. However, as should be clear from the exposition of chapter 2, terms of trade effects differ both depending on its origins but also on the structure of the economy (i.e.

[17] For a detailed discussion of the paper see section2 above.

the country) under investigation.[18] Hence, in section 3.3 the Jääskelä and Smith (2011)-model is modified in order to apply to the Norwegian context.

In order to estimate the effect of terms of trade shocks on output, inflation, the exchange rate and the interest rate, Jääskelä and Smith (2011) estimate the following SVAR:

$$A_0 \begin{bmatrix} w_t \\ d_t \end{bmatrix} = \alpha x_t + \sum_{i=1}^{p} A_i \begin{bmatrix} w_{t-i} \\ d_{t-i} \end{bmatrix} + B \begin{bmatrix} \epsilon_t^w \\ \epsilon_t^d \end{bmatrix} \tag{5}$$

where:

$$w_t = \begin{bmatrix} \pi_t^x & \pi_t^m & y_t^w \end{bmatrix}', d_t = \begin{bmatrix} y_t^d & \pi_t^d & \Delta q_t & i_t \end{bmatrix}'$$

Thus, the model contains two blocks: one foreign(w_t) and one domestic (d_t). The former consists of the world price growth of exports (π_t^x), the world price growth of imports (π_t^m) and world output growth (y_t^w), whereas the latter consists of domestic output growth (y_t^d), domestic inflation (π_t^d), the change in the real exchange rate (Δq_t) and the nominal interest rate (i_t). In order to ensure system stationarity, all variables, except i_t, are measured as quarterly growth rates.[19] Given the small open economy assumption, w_t is block exogenous to d_t, i.e. the variables in d_t and the domestic shocks ϵ_t^d do not affect the variables in w_t. Instead, w_t is entirely determined by its own lagged values and the world shocks, ϵ_t^w . Formally, this entails restricting the contemporaneous impact matrix B and the lag matrices A_i to be block lower triangular (i.e. the 3×4 upper right elements in B and the $A_i's$ are zero). The SVAR is estimated with 3 lags on the lag matrices (i.e. p=3). Finally, because the analysis runs from 1984 to 2010 and thus includes a period

[18] One crucial feature that makes the Norwegian economy different from the Australian is its dependence on petroleum export. This will be further discussed in section 3.3.1.

[19] Stationary variables is a key condition in VAR estimation. This is necessary to derive deviations from trend that is due to shocks. A necessary property of shocks is that they die out. With non-stationary data, a shock may set in motion an infinite process, which is a breach with the definition of a shock. Data for all variables utilized in this thesis, except interest rates, are first-differenced to secure stationary variables. See chapter 4 for details, and Appendix, section A.1 for unit root tests.

with shift in monetary policy to inflation targeting, the vector x includes a time dummy to mark this shift, in addition to a constant.[20]

The foreign shock vector ϵ_t^w contains three shocks that alter Australia's terms of trade;

$$\epsilon_t^w = \begin{bmatrix} \epsilon_t^{yw} & \epsilon_t^{com} & \epsilon_t^{glob} \end{bmatrix}',$$

where ϵ_t^{yw} is a world demand shock, ϵ_t^{com} a commodity-market specific shock, and ϵ_t^{glob} a globalization shock. The world demand shock has characteristics of a classic demand shock, only at the global level, leading to higher global economic activity and rise of both export and import prices. The commodity-market specific shock is associated with increase in export prices, but not in global output. It's effect on import prices is uncertain, due to two counteracting effects: On the one hand, lower global demand pulls the import prices downwards. On the other hand, a higher price on commodities entails a higher cost of production, which then exerts a positive pressure on the price of manufactured goods. Finally, the globalization shock stems from the influx of emerging economies in the global economy, leading to falling prices on manufactured goods, and a rising price on commodities. Hence, Australia, as a net importer of manufactured goods and net exporter of commodities, will face improvement in its terms of trade from a positive globalization shock. The three shocks are identified through sign restrictions on the response of the foreign block variables (for four periods, i.e four quarters), as reported in table 3.1:

Table 3.1: Sign restrictions in Jääskelä and Smith (2011) SVAR for Australia

	World demand shock	Commodity specific shock	Globalization shock
Price exports	+	+	+
Price imports	+	no restriction	-
World output	+	-	+

Jääskelä and Smith (2011) do not identifiy domestic shocks, i.e. the elements in ϵ_t^d. In addition, to determine the effect of terms of trade shocks on the do-

[20]Inflation targeting was introduced in Australia in mid-1993. The dummy is equal to 1 from 1993Q2 and onwards, and 0 in otherwise.

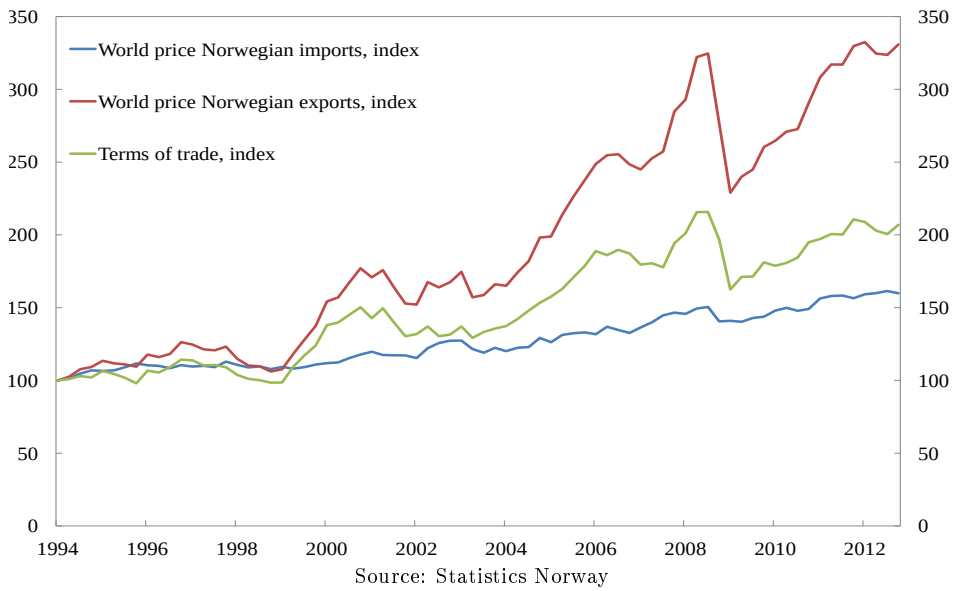

Figure 3.1: World price of Norwegian exports and imports, and implied terms of trade. Index, 1994Q1=100.

mestic economy, the response of domestic variables to the foreign shocks are left unrestricted.

3.3 An SVAR model for Norway: The Jääskelä and Smith (2011) model extended

Important global developments that contribute to the unprecedented improvement in Norwegian terms of trade since the early 90's are captured by figure 3.1 and 3.2. The figures display the development in the world price of Norwegian exports and imports together with development in terms of trade (3.1), and the development in the world price of all Norwegian exports together with the oil price (3.2). The figures display two important trends for Norway over the past two decades: First, improvements in terms of trade can be attributed to the combination of a soaring increase in export price, and a largely non-increasing price on imports. Second, the fluctuations in the aggregate export price is highly dependent on the oil price.

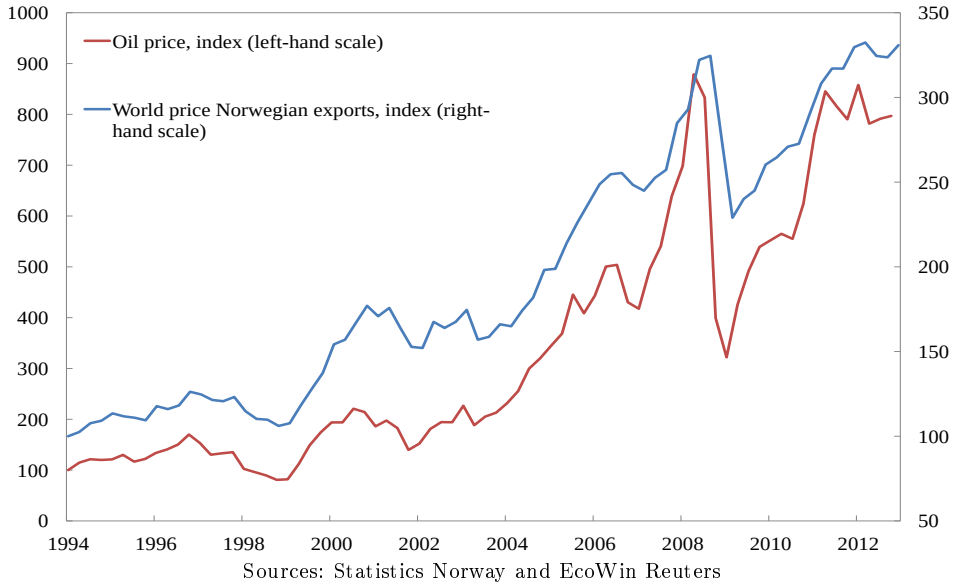

Figure 3.2: World price of Norwegian exports and spot oil price (dollars/barrel). Index, 1994Q1=100.

3.3.1 Terms of trade and domestic shocks in the Norwegian economy

The three shocks described by Jääskelä and Smith (2011) can be applied into the Norwegian context. First, a globalization shock, associated with increasing export price (mainly due to a higher oil price) and decreasing or constant import prices, seem to have taken place in Norway, too. Both Norges Bank and Statistics Norway have on several occasions referred the influx of China into the global economy as a main reason for the improvement in Norwegian terms of trade (Olsen 2013; Stensland and Martinsen 2012; SSB 2005, 2011; Gjedrem 2006). Cheap, and an increasingly larger share of imports from China, as well as higher Chinese oil demand, are key reasons for why the Norwegian terms of trade has soared over the past 15 years. Crucially, while import prices from Norway's traditional trading partners, like Sweden and the eurozone have risen, cheap Chinese imports have kept the aggregate import price non-increasing (see fig. 3.1), and in effect reduced inflationary pressure in Norway. With an inflation targeting central bank, aiming at 2.5 percent growth in consumer prices, the low import price inflation have in effect made it possible to keep interest rates at low levels over longer periods of

time, despite a positive output gap and inflation on domestically produced goods near or above 2.5 percent.

Second, figure 3.2 shows that, for Norway, a commodity specific shock can be thought of in terms of an oil price shock. Higher oil price directly influences, and greatly so, Norway's terms of trade through the export price. In 2012, oil and gas exports amounted to 64 percent of the total value of Norwegian exports (excluding oil rigs and ships)[21]. The price of oil has been steadily rising since the early 90's (although with a great slump during the 07-08 financial crises). A higher oil price is, all else equal, likely to dampen global demand and output growth, because most countries are net oil importers. Thus, the commodity specific shock in Jääskelä and Smith (2011) is similar (in qualitative terms) to that of an oil price shock in that it leads to a higher world price on their respective export prices and lower global output. The two shocks also share the uncertainty regarding the effect on import prices: on the one hand, a higher price on the factors of production, oil or commodities, will in isolation lead to a higher price on the imported good, while on the other hand, the associated decrease in global demand will act as a deflationary force. These two effects might plausibly be even more pronounced when it comes to an oil price shock.

Finally, given the small and open features of the Norwegian economy, a shock to global demand will affect the Norwegian economy's terms of trade. Increased global demand will increase the price of all goods, and hence, both Norwegian petroleum prices and import prices. The result is an uncertain aggregate effect on terms of trade. Furthermore, increased global demand for Norwegian petroleum will lead to higher domestic activity, as producers and related industries increase their effort to meet new and higher demand for their output. Firms will increase demand for labor, unemployment is reduced and wages increased. This in turn leads to improved purchasing power for the consumers and higher domestic demand.

In order to apply the Jääskelä and Smith (2011) model to the Norwegian context, the export price index is substituted with a variable measuring the movements in the oil price. Thus, in the model for Norway, the variables included in the foreign

[21] see web page: https://www.ssb.no/utenriksokonomi/statistikker/muh

block, w_t, contain oil price growth, π_t^{oil}, import price growth, π_t^m,and world output growth, y_t^w:

$$w_t = \begin{bmatrix} \pi_t^{oil} & \pi_t^m & y_t^w \end{bmatrix}'$$

Hence, the model in this thesis follows the vast literature that highlight the importance of the oil price for the Norwegian economy (see discussion in section 2), and the empirical observation that Norwegian terms of trade is heavily influenced by oil price fluctuations.[22] The foreign shock vector in the model for Norway is:

$$\epsilon_t^w = \begin{bmatrix} \epsilon_t^{yw} & \epsilon_t^{oil} & \epsilon_t^{glob} \end{bmatrix}'$$

Because the two shocks (ϵ_t^{oil} and ϵ_t^{com}) are assumed to be qualitatively similar with regard to their effect on world demand and export prices, the restrictions applied to identify the oil price shock are the same as in Jääskelä and Smith (2011) for the commodity specific shock. Similarly, the two remaining foreign shocks in the model, ϵ_t^{yw} and ϵ_t^{glob}, also share the same restrictions. The upper half of table 3.2 summarizes the three terms of trade shocks, and the sign restrictions imposed to identify them. Notice that the responses of all domestic variables are left unrestricted.

Furthermore, in order to address what is arguably a shortcoming of the Jääskelä and Smith (2011) model, namely its inability to evaluate the relative importance of foreign and domestic demand and supply shocks, domestic shocks are introduced, of which three are sought to be identified:[23]

$$\epsilon_t^d = \begin{bmatrix} \epsilon_t^{demand} & \epsilon_t^{supply} & \epsilon_t^q & \epsilon_t^i \end{bmatrix}'$$

These shocks correspond to each of the domestic variables of interest; a domestic

[22] Conversely, the label "commodity specific shock" reflects the commodity based nature of the Australian economy.

