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One Rate to Rule Them All

How US Monetary Policy is Increasingly Controlling European Economies

Lina Thomas (41203)

Abstract. When the Fed raises the interest rates, it does so to steer domestic activity. However, the effects of such monetary policy may inadvertently *spillover* to other economies. This study employs the Global VAR approach to examine such spillover effects to European economies before and after the crisis. I find evidence that while US monetary policy tightening had virtually no effect on European output before 2007, its impact became substantial and significant after the crisis. What is more, European output drops by as much or even more than American output. The analysis reveals that spillovers seem to propagate mainly through the bond markets. Overall, this thesis supports the hypothesis in the literature that growth and financial conditions are largely determined by the 'Global Financial Cycle', which is on its turn driven by one rate. The US monetary policy rate.
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Discussants: Colja Maser, Jörn Onken
Examiner: Mark Sanctuary

In the Land of Mortgages, where the Money is born
One Rate to rule them all, One Rate to find them
One Rate to bring them all, and in the wretchedness bind them
In the Land of Mortgages, where the Money is born

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1 Introduction

There is no denying it, the global economy has seen a significant deepening of trade and financial integration in recent decades. In such a globalized world, spillover effects of shocks to other countries are inevitable. In fact, it may well be that in today's world, growth and financial conditions are largely determined by the so-called 'Global Financial Cycle'. This cycle would in turn be driven by one rate. One rate to rule them all. The US monetary policy rate (Georgiadis, 2016).

Recent research shows that European financial markets cannot escape the influence of US monetary policy. And although awareness of these cross-border effects has grown over the last few years, European bond and equity markets fail to shield themselves from it. Indeed, research shows that spillovers on these markets have been strengthened after the recent crisis (Albagli, Ceballos, Claro, & Romero, 2018; Curcuru, De Pooter, & Eckerd, 2018). However, as far as the studies on the effects of US monetary policy on European economies are concerned, the number is limited, the results are mixed and the time periods analysed are limited to the period before the outbreak of the crisis. This thesis attempts to close this gap in the literature. It seeks to answer the question to what extent US monetary policy has an impact on European[1] output, and whether these effects have been amplified since the global financial crisis.
The answer is "Yes – It affects us all." The main result is that, while European economies experience virtually no impact from a US monetary tightening before 2007, European growth shrinks substantially and significantly when including the post-crisis years. In fact, the European economy suffers just as much, if not more, than the American economy. These findings show that spillover effects have increased dramatically in the last decade.

This study employs the Global Vector Autoregression (Global VAR or GVAR) model that comprises 33 countries accounting for about 90 % of world GDP. That way, the study includes third country effects and spill-backs. Ignoring such effects would produce misleading results. Since the main question of the thesis is whether and how US monetary policy spillovers differ before and after the crisis, this model is estimated over a period from 1979Q2 to 2006Q4 and extended to 2016Q4. The results are then compared across these two estimation periods.
Since the correct implementation of the GVAR model is based on two important assumptions, I examine these assumptions and find that a correct implementation of the model is indeed ensured. In addition, I show that the model measures what it is supposed to measure, namely policy spillover effects rather than common shocks and factors between two regions. Thus, the results can be interpreted correctly.
The results section reports first the contemporaneous effects of foreign variables on their domestic counterparts. These provide a good picture of the international linkages that exist within a single variable. The results section then proceeds with a dynamic analysis of an interest rate or monetary policy shock in the US to all other variables and countries in the system i.e. the impulse response analysis. Based on these analyses, I come to the conclusion that while Europe could still successfully shield its economy from an increase in US interest rates before the crisis, European growth shrinks just as much or even more than US domestic activity after the crisis. This indicates that spillovers are highly amplified over the last decade.
In order to curb this effect, the question arises as to how the US monetary policy effects are making their way to Europe. The analysis in this thesis suggests that these spillovers do not spread through direct trade, but penetrate the European economies via financial markets - equity prices and long-term interest rates. The bond market in particular seems to be largely responsible for this amplification of the cross-border effects. The results explain this phenomenon partly by the finding that the contagion for most European bond markets has increased in the last decade. The existing literature also adds that domestic activity is increasingly subject to developments in the bond markets. This is due to the fact that central banks all over Europe soon faced the effective zero lower bound, when the economy fell off the cliff in 2007. As a consequence, the focus shifted to influencing the long-term yields as a tool to steer the economy.