[23] For reasons that will be explained in more detail in section 3.3.2, this thesis does not identify the real exchange rate shock (ϵ_t^q).

demand shock (ϵ_t^{demand}), entailing increased output (y_t^d); a domestic supply shock (ϵ_t^{supply}), involving higher supply and in effect lower inflation (π_t); a real exchange rate shock (ϵ_t^q) which depreciates the value of the Norwegian krone (q_t), and finally; an interest rate shock (ϵ_t^i) which increase the interest rates (i_t) faced by economic agents. The latter is interpreted as a monetary policy shock, assumed to be captured by the fact that Norges Bank sets its key policy rate with the goal of affecting the short term interest rate. The identification scheme for the three domestic shocks that are sought to be identified is presented in the lower part of table 3.2, and will be further discussed and defended in section 3.3.2. In the table "+" and "-" refer to the restrictions imposed on the response of a variable, following a positive shock.

Table 3.2: Sign restrictions on foreign terms of trade shocks and domestic shocks in the SVAR model for Norway

Foreign block			
	World demand shock	Oil price shock	Globalization shock
Oil price growth	+	+	+
Import price growth	+	no restriction	-
World output growth	+	-	+
Domestic block			
	Demand shock	Supply shock	Monetary policy shock
Domestic output growth	+	+	no restriction
Domestic inflation	+	-	-
Real exchange rate growth	no restriction	no restriction	-
Interest rates .	no restriction	no restriction	+

3.3.2 A formal identification scheme for the Norwegian SVAR

To evaluate the responses to shocks, shocks are calculated from the residuals obtained after OLS estimation of the reduced form VAR of the underlying structural model in this thesis. Number of lags are set to 2 periods (i.e. 2 quarters), and the

reduced form for the Norwegian model is specified as follows:[24]

$$\begin{bmatrix} \pi_t^{oil} \\ \pi_t^{m} \\ y_t^{w} \\ y_t^{d} \\ \pi_t^{d} \\ \Delta q_t \\ i_t \end{bmatrix} = \alpha z_t + C_1 \begin{bmatrix} \pi_{t-1}^{oil} \\ \pi_{t-1}^{m} \\ y_{t-1}^{w} \\ y_{t-1}^{d} \\ \pi_{t-1}^{d} \\ \Delta q_{t-1} \\ i_{t-1} \end{bmatrix} + C_2 \begin{bmatrix} \pi_{t-2}^{oil} \\ \pi_{t-2}^{m} \\ y_{t-2}^{w} \\ y_{t-2}^{d} \\ \pi_{t-2}^{d} \\ \Delta q_{t-2} \\ i_{t-2} \end{bmatrix} + \begin{bmatrix} u_t^{oil} \\ u_t^{\pi m} \\ u_t^{yw} \\ u_t^{yd} \\ u_t^{\pi d} \\ u_t^{\Delta q} \\ u_t^{i} \end{bmatrix} \tag{6}$$

Recall, from section 3.1, equation (1), that C_1 and C_2 are defined such that $C_i = A_0^{-1} \times A_i$ for i=[1,2]. The elements in each C_i contain free coefficients to be estimated, but where the upper right 3×4 elements are restricted to be zero in all periods. Recall also, that the estimated u_t's have no economic interpretation, but are simply residuals. However, these unexplained innovations to each variable are assumed to be functions of the underlying structural shocks, i.e. of the ϵ's described above. These shocks are identified by imposing restrictions on the response of variables following a shock.

As already implied by the discussion in section 3.3.1 and table 3.2 , this thesis utilizes sign restrictions to identify each shock for the following two reasons: First, there are clear theoretical foundations for expecting that the three foreign shocks affect the three foreign variables in the way described above in a consistent manner. Actually, the shocks are *defined* by the way (i.e. the sign) they affect the three foreign variables, based on empirically observed developments in Norway. Second, sign restrictions have the benefit of making selection criteria for the models presented clear and precise. Utilizing equation (3), the sign restrictions presented in table 3.2 is formalized to:

[24]The lag length is set to 2 periods based on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), to test optimal number of lags. Both test which number of lags that provides the best fit of the model to the data.

$$\begin{bmatrix} u_t^{oil} \\ u_t^{\pi m} \\ u_t^{yw} \\ u_t^{yd} \\ u_t^{\pi d} \\ u_t^{\Delta q} \\ u_t^{i} \end{bmatrix} = \begin{bmatrix} + & + & + & 0 & 0 & 0 & 0 \\ + & na & - & 0 & 0 & 0 & 0 \\ + & - & + & 0 & 0 & 0 & 0 \\ na & na & na & + & + & na & na \\ na & na & na & + & - & na & - \\ na & na & na & na & na & na & - \\ na & na & na & na & na & na & + \end{bmatrix} \times \begin{bmatrix} \epsilon^{yw} \\ \epsilon^{oil} \\ \epsilon^{glob} \\ \epsilon^{demand} \\ \epsilon^{supply} \\ \epsilon^{q} \\ \epsilon^{i} \end{bmatrix} \tag{7}$$

where notations, "+", "-" indicate positive and negative effects, respec on the variables, "na" indicates no restriction imposed, and "0"s imply a strict exogenous relationship, i.e. that domestic shocks do not affect the three foreign variables. Restrictions are imposed for one period, i.e. one quarter, after the shock. As one example, the upper left "+" means that, following a world demand shock, ϵ_t^{yw}, the impulse response of oil price growth is restricted to be positive in the first period. Conversely, the lower left "na" means that the response of the interest rate, i_t is not restricted, after the same shock. Finally, the upper right "0" reflects that, in line with the small open economy assumption, a monetary policy shock to the domestic economy does not have any effect on the (globally determined) oil price.

The restrictions on the parameters in the 3×3 upper left block, i.e. the terms of trade shocks, have already been discussed above (see section 3.3.1). Similarly, the 3×4 upper right block is based on the small, open economy assumption. Furthermore, as visualized by equation (7), the real exchange rate shock is not identified (the 6th column of the impact matrix contain only "0"s and "na"s). The rationale for this is that the VAR are not believed to contain sufficient information to exactly pin down the shock. Still it should be emphasized that inclusion of the real exchange rate variable in the model is useful, both because it provides a way to identify the monetary policy shock, and because it enables us to estimate the

response of the real exchange rate following foreign and domestic shocks.[25]

The remaining three domestic shocks are identified through sign restrictions, and need further justification. The demand and supply shocks, ϵ_t^{demand} and ϵ_t^{supply}, have characteristics that are typically described in the classical macroeconomy literature: a demand shock is associated with increased output and increased inflationary pressure. A supply shock leads to lower inflation, because of increased supply. Increased supply may be either due to technological improvements in the production process, or reduced price on factors of production. This in turn cause higher activity and output.

The nominal interest rate shock (ϵ_t^i), is interpreted as a monetary policy shock, as is standard in the SVAR literature (see e.g. Christiano, Eichenbaum and Evans 1998). Norges Bank's main policy tool is its key policy rate, which is the interest rate offered banks for deposits at Norges Bank. Aiming at low and stable inflation and minimized output gap, Norges Bank sets the key rate to affect the short term interest rates in the money market, and thus the interest rate faced by economic agents. Hence, a positive innovation to the key policy rate is associated with a positive increase in the money market rate and the bank lending rate to households and corporations. A higher interest rate dampens domestic activity through the investment- and household consumption channels (negative sign restriction). Thus, a positive monetary policy shock will reduce inflationary pressure (negative sign restriction). This latter restriction is crucial also because of what has been commonly referred to as the "price-puzzle", i.e. that following a monetary policy shock, several papers utilizing SVAR have found that prices actually increase in the very short run (Sims 1992, Uhlig 2005). The puzzle is partly explained by the fact that a central bank may posit information that future inflation is likely to increase, and hence increase interest rates to dampen inflationary pressure before it

[25] One might plausibly argue that a positive exchange rate shock (a depreciation of the Norwegian krone) could be identified by imposing a positive response of inflation, and a positive response of domestic output. This could be based on the relationship that with higher import prices, inflation will, all else equal, rise. Furthermore, because a cheaper krone implies a lower price of Norwegian exports, one should see increased demand for Norwegian goods from abroad. However, this identification fails to distinguish the exchange rate shock from the domestic demand shock, so there is no way to separate whether responses are due to a demand shock or a real exchange rate shock.

has actually materialized. By imposing a negative sign restriction on the response of inflation, the possibility of a price puzzle is excluded form the model. Similarly, the negative sign restriction on the response of the exchange rate, excludes the so-called "exchange rate puzzle" (Cushman and Zha 1997, Grilli and Roubini 1995). Several SVAR analyses have found that, following positive monetary policy shocks, the response of the exchange rate have been one of depreciation, which contradicts conventional intuition. The puzzle might reflect a central bank which foresees a depreciation, and acts to neutralize it. By imposing the negative sign restriction on the real exchange rate, i.e. that the Norwegian krone appreciates following a monetary policy shock, the exchange rate puzzle is by construction excluded from the model.

3.3.3 The Norwegian SVAR model

Based on the assumptions laid out above, this thesis estimates the following sign restricted SVAR model for Norway, over the period 1994Q1-2012Q4:

$$A_0 \begin{bmatrix} \pi_t^{oil} \\ \pi_t^m \\ y_t^w \\ y_t^d \\ \pi_t^d \\ \Delta q_t \\ i_t \end{bmatrix} = A_1 \begin{bmatrix} \pi_{t-1}^{oil} \\ \pi_{t-1}^m \\ y_{t-1}^w \\ y_{t-1}^d \\ \pi_{t-1}^d \\ \Delta q_{t-1} \\ i_{t-1} \end{bmatrix} + A_2 \begin{bmatrix} \pi_{t-2}^{oil} \\ \pi_{t-2}^m \\ y_{t-2}^w \\ y_{t-2}^d \\ \pi_{t-2}^d \\ \Delta q_{t-2} \\ i_{t-2} \end{bmatrix} + B \begin{bmatrix} \epsilon_t^{oil} \\ \epsilon_t^{\pi m} \\ \epsilon_t^{yw} \\ \epsilon_t^{yd} \\ \epsilon_t^{\pi d} \\ \epsilon_t^{\Delta q} \\ \epsilon_t^{i} \end{bmatrix} \tag{8}$$

where all variables, except the nominal interest rate (i_t), are measured in quarterly growth rates. Notice that the vector z_t is excluded from the structural model, implying that neither constants nor regime dummies that capture the change in monetary policy regime is included. The former is excluded because it simply ensures that estimates are not affected by the initial level of the variables. It is therefore a purely econometric feature, with no economic interpretation. Conversely, a monetary policy regime dummy could have been included, as in Jääskelä and Smith (2011). In March 2001, Norges Banks monetary policy target was in

fact shifted from a stable krone exchange rate (measured against European currencies), to flexible inflation targeting. This shift in policy could plausibly affect the response of the variables following both foreign and domestic shock, because monetary policy might react differently. However, as argued by Bjørnland (2008), the period after 1994 have been characterized by a relatively stable monetary policy regime that have sought to stabilize inflation. Still, in order to test whether the formal shift in monetary policy target has had any important effects, a second model accounts for this shift in policy by including a monetary policy regime dummy equal to 0 before 2001Q2 and 1 from 2001Q2 and onwards. However, because this inclusion did not affect the results, the main model discussed excludes the regime dummy. Due to exceptional circumstances in the Norwegian economy during the late 80's and early 90's, the period of analysis is chosen from 1994Q1 to 2012Q4.[26] Furthermore, as the model assumes block exogenity (i.e. Norway is a small, open economy, and hence, Norwegian domestic variables and shocks do not affect foreign variables) the matrices A_0, describing the contemporaneous relationship between foreign and domestic variables and the lag matrixes, A_is are all block lower triangular. The matrix B is the shock matrix, which multiplied by A_0^{-1}, produce the main matrix of interest, P, which in this thesis contain a total of 22 free coefficients to be estimated (i.e. the number of "na."s in equation (7))

The structural relationship described by equation 8, imply that structural shocks may affect the endogenous variables immediately. These impulse responses are estimated by substituting the identification scheme, set out in equation (7), into equation 6. This gives the set of impulse responses following each of the six identified shocks, three foreign and three domestic. Furthermore, because domestic shocks are identified, the relative importance of these, compared to foreign shocks, can be derived by variance decomposition. Section 5 sets out the results of the empirical analysis.

[26]See section 4 for further notes on the choice of period of analysis.

4 Data

The following seven variables are included in the analysis: import price inflation, π_t^m; oil price growth, πoil_t; foreign output growth, y_t^w; domestic output growth, y_t^d; domestic consumer price inflation, π_t^d; the real exchange rate growth, Δq_t, and; the nominal interest rate, i_t. The sample covers 1994Q1 to 2012Q4.[27] Two considerations induce starting the analysis in 1994: First, Norway experienced an exceptional period from 1989 to the early 1990's, with a housing bubble bursting followed by a banking crisis comparable to that in the US in 2007-2008. This led to a recession and culminated with unprecedented policy measures on behalf of the Norwegian government. Second, in the wake of the Norwegian banking crisis there was a shift in monetary policy regime from a fixed to a floating exchange rate. Thus, including this period in the analysis is likely to affect the results unproportionally, and blur the effects we should expect in the current economic environment and regime. [28]

The variable measuring import price growth, π_t^m, is an in-house measure from Norges Bank that measures the seasonally adjusted price indexes for imported consumption goods.[29] I focus on consumption goods in order to capture the essence of the terms of trade shocks described in section 3.3.1. Movements in this index reflect the exogenous changes in the world price of imported consumption goods, and abstracts from fluctuations in the exchange rate.

[27]Data are log first-differenced in order to achieve stationarity. Unit-root tests (Augmented Dicky-Fuller test) reject the null hypothesis of a unit root in all first-differenced variables included in the analysis. See Appendix, section A.1, for results of these unit root tests. Interest rates are not first-differenced, and fail to reject the null of no unit root. Still, interest rates are included as levels, as is standard in SVAR-analysis on monetary policy (see e.g. Christiano, Eichenbaum and Evans (1998). There is also evidence that suggest that despite failing simple unit-root tests, nominal interest rates do not contain a unit root. See Lee and Tsong (2011) for discussion and analysis. Lee and Tsong (2011) find that Norwegian nominal interest rates do not contain a unit root..

[28]Delimiting the analysis to this period after 1994 is standard in the literature on Norway, see e.g Bjørnland (2008). The exceptionality of the period has been highlighted in Moe, Solheim and Vale (2004).

[29]The variable description and calculation is documented in Norges Banks's Economic Bulletin 3/2004. See web page: http://www.norges-bank.no/en/about/published/publications/economic-bulletin/economic-bulletin-32004/.

The oil price growth variable, π_t^{oil}, is calculated from the spot price (measured in USD) of brent blend oil. Quarterly averages are calculated from daily figures collected from Reuters Ecowin. Growth rates are calculated based on these quarterly averages.

World output, y_t^w, is a trade weighted index of output in Norway's 26 major trading partners. The variable is an in-house measure from Norges Bank, and includes the quarterly growth rates originally.

Following the literature, domestic output, y_t^d, abstracts from the large petroleum sector, and focuses on real GDP in Mainland Norway. The reason for this is that while the oil sector is important for the economy, its ups and downs are largely due to international (exogenous) factors. Thus, the productivity of the total Norwegian economy is very likely to be a reflection of the oil price, and not necessarily a sound measure of the well-being of the domestic economy. For instance, the oil price have doubled over the past 15 years. This will be reflected in total GDP, but does not reflect a real increase in productivity. Total GDP-measures are therefore likely to overshadow the development in the rest of the economy. Arguably, mainland GDP therefore provides a better measure of the health of the economy. The variable is measured as quarterly growth, and produced by Statistics Norway.[30]

Domestic inflation, π_t^d, are measured by consumer price inflation, adjusted for tax changes and excluding energy products (CPI-ATE).[31] It is produced by Statistics Norway. The variable is expressed in annual growth terms since the monetary policy target is annual rates, not quarterly. Thus, the response of monetary policy following shocks will be more correctly interpreted by this transformation.[32] CPI-ATE is conventionally believed to capture the underlying rate of inflation better than total CPI. The nominal interest rate, i_t, is quarterly averages of the 3-month Norwegian Interbank Lending Rate (NIBOR). Daily figures are reported by Reuters Ecowin. NIBOR reflects the interest rate at which banks are willing to lend to each other.[33] The 3-month NIBOR refers to loans with a duration of 3

[30]See: http://www.ssb.no/nasjonalregnskap-og-konjunkturer/statistikker/knr/kvartal
[31]See: http://www.ssb.no/priser-og-prisindekser/statistikker/kpi
[32]A similar argument is made in Bjørnland and Jacobsen (2009)
[33]NIBOR is calculated as the average of the reported lending rates from banks in the NIBOR-panel.

months, and is often referred to as the Norwegian money market rate. This is the interest rate that Norges Bank seeks to affect through its key policy rate, and is therefore assumed to capture movements and shocks to the key interest rate.

Finally, the real exchange rate, q_t, is based on a transformation of the trade weighted exchange rate index (I-44), calculated at Norges Bank.[34] Nominal I-44 is converted to real terms by multiplying it with the ratio between domestic and world CPI. The latter is collected from a Norges Bank in-house calculation based on CPI in 26 trading partner's economies.[35] This final measure is converted to quarterly growth rates. Table 4.1 summarizes descriptives of each variable, and their sources.

[34] I-44 is based on a weighted index of exchange rates with the currencies of 44 Norwegian major trading partners, and is originally in nominal terms. See web page: http://www.norges-bank.no/en/price-stability/exchange-rates/calculated-rates-explanation/.

[35] The formula for the real exchange rate is: $q_{I44} = e_{I44} \times (CPI^{foreign}/CPI^{domestic})$, where q is the real exchange rate, e is the nominal exchange rate, and $CPI^{foreign}$ and $CPI^{domestic}$ are foreign and domestic consumer price indexes, respectively. While the nominal rate is based on 44 trading partners, foreign CPI is based on only 26 countries. However, the contribution of the smallest 18 trading partners to the index is so small that it should not affect the real exchange rate measure.

Table 4.1: Variables, data descriptives and sources

Variable name	abbrev.	Data	measure	min/max	mean	st.dev	Source
Oil price growth	π^{oil}	Spot oil price, \$/barrel	Quarterly growth,percent	-52.06/36.37	3.66	13.91	EcoWin
Import price growth	π^{m}	Price index, imported consumption goods, seasonally adjusted	Quarterly growth, percent	-1.10/0.87	-0.08	0.33	Norges Bank INT
World output growth	y^{w}	GDP 26TP[a] (weighted)	Quarterly growth, percent	-2.18/1.44	0.59	0.58	Norges Bank INT[b]
Domestic output growth	y^{d}	GDP, Norway seasonally adjusted	Quarterly growth, percent	-1.36/4.36	0.72	1.03	Statistics Norway
Domestic inflation	π^{d}	CPI-ATE[c] seasonally adjusted	Quarterly growth, percent	-0.17/0.95	0.41	0.23	Statistics Norway
Real exchange rate growth	q	I-44,[d] CPI-Norway CPI-26TP	Quarterly growth, percent	-4.91/9.39	-0.26	2.38	Norges Bank, Norges Bank INT Statistics Norway
Nominal interest rate	i	3-month NIBOR	Quarterly average	1.89/8.04	4.52	1.89	EcoWin

[a]Norway's 26 major trading partners
[b]Norges Bank, International Economy Unit
[c]Consumer price inflation adjusted for tax changes and excluding energy prices
[d]Nominal effective exchange rate measured against currencies of 44 Norwegian major trading partners

5 Results

This chapter reports the impulse responses from estimating the Norwegian SVAR model set out in equation (8). For each identified shock, the model creates a time-series variable, from which the standard deviation is calculated. The impulse responses reported are median model responses following a shock equal to one standard deviation.[36] Recall that sign restrictions are imposed for one period only, leaving the subsequent period responses unrestricted. The impulse response figures reported in section 5.1 also report 97.5 percent probability bands, i.e. the range of the responses of the 97.5 percent of the "successful models" (models that satisfy the identification scheme). These reflect the uncertainty of the estimated median response. Section 5.2 reports forecasting error variance decomposition for the median model, and discuss the relative importance of foreign and domestic shocks, in light of earlier findings in the literature on foreign shocks in small, open economies. A more detailed discussion of the robustness is saved for section 5.3.

5.1 Impulse responses

5.1.1 Terms of trade shocks

World demand shock: Figure 5.1 reports responses following a world demand shock. The shock was identified by positive initial responses of all foreign variables, which is reflected in the impulse response functions for the oil price growth, import price growth and foreign GDP. The initial response of the oil price is 6 percentage points increase. The positive effect lasts for two quarters, before falling into negative territory and flattening out by the end of the first year. The price of imported consumption goods expectedly increases on a much smaller scale, about 0.2 percentage points. The positive impulse is however longer lasting, and is close to trend

[36] The estimates are based on 2000 draws, i.e. 2000 models that fit the identification scheme laid out in the section 3.3.2. The "median model" refers to the one model drawn that is closest to the median response in each period. Hence, the median in each period is not necessarily identical to the median model chosen, but the median model is the model that minimizes the cumulative deviation over the entire period. Focusing on one single model is in line with recommendations by Fry and Pagan (2011).

after $1\frac{1}{2}$ years. Hence, the responses of the oil price and import prices indicate a strengthening of terms of trade. The quarterly growth rate of foreign GDP increase by 0.25 percentage points above trend growth. This implies a positive output gap. The growth rate dampens off and turns slightly negative after one year. Thus, in addition to the correction in the oil price in the subsequent quarters, the negative oil price growth can be partly explained by this fall in GDP and demand.

The immediate response of domestic variables to the world demand shock are largely as expected, and in line with findings in Aastveit et al. (2011), Karagedikli and Price (2012) and Jääskelä and Smith (2011). By increasing terms of trade and foreign demand for Norwegian goods, the world demand shock is transmitted to the Norwegian economy and increases GDP mainland growth (0.25 percentage points initially) and, eventually, domestic inflation. Although initially the inflation response is zero, inflation rises steadily from the second quarter after the shock. After five to six quarters, annual inflation has increased by 0.1 percentage points. The lagged response may be interpreted as reflecting price and wage rigidities in the economy. In response to these developments the interest rate is pushed up, and increasingly so as inflation rises. Whereas domestic GDP growth normalizes after three to four quarters, the world demand shock leads to a much longer lasting inflationary pressure.[37] Inflation starts falling only after seven quarters, four quarters after interest rates is at its highest. The relatively quick dampening of foreign output gap and oil price growth abroad fills out the picture. Furthermore, the lagged response of inflation in the aftermath of the shock may also be explained by an initial real exchange rate appreciation (1 percentage point appreciation), and a subsequent correction. In sum, the identified world demand shock boosts mainland GDP growth and inflation, which in turn induces contractionary policy of Norges Bank. Higher oil price, higher inflation expectations and higher interest rates all contribute to a real exchange rate appreciation.

Oil price shock: The oil price shock is identified by imposing a positive initial response of the oil price, and a negative response of foreign GDP. As pointed out in section 3.3.1, this identification scheme implies that the oil price hike is due to

[37] A more detailed discussion of the persistence of all shocks with respect to GDP growth, inflation and the interest rate is laid out in section 5.1.2, page 45.

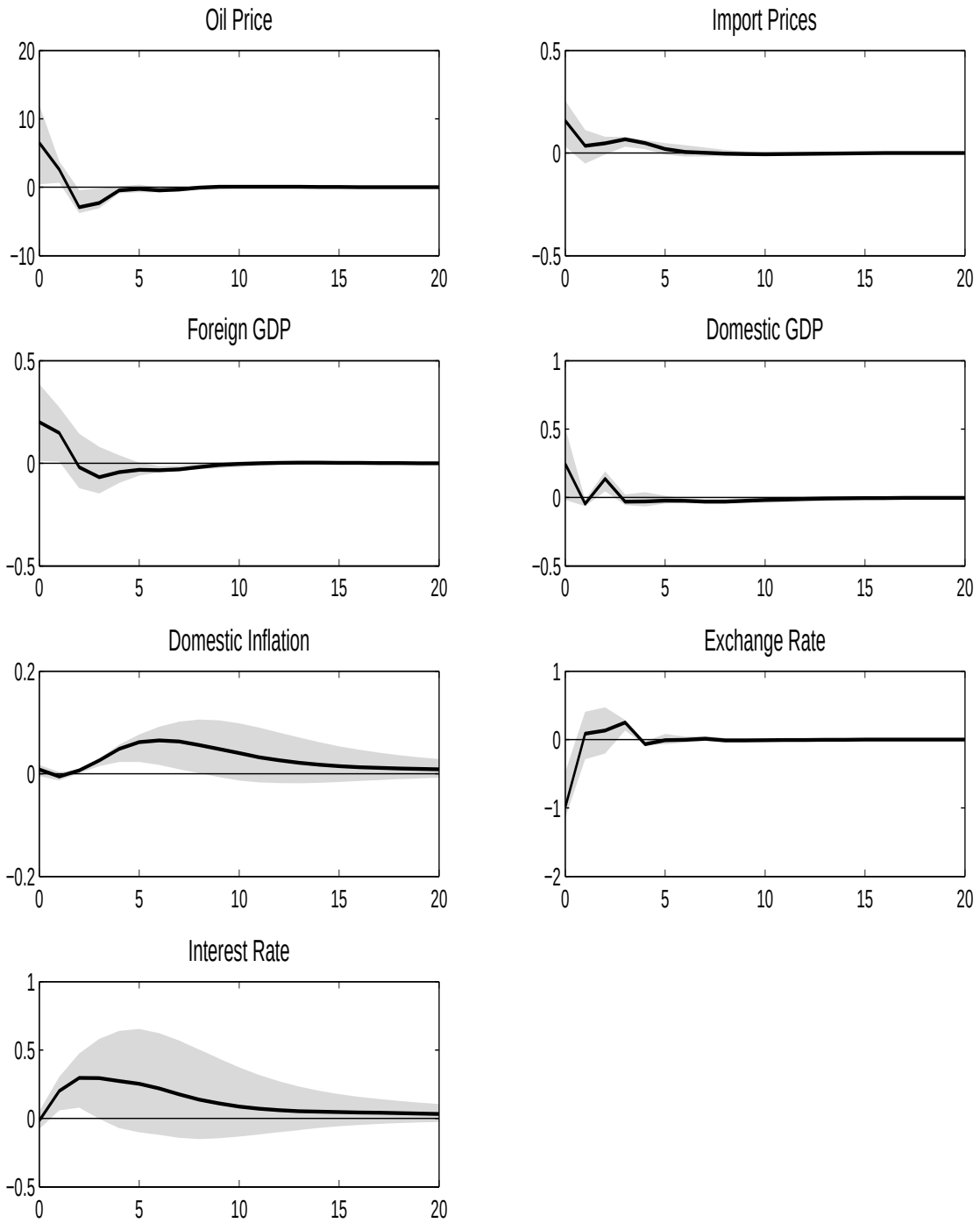

Figure 5.1: Impulse responses following a world demand shock

decreased supply. Results are reported in figure 5.2. Import price growth was left unrestricted due to uncertainty of the aggregate effect of increased factor costs and lower demand. This uncertainty is further reflected in the results. The median response shows a very small effect, and there are draws that point in both positive and negative direction. Foreign GDP growth is below trend for five quarters.

This negative development for Norway's trading partners have consequences for the Norwegian mainland economy. Mainland GDP growth initially falls by 0.3 percentage points, creating a negative output gap. However, quarterly growth returns to normal levels after only one quarter, and is largely unaffected for the rest of the period. Utilizing total GDP data (i.e. including the petroleum sector), Aastveit et al. (2011) find a parallel development in output growth during the first two years following an oil price shock, but a significant positive growth effect thereafter. Hence, what must be considered a positive development for the Norwegian economy as a whole, is not necessarily so for the non-petroleum sector in Norway. The main reason is to be found in decreasing foreign demand for Norwegian goods. At least initially, the negative foreign demand effect dominates any positive spillover effect from the petroleum industry to the mainland economy. Consequently, any inflationary pressure stemming from higher oil revenues and petroleum sector activity is initially dampened, leaving inflation largely unaffected by the shock. Furthermore, after the first year, inflation starts falling below trend, with a minimum of nearly -0.1 percentage points two years after the shock. In order for the central bank to neutralize the negative GDP and inflation effects, the interest rate is pushed down almost half a percentage points within five quarters following the shock. This contributes to a fast normalization of growth rates in GDP. Inflation, on the other hand, looks more persistent, and responds to the monetary easing only after four to five quarters. In line with a conventional view of the effect of an oil price hike, the real exchange rate initially appreciates by -0.4 percentage points in the median model. Together with a non-significant response of import prices, this Krone appreciation entails lower imported inflation, which also contributes to neutralize any domestic inflationary pressure stemming from increased activity in the petroleum sector of the economy. Note, however, that the real exchange rate response looks uncertain with responses ranging from -1 to +0.5 percent change

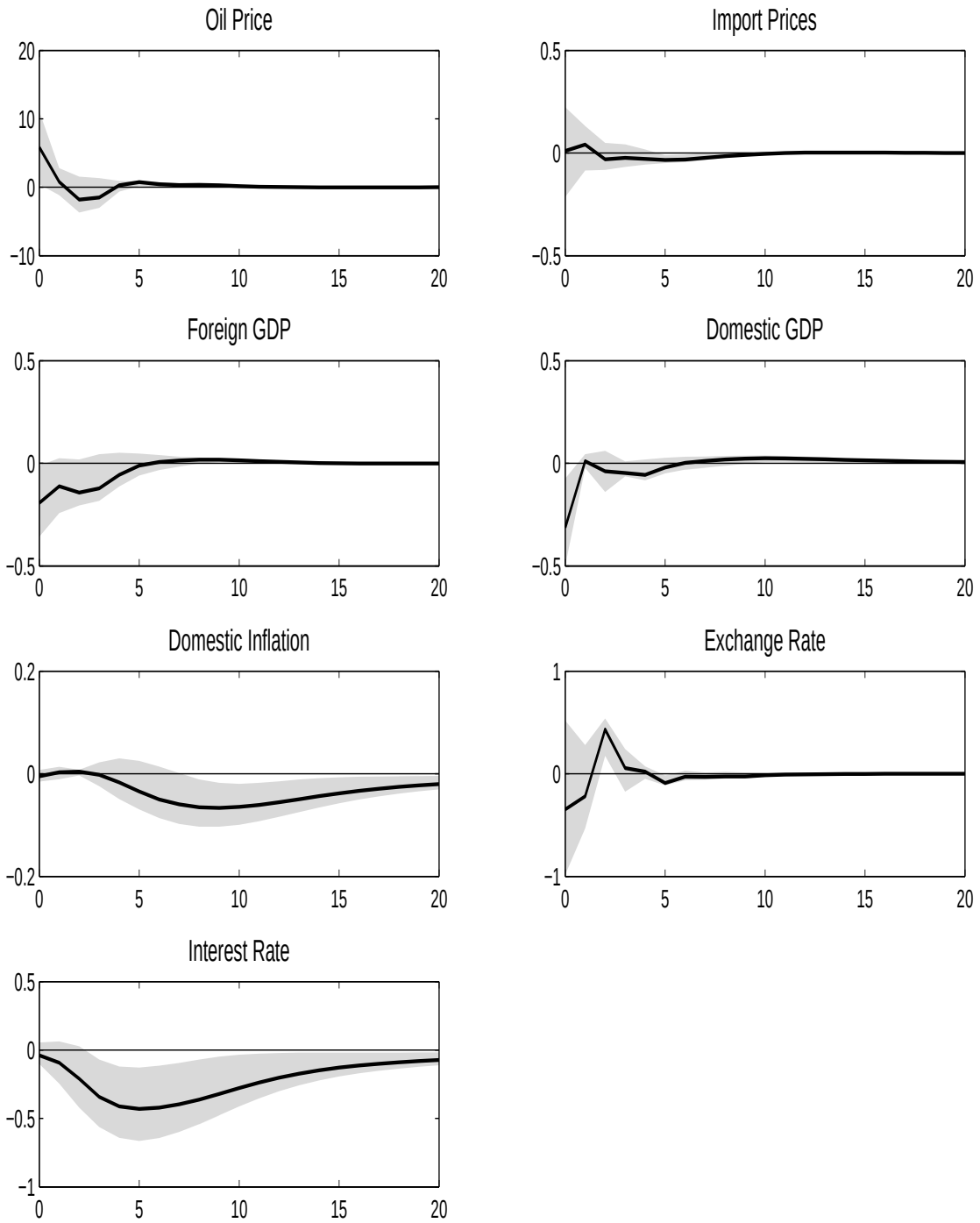

Figure 5.2: Impulse responses following an oil price shock

within the 97.5 percent uncertainty band. Furthermore, the initial appreciation is followed by a depreciation, likely due to monetary policy easing, and subsequent normalization within the first year following the shock.

A wide-held view is that an oil price shock has positive effects on the Norwegian economy, including the mainland economy (see e.g. Solheim 2008). The results from this analysis are in stark contrast to that view. Furthermore, the results contrast findings in Bjørnland's (2008) SVAR analysis of oil price shocks, where inflation drops during the first year, but then increase significantly above zero for the rest of period. Furthermore, in that analysis, unemployment falls and interest rates increase. However, the unemployment effect could at least be partly due to higher activity in the oil sector, not necessarily mainland activity as measured here. It should also be highlighted that in Bjørnland's analysis interest rates are largely unaffected the first five quarters, and rising only thereafter. Furthermore, foreign interest rates increase in Bjørnland (2008) following the oil price shock, possibly indicating that the oil shock is driven by increased demand, not lower supply. This contrasts the identification scheme in the model estimated in this thesis, where the shock is identified by imposing a negative response of foreign GDP. While the model in this thesis does not include foreign interest rates, a plausible response to this sort of oil price shock is for foreign rates to fall. As section 5.2 will show, among domestic variables interest rates are the most dependent on foreign factors and, historically, Norges Bank's key interest rate closely follow interest rate movements abroad. Thus, given the imposed negative response of foreign GDP, and a likely fall in interest rates abroad, a fall in domestic mainland GDP, inflation, and the interest rate might be rationalized. An interesting extension of this thesis would be to include foreign interest rates in the model to investigate this issue further.

Globalization shock: The impulse responses of domestic variables following the globalization shock are in line with the expectations, see figure 5.3. This shock was identified by imposing a negative response of import prices and a positive response of the oil price and foreign GDP. Impulse responses for these three variables in periods following the initial period are ones of steady movements back to normal growth levels by three to five quarters. By construction, terms of trade

improve initially, and the results indicate that terms of trade continue to improve for approximately one year.

Higher foreign GDP growth entails increased foreign demand for Norwegian goods, and in effect higher domestic activity. On top of this, a higher oil price will eventually have spill-over effect to the mainland economy. Thus, these developments abroad lead to a positive output gap in the mainland economy. The impulse response indicates an initial 0.2 percentage points increased quarterly growth rate in mainland GDP, and fluctuating movements between 0 and 0.2 percentage points in the following periods up to $1\frac{1}{2}$ years after the shock. These findings contrast the effects of the oil price shock, and highlight the importance of foreign demand. The lower growth rate of imported consumption goods neutralizes inflationary pressure from higher domestic activity for up to four quarters. After the first year, inflation rises as the deflationary impulse from lower import prices phases out. As with the world demand shock, the magnitude of change in inflation is relatively small, with a maximum of 0.5 percentage points above trend, measured on an annual basis. During the first year, Norges Bank's dual goal of low and stable inflation over time and stable output might appear to be in conflict. Thus, in real-time, the central bank faces a policy dilemma of whether to increase the interest rate to dampen output growth, and risk lower inflation. However, the impulse response of the interest rate suggests that the Norwegian central bank foresees that the non-increasing inflation is mainly due to lower import prices, and that inflation will pick up as domestic and foreign GDP growth increase. The response is therefore to push the interest rate up. Notice, however, that it is only pushed up gradually, and reaches its maximum only once inflation picks up, reflecting a cautious approach to the apparent policy dilemma. As with the world demand shock and the oil price shock, inflation is stalled and starts falling towards normal levels within four to five quarters after the interest rate reaches its maximum. The median response of the real exchange rate indicates an appreciation in the first two quarters, but a relatively quick depreciation back to normal levels. However, as can be seen from the figure, there is much uncertainty, with draws ranging from -1 to +0.5 percent exchange rate change in the period immediately following the shock. A comparison of these responses with those of Jääskelä and Smith's (2011)

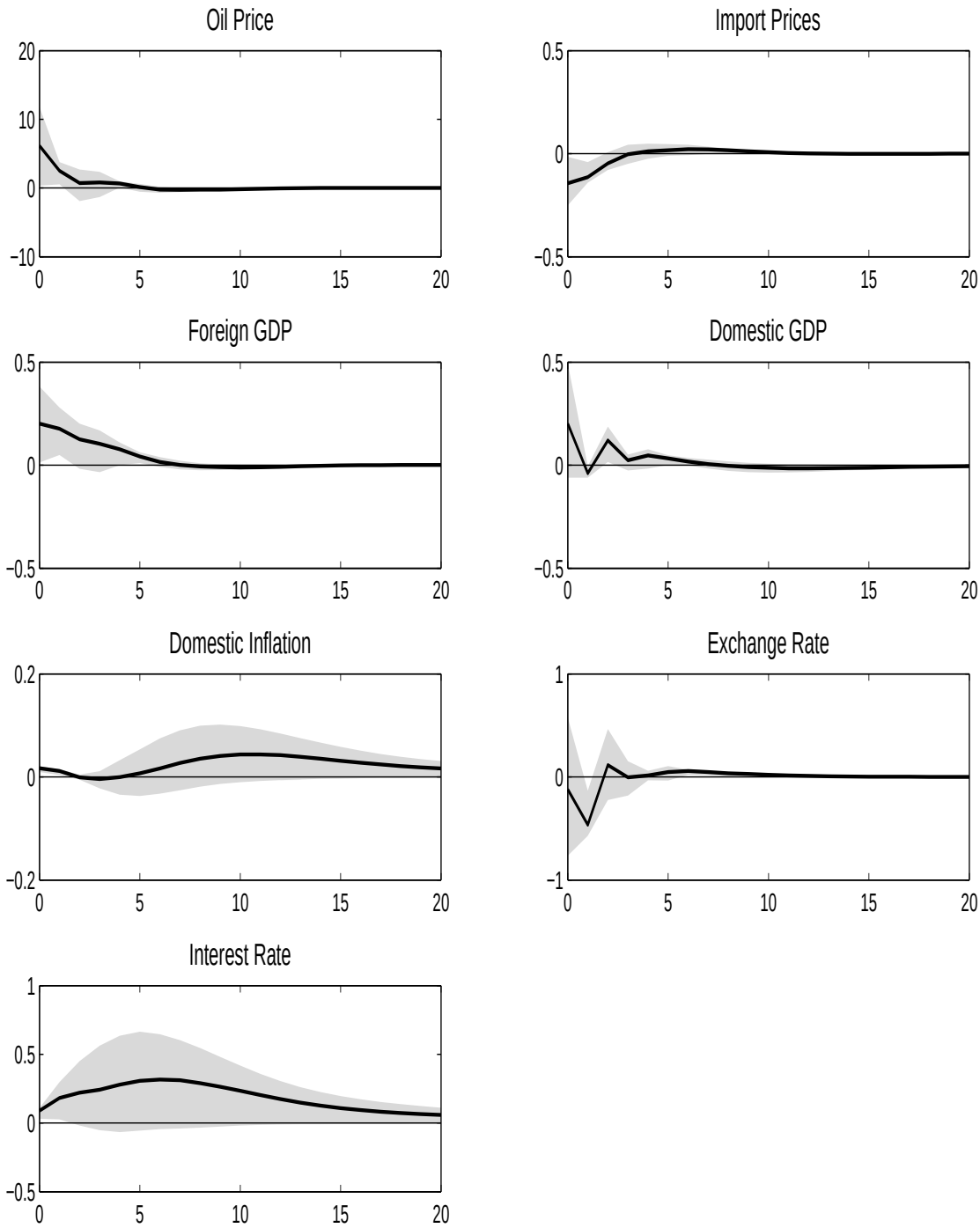

Figure 5.3: Impulse responses following a globalization shock

for Australia, emphasizes that a globalization shock does not necessarily decrease inflation. For Norway, it certainly counteracts domestic inflationary pressure, and therefore may push aggregate inflationary pressure out in time. Furthermore, the response of other domestic variables are quite different for the two economies. In contrast to the results for Norway, GDP in Australia is unaffected, explaining why lower imported inflation is directly observable in lower aggregate inflation. Thus, in sharp contrast to Norway, the interest rate initially falls and the real exchange rate depreciates in Australia. Hence, while the price impulse from abroad after a globalization shocks looks more or less uniform, the broader macroeconomic effect depends on the structure of the economy. The arrival of developing economies on the world market might have especially profound (positive) effect on the Norwegian economy due to its oil exporting industry which experience a boom as global demand for oil increase.

On the real exchange rate as a buffer against foreign shocks: Jääskelä and Smith (2011) emphasize the importance of flexible exchange rate for the neutralizing of foreign shocks that hit the Australian economy. In light of this conclusion it is interesting to take a step back and look at the general picture arriving from the analysis of exchange rate responses in Norway. The initial impulse response of the real exchange rate following two of three foreign shocks were uncertain. Draws within the 97.5 percent uncertainty band were both on the positive and negative side of the trend following the globalization shock and the oil price shock. This suggests that fluctuations in the real exchange rate depends on factors not captured by the structural model, and that these factors interact with the structural shocks. Perhaps most interestingly, these results highlight that it is not given that an oil price shock causes a krone appreciation. This is in line with the finding in Bjørnland (2008), but contradicts what must be considered a consensus view in the literature and the more general debate in Norway (see e.g. Haldane 1997; Solheim 2008). The most robust finding is that the exchange rate appreciates following a world demand shock.[38] In this case, as in Jääskelä and Smith (2011), the exchange rate clearly acts as a buffer against the propagation of the shock

[38] Although the exchange rate appreciates significantly following a monetary policy shock, this was an imposed restriction used to identify the monetary policy shock.

to the Norwegian economy: with a stronger krone exchange rate the higher world price on Norwegian oil and Norwegian imports is less felt on the domestic economy. Focusing solely on the median response model, such "buffer-effects" can also be detected for the other foreign shocks, but due to the uncertainty surrounding the estimates, it is hard to conclude as forcefully in this thesis as Jääskelä and Smith (2011) do in their paper.

5.1.2 Domestic shocks

Three domestic shocks were identified: a demand shock, a supply shock and a monetary policy shock. Foreign variables are by construction not affected by these shocks, and hence, impulse responses in figures 5.4-5.6 are only for domestic variables.

Domestic demand shock: Impulse responses of mainland GDP, inflation, the real exchange rate and short-term interest rates following the domestic demand shock are presented in figure 5.4. The shock was identified by imposing a positive initial response of both GDP growth and inflation in the first period, and are estimated to be of magnitude 0.35 and 0.13 percentage points, respectively. The inflation response is relatively persistent, and reaches annual trend levels only towards the end of the period. Quarterly GDP growth however, sees a sharp drop already in the second period, and remains slightly below trend levels after the third quarter. This development in GDP growth is somewhat puzzling, and must be interpreted as partly a correction towards trend growth levels, and partly a consequence of central bank policy, which acts to neutralize the shock by increasing the interest rate.[39] The interest rate is further increased in order to stall the inflationary pressure developing in the economy and reaches it's maximum in the third quarter. This leads to a real exchange rate appreciation in the median model during the first year, which in turn decreases inflationary pressure from imported goods. Notice again however, the uncertainty surrounding the first period response of the exchange

[39]See also the last paragraph in this section, page 45, for an interpretation with respect to the output gap measured in annual growth rates. One could have argued that the shock would have been better identified by imposing a positive response of GDP for a longer period than simply one quarter. This extension, however, is beyond the scope of this thesis.

rate (97.5 percent interval ranges from -1.6 to + 1.2), but as interest rates is raised further up to the third quarter, the response is more clearly one of appreciation compared to initial values. There is also some uncertainty with respect to the interest rate response, but the large majority of draws indicate an interest rate increase.

Domestic supply shock: A positive domestic supply shock is characterized by increased supply, either due to lower costs of production, or improved technology. Thus, it can be identified by lower inflation and higher GDP growth. Figure 5.5 displays that after the initial positive growth impulse that leads to a positive output gap (0.3 percentage points increased growth rate), GDP growth falls, then rises in the second and third quarter. Thus, the movement towards initial (trend) quarterly growth is relatively fast. The deflationary pressure on the other hand, is longer lasting. From an initial response of -0.1 percentage points, annual inflation falls further to a total of -0.13 percentage points, before moving steadily towards normal levels. Only a limited number of draws indicate that inflation grows above trend levels after the initial period following the shock. In response to a supply shock, the central bank faces a dilemma of weighing the inflation target against the goal of stable output growth. In contrast to the response following the globalization shock, which can be viewed as a global supply shock, Norges Bank seems to put more weight on the inflation target, and pushes the interest rate down. One interpretation is also that the central bank posits information regarding the source of the shock, and that quarterly growth rates normalize after a relatively short period. Furthermore, the inflation effect of the shock is clearly more uniform and persistent compared to the globalization shock, and thus poses a greater threat to Norges Bank's inflation target. With inflation and the interest rate falling, the Norwegian krone depreciates. The weaker Krone in turn contributes to increasing the inflation rate in the initial four quarters. However, once again the response of the real exchange rate looks highly uncertain.

Monetary policy shock: Responses to the final shock identified, the monetary policy shock, are displayed in figure 5.6. To avoid price- and exchange rate puzzles in the first period, inflation and the real exchange rate were restricted to have

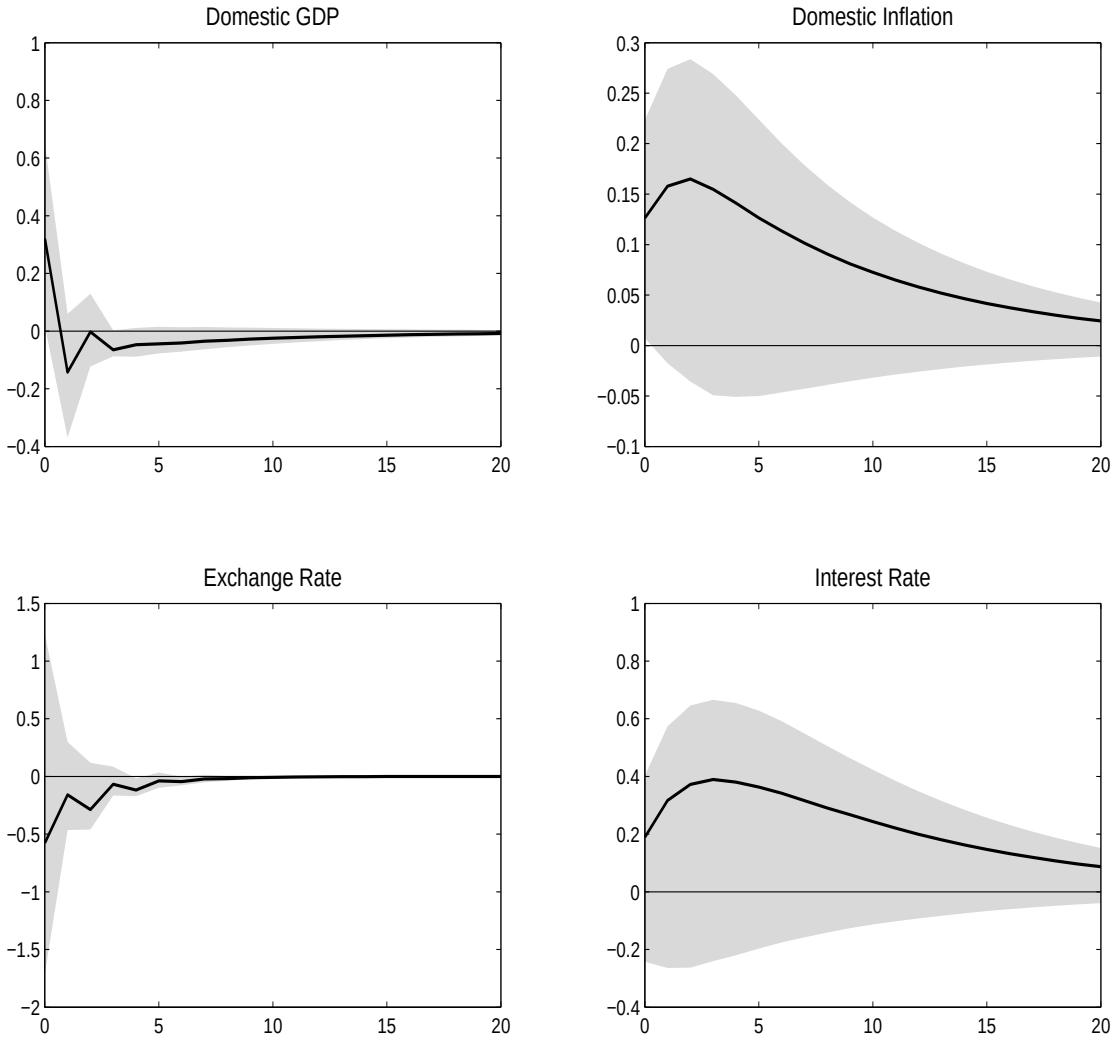

Figure 5.4: Impulse responses following a domestic demand shock

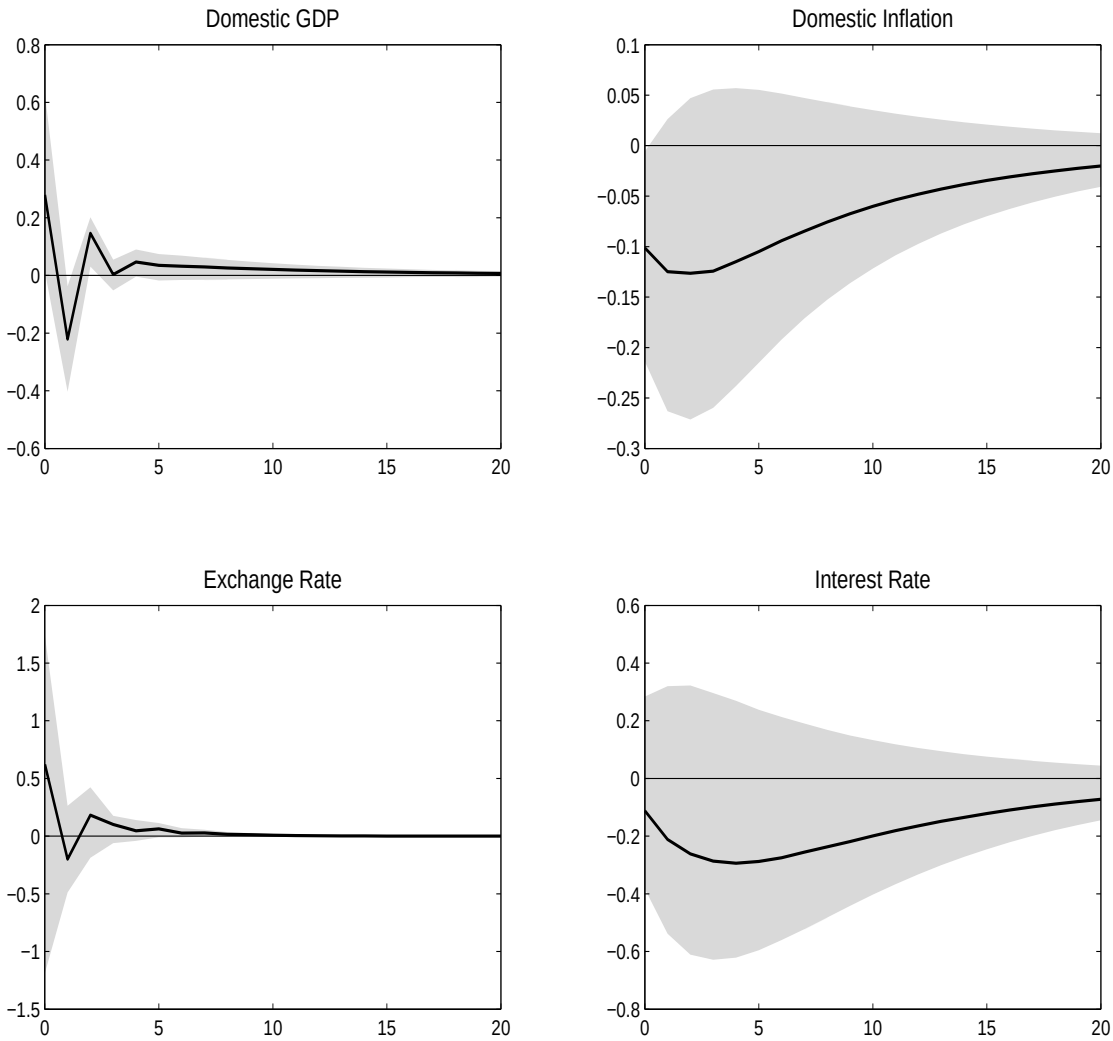

Figure 5.5: Impulse responses following a domestic supply shock

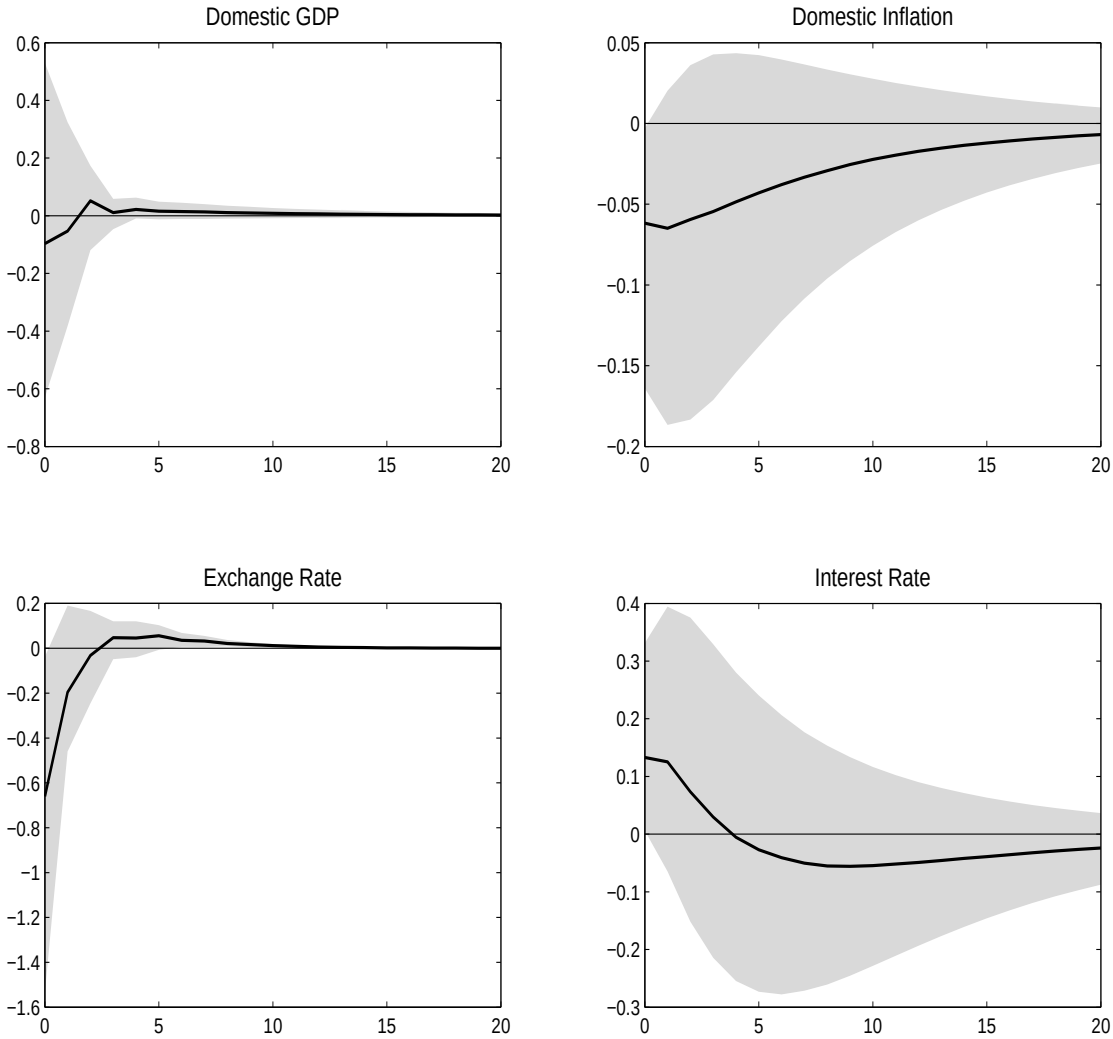

Figure 5.6: Impulse responses following a monetary policy shock

negative responses.[40] Thus, the only variable left unrestricted is quarterly growth in mainland GDP. Although the median model suggests an expected initial fall (-0.1 percentage points below trend growth), these estimates look highly uncertain, with draws within the 97.5 percent interval falling in between -0.6 and +0.5 percentage points. In subsequent periods, GDP growth is largely unaffected by the shock. Partly, this can be explained by the fact that the monetary policy shock is relatively "effective" with respect to inflation and the exchange rate. Inflation falls not only in the first period (-0.06 percentage points), but is persistently below normal levels for the entire period. Furthermore, the initial Krone appreciation is quite substantial (0.7 percentage points). Thus, in line with a goal of stabilizing the economy, interest rates are pulled down towards normal levels already in the second quarter, and falling below zero after the first year. As the initial monetary policy contraction is shifted towards more expansionary interest rate policy, inflation is pushed up towards normal levels. Notice also the uncertainty surrounding the size of the shock effect on the interest rate and inflation. Clearly, a significant share of the draws indicate that the interest rate responds even more strongly to the monetary policy shock, with the effect of decreasing annual inflation by 0.2 percentage points.

On the persistence of shocks: The impulse responses for domestic variables following all shocks above display some common features. One is that the shocks seem to have a relatively long lasting effect on the annual inflation rate: after a shock, inflation moves (more or less) steadily towards trend level, but reaches them only towards the end of the period displayed in the figures. It also seems clear that inflation responds to movements in the interest rate with a lag. This can be interpreted as reflecting wage and price rigidities in the economy, and also explains why the interest rate also moves toward normal levels only towards the end of the period. Furthermore, it explains why inflation in some cases, notably following foreign shocks, keeps rising (or falling) despite the fact that the interest rate is also rising (falling). For instance, while the price of imports is relatively quickly reflected in the price paid by consumers in stores, an interest rate increase

[40] Recall that a negative sign restriction on the real exchange rate, is the equivalent of imposing a Krone *appreciation*.

affects prices with a lag because producers and workers do not make decisions on production level, price and wage demands on a daily basis. A second observation is that the initial response of quarterly GDP growth, whether positive or negative, seems to be corrected already in the next period. Furthermore, it is difficult to observe any significant shock effect, nor interest rate effect, on GDP beyond the fifth quarter after the initial shock. Hence, the shock effect appears less persistent when it comes to GDP growth than inflation or the interest rate. Thus, the effect of interest rate movements on the output gap also appear insignificant beyond the fifth quarter. However, these observations are somewhat misleading, because they do not imply that the output gap is closed by the end of the fifth quarter. A growth rate above trend in the fifth quarter will, unless countered by a growth rate below trend in the subsequent quarters, imply a positive output gap for a year forward, if one looks to annual growth rates, or the average quarterly growth rate over a year. Similarly, the correction in the period after the initial response does not imply a closing of the output gap, once measured in annual rates. In effect, this also implies that GDP growth is responsive to the interest rate. For instance, the rise in the interest rate following the globalization shock, which reaches maximum in the sixth quarter, leads to a closing of the output gap within the ninth quarter, not the sixth as it appears in figure 5.3.

5.2 Variance decomposition

Based on the median model impulse responses discussed in the previous section, the Forecasting Error Variance Decomposition (FEVD) is calculated for each variable. The variance decomposition sheds light on the relative importance of the six shocks for each variable. The main focus here is to investigate the relative importance of foreign shocks, compared to domestic shocks. Table 5.1 reports variance decomposition 20 quarters after the shock, with the shocks' (listed in the columns) contribution to variance in each variable (listed in the rows). The numbers reported below are more or less the same for all variables with a horizon above six to eight quarters. The exception is inflation, where the relative contribution

from foreign shocks become positive only after 10 quarters.[41]

Looking to the foreign block, all three shocks account for sizable shares of variation in the oil price, import prices and foreign GDP growth. Thus, they all contribute to explaining movements in Norwegian terms of trade. In contrast to the findings in Jääskelä and Smith (2011), where the globalization shock is found to be of relatively small importance, the globalization shock explais a large share of variation in foreign variables. Table 5.1 also displays that the foreign shocks are important determinants for the Norwegian economy. Together the foreign shocks contribute on average with roughly $\frac{1}{3}$ of variation in domestic variables. However, the average conceals a great deal of variation between the effects on domestic GDP (31 percent), inflation (14 percent), the exchange rate (34 percent) and the interest rate (45 percent). With regards to domestic GDP and interest rates, these numbers are of similar magnitude to those found by Jääskelä and Smith (2011) for Australia. Both analyses suggest that roughly 30 percent of variation in GDP and 40-45 percent of variation in the interest rate is due to foreign shocks. By contrast, Aastveit et al. (2011) find that foreign (regional and world) factors explain on average 62 percent of variation in Norwegian domestic variables.

Comparing the relative importance of the three foreign shocks, the world demand shock and the oil price shock both explain on average 12 percent of variation in the domestic variables, compared to 8 percent for the globalization shock. Although these numbers are within the same range, they seem to indicate that for the domestic economy, the globalization shock is the least important among the foreign shocks. Qualitatively, this is the same conclusion as Jääskelä and Smith (2011) reach, but quantitatively, the globalization shock is far more important for Norway than for Australia (for Australia, the average is 3.5 percent). Furthermore, as already noted, the globalization shock is given more importance for variation in foreign variables in this analysis than in Jääskelä and Smith (2011). Note that the average effect of the oil price shock is dragged down because of its marginal importance for import prices. Thus, the overall picture arriving from the variance decomposition is that foreign shocks are important, but less important than

[41] Variance decomposition over different horizons, 1-20, can be found in Appendix (section A.2), figure A.1

Table 5.1: Variance decomposition

	World demand	Oil price	Globalization	Domestic demand	Domestic supply	Monetary policy	Unidentified shocks
Oil price	0.33	0.38	0.29	0	0	0	0
Import prices	0.49	0.07	0.44	0	0	0	0
Foreign GDP	0.27	0.30	0.42	0	0	0	0
Domestic output	0.11	0.12	0.08	0.37	0.26	0.03	0.03
Domestic inflation	0.05	0.06	0.03	0.29	0.46	0.08	0.03
Real exch. rate	0.20	0.09	0.05	0.13	0.05	0.18	0.30
Interest rate	0.09	0.20	0.16	0.17	0.28	0.02	0.08

domestic shocks.

As indicated in the discussion of the interest rate responses in section 5.1.1, the interest rate is the domestic variable most dependent on foreign shocks, with 45 percent, thus corresponding with the observation that Norwegian interest rates are highly dependent on developments abroad. This also reflects the notion that Norges Bank closely monitors the development in trading partners' economies, and seeks to alleviate shocks originating abroad with its main policy tool. Interestingly, 20 percent of the variation in the interest rate is being explained by oil price shocks. Hence, the oil price shock is a key shock that explains variation in the interest rate, possibly indicating that the central bank is vary of the long term effects such shocks may have on the Norwegian economy if not met by effective policy measures. Domestic supply is the single most important factor explaining variation in interest rates, contributing with 28 percent. Domestic demand shocks contribute with 17 percent, leaving only 2 percent of variation due to monetary policy shocks. This is not a reflection of an ineffective monetary policy instrument. Rather, it indicates that monetary policy *shocks* are relatively seldom or small, compared to other domestic shocks. Furthermore, it reflects that interest rate decisions made with the intention of moving short term interest rates in the market is often expected, and based on public information available to economic agents.

Foreign shocks are, according to these estimates, of relatively small importance for development in consumer price inflation (altogether 14 percent). This was also reflected in the impulse response functions that displayed relatively small changes in the annual inflation rate following foreign shocks. This might be partly due to the fact that the data used was CPI-ATE, i.e. consumer prices adjusted for changes in taxes and excluding energy prices, and thus a less volatile measure of inflation. In contrast, Aastveit et al. (2011) utilize non-adjusted CPI, and find 60 percent of variation due to foreign factors. Instead, inflation is predominantly determined by domestic supply shocks (46 percent), and with significant contributions from demand shocks (29 percent). Monetary policy shocks contribute with 8 percent. Thus, while foreign factors seen in isolation may affect inflation as described in section 5.1.1, the analysis in this thesis suggests that variation underlying inflation is very much a domestically determined phenomenon. This might seem to contra-

dict the notion that global developments, especially the spread of cheap imports from China, have been a significant explanatory factor for the low inflation rate in Norway. However, the estimates does not necessarily indicate this. Rather, they suggest that cheap imports have brought down the level of aggregate inflation on a permanent basis, but do not necessarily explain smaller and short-term fluctuations away from this low level.

The output gap for mainland Norway is significantly affected by both domestic and foreign shocks. Foreign shocks explain roughly equal shares of variation in GDP growth, and together 31 percent. Domestic demand and supply side factors are the most important, with 37 and 26 percent respectively. The monetary policy shock plays only a minor role (3 percent), reflecting the relatively small negative impulse response discussed in section 5.1.2.

The model did not try to identify any real exchange rate shock, and table 5.1, shows that in the median model, 30 percent of variation in the real exchange rate is due to unidentified shocks. "Unidentified shocks" refer to shocks that "explain" any remaining share of variation in a variable not explained by the identified shocks. In the model in this thesis, the exchange rate shock was not identified. The large share of variation unaccounted for is therefore likely due to real exchange rate shocks. However, as discussed in section 3.3.1 (and footnote 25), it was believed at the outset that the model did not contain enough information to pin down the shock. Apart from this, the variation in the real exchange rate is equally divided between domestic and foreign factors (36 and 34 percent, respectively). As suggested by the impulse response functions, the most important among foreign shocks is the world demand shock (20 percent). Monetary policy shocks account for 18 percent of variation. This confirms the empirical observation that the real exchange rate is very responsive to interest rate movements, and in particular unexpected movements. In contrast, the same basic model in Jääskelä and Smith (2011), suggests that the real exchange rate in Australia is overwhelmingly determined by foreign factors (76 percent), and that it acts as a buffer against all types of foreign shocks. As discussed in section 5.1 above, impulse responses for the median model suggest a similar buffer-effect for Norway, but also that this effect is much more uncertain. Altogether, the impulse responses and the variance decomposition suggest, that

fluctuations in the real exchange rate in Norway do not necessarily act according to theory or in a consistent manner. It is likely affected by factors such as speculation and expectations which is not captured by the model in this thesis. This is an area that clearly is open for further research.

5.3 Robustness

In order to test the robustness of the results reported in sections 5.1-5.2 two changes to the model and the variables are done. In this section, I briefly discuss the main results from these tests, by comparing impulse response functions and variance decomposition.

First, to test whether the results were biased due to a monetary policy regime change in 2001, a dummy variable equal to 1 from 2001Q2 to present, and 0 otherwise, was included in the analysis. The results were strikingly similar to those reported in section 5.1, and hence, the more parsimonious model was chosen.[42] A detailed investigation into the reason for the similar results in the two models seems to be a field of future research, as these results suggest that the shift in monetary policy regime has not led to very different responses following foreign and domestic shocks. One line of reasoning, in line with Bjørnland and Jacobsen (2009) is that the fundamental and practically important shift in monetary policy in the past has been the shift from fixed to flexible exchange rate, not towards flexible inflation targeting.

Second, in chapter 3.3, section 3.3.1, it was argued that the oil price influences the aggregate export price index and the Norwegian economy to such a degree that including the oil price, and thus an oil price shock, in the model was the most fruitful approach to modeling foreign factors affecting the Norwegian economy. To test this proposition, the oil price variable was substituted with an aggregate price index for all exported goods and services from Norway. Furthermore, import price growth was measured as the price growth in imported consumption goods, not all imported goods. Thus, in this robustness test, the import price variable

[42] The results from this robustness test is available from the author upon request.

was changed to include all imported goods. Both variables are seasonally adjusted indexes produced by Statistics Norway. Apart from these two changes, the model and variables were left unchanged.

Results from this modified model are as follows: Impulse responses from the domestic shocks were unaltered, because the modifications are done only in the foreign block, which is not affected by domestic shocks.[43] Furthermore, the response of domestic variables to foreign shocks are, largely, in line with those discussed in section 5.1, see figures 5.7-5.9. Notice however, that compared with the main model, all three foreign shocks give a larger effect on import prices, and a smaller effect on export prices, measured in percentage points. This in turn explains a somewhat more volatile response of inflation following foreign shocks: a world demand shock initially increases inflationary pressure, whereas in the main model, inflation were more or less unaltered the first half year. A shock to the export price (parallel to the oil price shock in the main model) increases inflation immediately, and annual inflation is above trend for six quarters following the shock. In both cases, the foreign shock affects the mainland economy more directly, by increasing the price of mainland exports, as well as the petroleum sector. This partly explains the increased inflationary pressure. Still, after the export price shock, GDP growth falls, due to falling demand from abroad. Thus, in this case, the shock has the characteristics of an adverse cost-push shock. Finally, import prices fall more drastically following the globalization shock, thus pulling inflation below trend, even though the domestic economy is booming. The implication is that cheaper imported investment goods contribute to lower inflation by lowering production costs, and in effect, the price of domestically produced goods. Notice however, the uncertainty surrounding the response over the first four quarters. It is also interesting to observe that the estimated response of the interest rate indicates that the central bank acts in the same way as before, i.e. that they expect inflation to pick up relatively fast. Apart from these relatively small adjustments, impulse responses are more or less similar as before. Thus, the initial proposition that the oil price is a crucial determinant of the export price, terms of trade and the Nor-

[43] Impulse response figures for domestic shocks are not reported, but can be obtained from the author upon request.

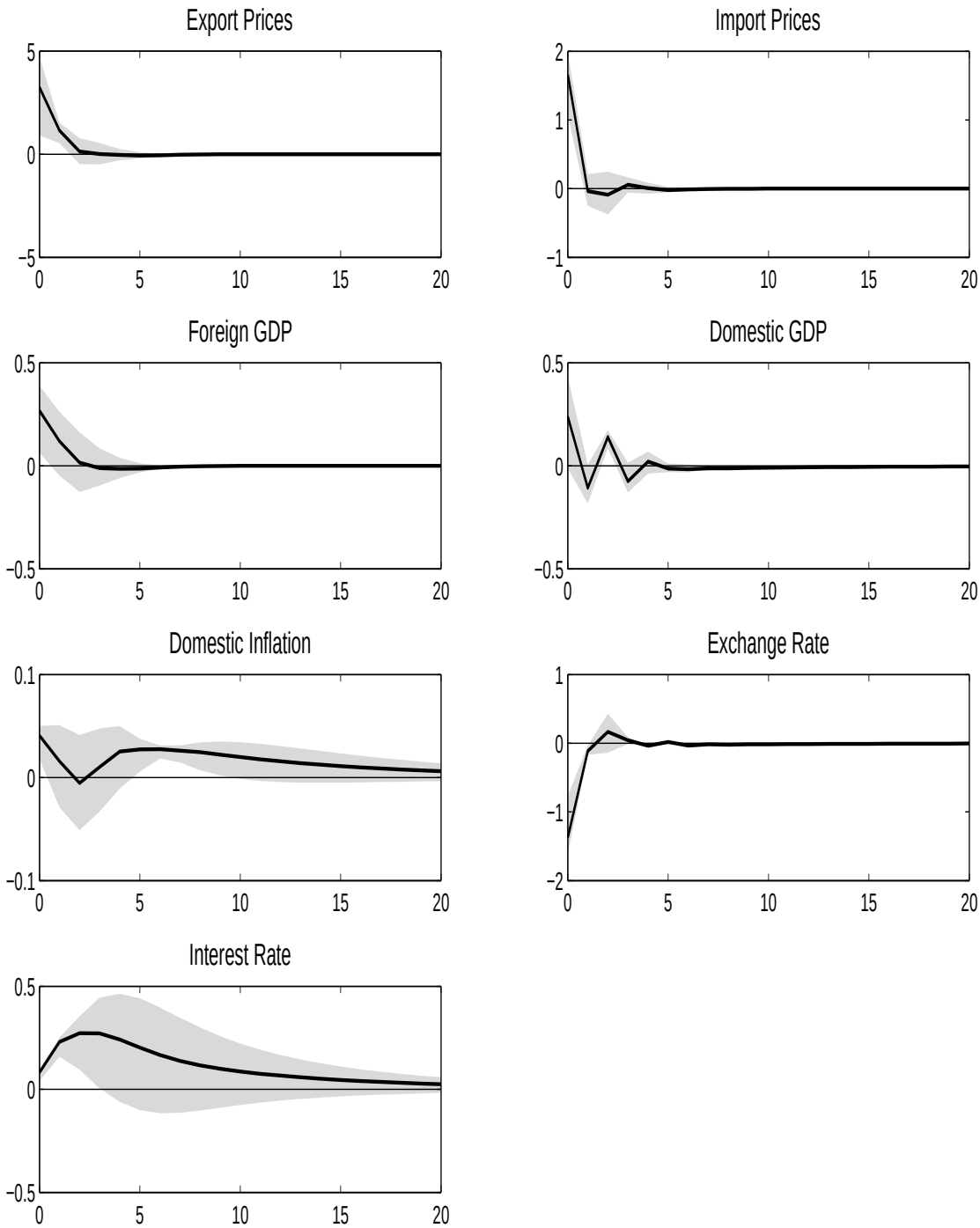

Figure 5.7: Impulse responses following a world demand shock. Model with growth in price of total exports and imports

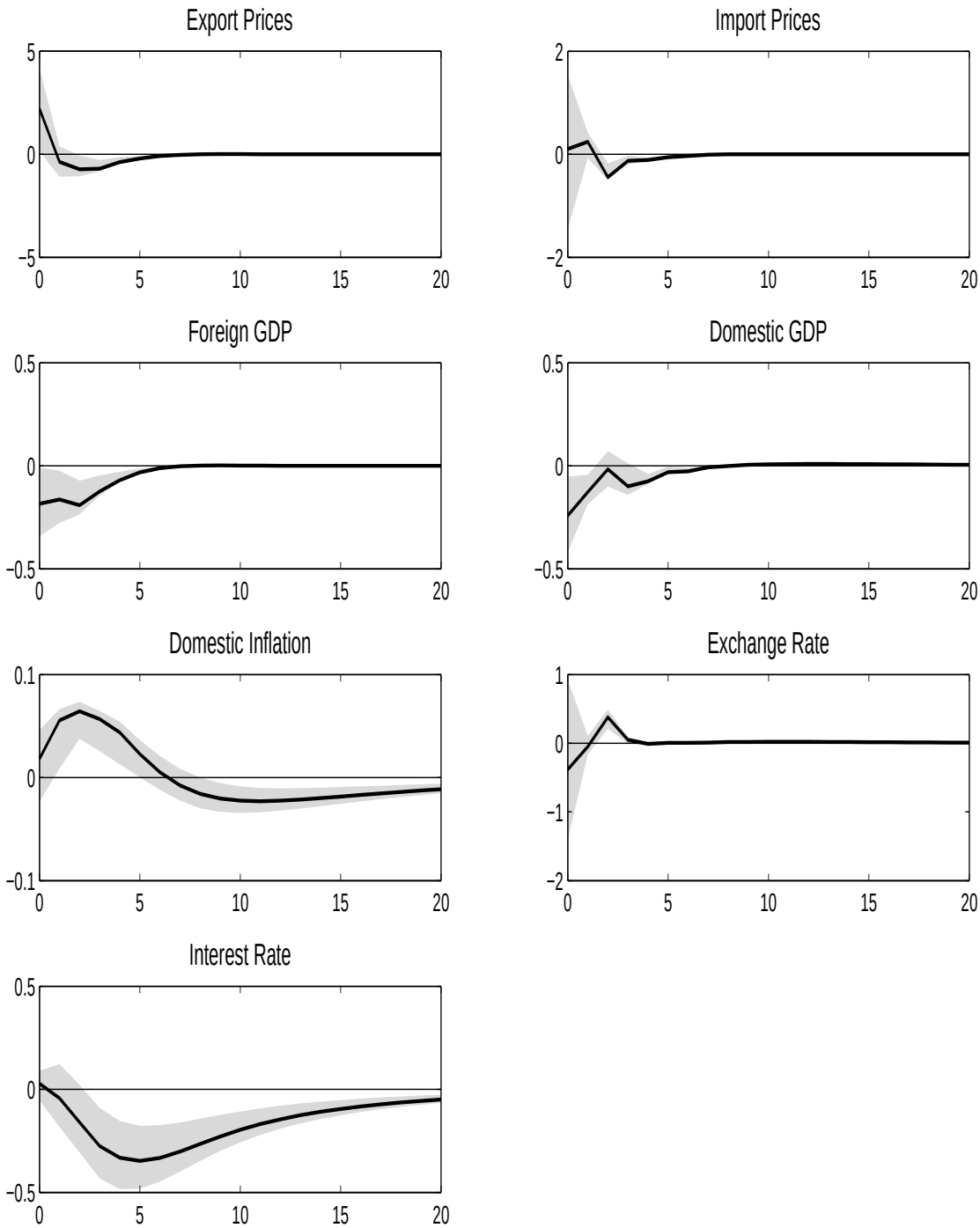

Figure 5.8: Impulse responses following an export price specific shock. Model with growth in price of total exports and imports

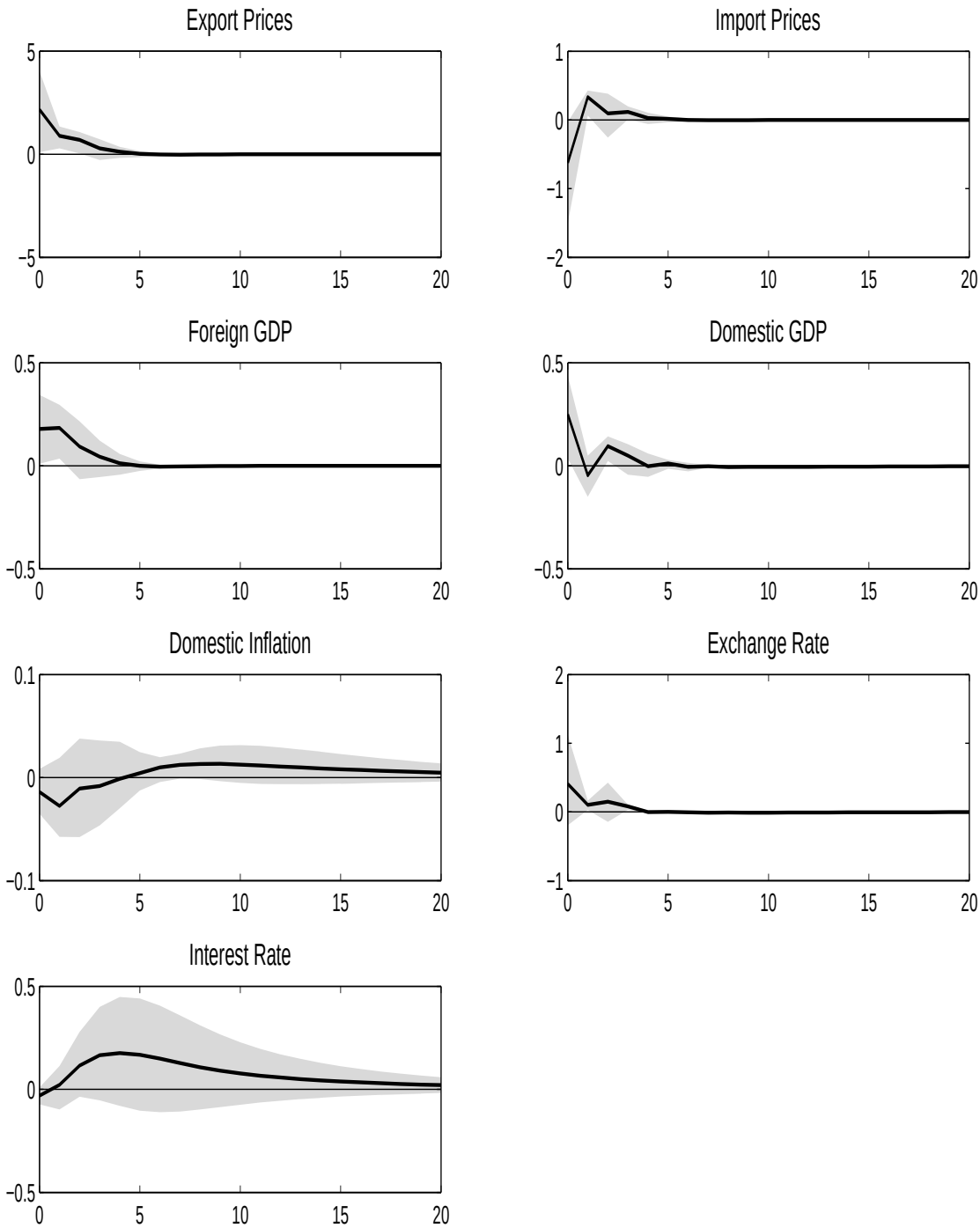

Figure 5.9: Impulse responses following a globalization shock. Model with growth in price of total exports and imports

wegian economy is strengthened. Taking into account price movements in other Norwegian exports does not significantly alter the conclusions about the response of the Norwegian economy following foreign terms of trade shocks. Furthermore, the inclusion of all imported goods affect the inflation response somewhat, but do not affect the qualitative conclusions in any significant manner.

The variance decomposition in the model with total export and import prices, is presented in table 5.2.[44] Compared to table 5.1, several differences appear. First world demand is attributed a significantly more important role in explaining movements in export and import prices, and thus terms of trade. Second, 50 percent of variation in the real exchange rate is explained by foreign shocks, compared to 35 percent in the main model. The great bulk of these, 40 percent, is due to world demand shocks, and the identified domestic shocks contribute with only 17 percent. Third, interest rates are less dependent on foreign shocks (32 versus 45 percent), and domestic demand shocks are the single most important factor. Furthermore, domestic demand is more important for explaining variation in inflation and the interest rate. Overall, these numbers seem to suggest a more important role of demand side factors, both foreign and domestic. Note also that inflation in this model is still very much domestically determined. Thus, the interpretation offered in section 5.2, namely that the foreign factors (and specifically the influx of developing economies into the world market) have led to a lower level of inflation overall, but not necessarily to variation in inflation, is supported by this robustness test. Finally, the importance of foreign factors for variation in the real exchange rate, and a large share attributed to unidentified shocks, highlight the uncertainty surrounding fluctuations and responses of the Norwegian Krone following both domestic and foreign shocks. This underscores the need for further research on determinants of exchange rate fluctuations.

[44] A figure with variance decomposition over a 20 period horizon is reported in the Appendix (section A.2) see figure A.2

Table 5.2: Variance decomposition

	World demand	Export price	Globalization	Domestic demand	Domestic supply	Monetary policy	Unidentified shocks
Export prices	0.55	0.28	0.17	0	0	0	0
Import prices	0.73	0.09	0.17	0	0	0	0
Foreign GDP	0.24	0.38	0.39	0	0	0	0
Domestic output	0.09	0.10	0.10	0.41	0.25	0.05	0.001
Domestic inflation	0.02	0.03	0.01	0.51	0.40	0.03	0.003
Real exch. rate	0.41	0.04	0.06	0.04	0.03	0.10	0.32
Interest rate	0.06	0.18	0.08	0.40	0.20	0.03	0.05

6 Conclusion

Based on the empirical observation that Norway's terms of trade have been steadily improving over the past 20 years, and the lack of thorough empirical analysis on the causes and effects of this improvement, this thesis set out to investigate the following two questions:

1. *How do Norwegian output, inflation, exchange rate and interest rate respond to foreign shocks that alter the terms of trade in a small, open, oil-exporting economy, like Norway? And;*
2. *What is the relative importance of these terms of trade shocks compared to domestic shocks?*

In order to answer these questions, an SVAR model for Norway was developed. The former question has been addressed by identifying and estimating the impulse responses of foreign and domestic variables following three foreign terms of trade shocks: a world demand shock an oil price shock, and a globalization shock. In order to answer the second question, the effects of three domestic shocks were estimated: a domestic demand shock, a domestic supply shock, and, finally, a monetary policy shock. By doing so, the relative importance of each of the foreign and domestic shocks for variation in domestic variables were made possible through variance decomposition. The key findings are as follows:

All three foreign shocks contribute significantly to explaining movements in the oil price and the price of imported consumption goods, and thus Norwegian terms of trade. Furthermore, each shock explains variation in foreign GDP growth, and thereby foreign demand for domestic goods. There is strong evidence to suggest that the foreign shocks not only affect terms of trade differently, but also that the response in the domestic economy depends on the source of the shock. Expectedly, a world demand shock was shown to be expansionary. Domestic output gap, inflation and interest rates increase. However, because the exchange rate appreciates, the full effect of the foreign shock is alleviated. An oil price shock was found to dampen activity in mainland Norway and inflationary pressure, indicating that what may seem as a positive development for the Norwegian economy as a whole,

may not necessarily be true for the mainland economy. This effect was traced in a sharp fall in foreign output, and thus foreign demand for goods produced in mainland Norway. In response to these developments in the domestic and foreign economies, the interest rate falls. The real exchange rate appreciates, but estimates are uncertain. A globalization shock, entailing lower import prices and a higher oil price, is expansionary, but in the short run not inflationary. However, in the longer run, inflation picks up, and the interest rate is pushed up in order to dampen activity and inflationary pressure in the economy. The effect on the exchange rate is uncertain, but seems to appreciate following the shock.

The domestic shocks affect the domestic economy largely as expected. By increasing activity and inflationary pressure in the economy, a domestic demand shock is met by contractionary monetary policy, and in turn a stronger Krone exchange rate. The supply shock was identified by imposing a positive output effect, but a lower inflation rate. In response, the interest rate is pushed down, and the real exchange rate depreciates. Finally, the identification scheme imposed a positive inflation rate response and a Krone appreciation following a monetary policy shock. The output growth effect was found to be negative, but short-lived and uncertain.

On average, the three foreign shocks altogether explain roughly $\frac{1}{3}$ of variation in domestic variables. Variation in mainland output growth and the real exchange rate growth, lies close to this average. Domestic inflation is least dependent on foreign factors, seemingly in contradiction with the notion that cheap imports from developing economies is a key reason for the low inflation rate in Norway. However, one plausible interpretation is that these global developments have decreased the level of inflation on a more permanent basis, rather than contributing to explaining variation around this level. Movements in interest rates is most dependent on foreign factors, reflecting that the Norwegian central bank is carefully monitoring the development in trading partners' economies, and often respond to changing economic conditions abroad. Still, fluctuations in domestic output growth, inflation and the interest rate is predominantly determined by domestic demand and supply side shocks. Monetary policy shocks contribute with only a marginal share in these three variables, but is the single most important domestic factor that explains variation in the real exchange rate. This finding highlights the sensitivity of

the exchange rate to changes in the key policy rate, and in particular unexpected moves by the central bank. A significant share of variation in the real exchange rate was unaccounted for by the model, due to the choice of not trying to identify any exchange rate shock.

Thus, I find that terms of trade shocks are important for the Norwegian economy, but clearly less important than domestic factors. All foreign shocks contribute with sizable shares. At the same time they affect the economy differently. While all shocks improve Norwegian terms of trade, they induce different response of monetary policy, both in the immediate aftermath of the shock, and in the longer run. Thus, the findings in this thesis highlight the importance of disentangling the source of the terms of trade shock, in order for economic policy to respond correctly.

The results and the conclusions drawn in this thesis should by no means be the final words in the investigation into the effect of improvement in terms of trade, and more broadly the effect of foreign shocks in Norway. Notably, two findings should be subject for further research. First, the effect of the oil shock was to dampen domestic economy and inflationary pressure in Norway, due to decreasing foreign demand for mainland exports. As a response, interest rates were pulled down. This suggests that the negative effect of oil price hikes on output and demand abroad outweighs the positive effect of increased activity in the oil sector in Norway. Future investigation of the consequences of oil price shocks for the Norwegian economy should therefore take more explicitly into account the effect of the shock abroad. This could bring into light the mechanisms at work. Second, the results showed some indications that the exchange rate acts as a buffer against foreign shocks. However, the results appeared to be uncertain. One line of interesting research for the future is therefore to investigate these effects more in detail, in order to evaluate the role and importance of exchange rate fluctuations in Norway.

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A Appendix

A.1 Unit root tests

Table A.1 reports results from unit root tests on each of the seven variables included in the analysis. The tests performed were Augmented Dicky-Fuller tests. For all variables, except the non-differenced nominal interest rate, reject the null hypothesis of a unit root (i.e. that the variable is non-stationary). The nominal interest rate is still assumed to be stationary, based on findings in Lee and Tsong (2011). See footnote 27, in section 4.

Table A.1: Unit root tests: Augmented Dicky-Fuller tests.

Variable		Test statistic	p-value [a]
Oil price growth	π^{oil}	-6.629	0.00
Import price growth	π^{m}	-4.955	0.00
World output growth	y^{w}	-3.729	0.0037
Domestic output growth	y^{d}	-11.047	0.00
Domestic inflation	π^{d}	-4.791	0.00
Real exchange rate growth	q	-8.340	0.00
Nominal interest rate	i	-1.169	0.6869

[a] With 75 observations, critical values for 1 %, 5 % and 10 % significance levels are -3.545, -2.910 and -2.590, respectively

A.2 Variance decomposition over different horizons

Figure A.1 display the contribution of each shock to variation in each of the variables in the analysis, over a period of 20 quarters after the shock. The figure shows a stable contribution from each shock after five quarters. The exception is inflation, where foreign shocks contribute with a small, but increasing share beginning after the 5th quarter, and stabilizing only towards the end of the period. In order to capture this contribution from foreign shocks, Table 5.1 in section 5.2 reports the numbers in the 20th quarter. Note however, that for all other variables, the contribution in the 20th quarter is more or less the same as in the 8th quarter

(that is, two years). Figure A.2, is the parallel figure for the model where the oil price and price of imported consumption goods, is replaced by the prices of all exports and imports, respectively. Table 5.2 in section 5.3 similarly report the contribution of each shock in the 20th quarter after shocks.

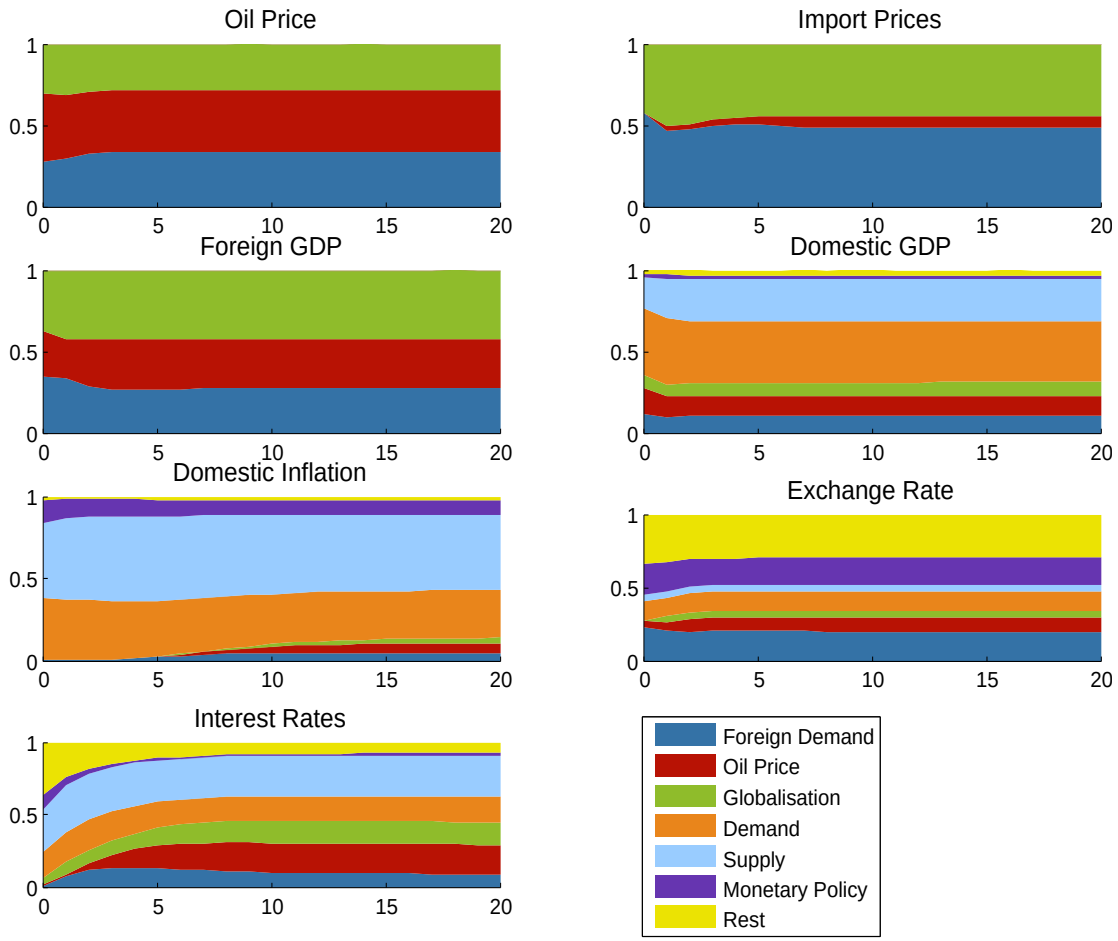

Figure A.1: Forcasting error variance decomposition for model with growth in oil price and price on imported consumption goods (main model). Contribution from each shock, graphed over a horizon of 20 quarters.

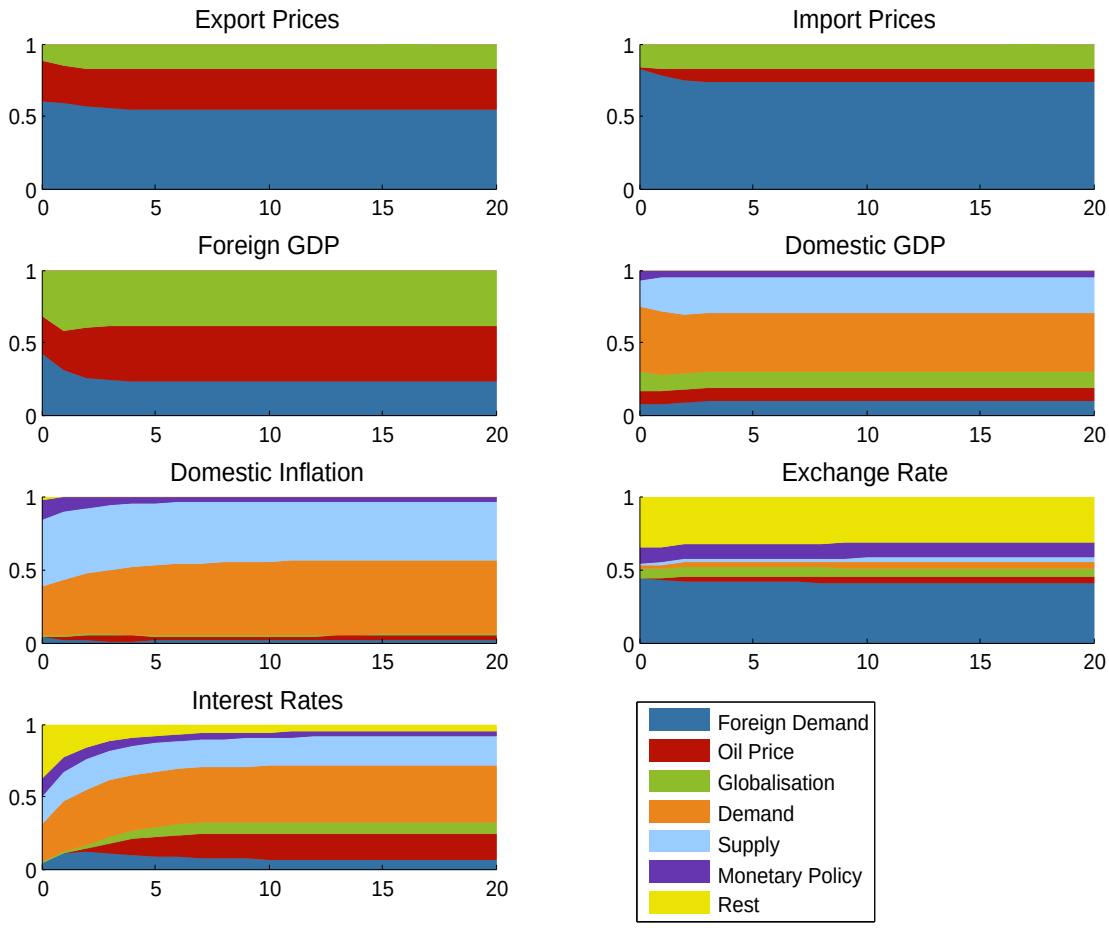

Figure A.2: Forcasting error variance decomposition for model with growth in aggregate export price and import prices (robustness test). Contribution from each shock, graphed over a horizon of 20 quarters.