The remainder of this thesis is structured as follows. Section 2 briefly reviews the transmission channels that are most commonly referred to in the context of monetary policy spillovers and provides an overview of the

[1]The analyzed European countries are the euro area, Norway, Sweden, Switzerland and the UK

current state of knowledge of these cross-border effects. Section 3 elaborates on the empirical approach of this thesis, the Global VAR. In section 4, I specify and estimate this Global VAR model. To guarantee the correct initial implementation of the model, the two underlying assumptions of the model are verified. In addition, I check whether the model has filtered out all the common factors and shocks that drive the world economy. That way, the remaining interdependencies underlying the results can be correctly interpreted as policy spillovers, which is exactly what this thesis aims at estimating. Section 5 then presents the results. By reporting the contemporaneous effects of foreign variables on their domestic counterparts, this section first provides the reader with an initial picture of the global interlinkages. Then, this section proceeds by analyzing the responses following a hike in American interest rates, which gives the reader a good glimpse of how these shocks propagate. Since this approach is silent as to reasons behind these interest rate changes, I also provide the results of an identified monetary policy shock. Such identification ensures that the changed interest rates are attributed to (discretionary) monetary policy. As the results might be sensitive to the chosen specification, I explore a different identification in the robustness checks. Section 6 then concludes.

2 Literature Review

This section starts with defining monetary policy spillovers, after which it describes the main channels through which such spillovers propagate. Finally, it provides a comprehensive overview of the current state of knowledge about this phenomenon.

2.1 Monetary Policy Spillovers

2.1.1 Definition

Stabilising domestic output and inflation is usually what drives central banks to adjust interest rates. However, the effects of such a monetary policy, aimed at steering domestic economic activity, may inadvertently *spill over* to other economies. This phenomenon is suitably referred to as monetary policy 'spillovers' or 'cross-border effects'.

2.1.2 Transmission Channels

The hike in interest rates in one country affects other countries through multiple channels. The main transmission mechanisms referred to in the literature are

(i) Trade or aggregate demand channel

(ii) Exchange rate channel

(iii) Financial channel

The first two channels draw on Mundell-Fleming-Dornbush framework, while financial channels are only recently emphasized in the spillover literature (Georgiadis, 2016).

The *trade channel* - also known as the *aggregate demand channel* - captures the reduced demand for foreign goods and services in the event of a monetary tightening. That is, a higher US interest rate reduces US income and expenditures, leading to lower demand for both domestic and imported goods in the US. As a result, net exports, and hence the GDP of trading partners, are declining. If so, a country with closer trade ties with the US would also face a greater drop in output when the Fed decides to raise interest rates (Ammer, De Pooter, Erceg, & Kamin, 2016; Georgiadis, 2016).

At the same time, the monetary tightening in the US is also generating positive effects abroad through the *exchange rate channel*. This channel is predicated on the idea that higher US interest rates lead to an appreciation of the dollar through the uncovered interest rate parity[2]. The stronger dollar, in turn, causes American goods around the world to be replaced by now cheaper foreign products. Thus, under flexible exchange rates, the GDP of other countries should increase as a result of improved competitiveness. By contrast, a country that pegs its exchange rate to the dollar would see its GDP fall due to a loss of competitiveness (Ammer et al., 2016; de Guindos, 2019; Georgiadis, 2016).

Finally, there is the *financial channel* that has recently received much attention in the literature and is perhaps the most important mechanism behind the transmission of the US monetary policy to the rest of the world. When the Fed raises interest rates, this is first and foremost felt on the US stock markets, where long-term yields will rise and asset prices will fall.[3] This then leads - through portfolio balance effects among

[2]The uncovered interest rate parity states that in a floating exchange regime, the rates of return on comparable assets between two different countries are equalized.

[3]As a matter of fact, interest rates define the risk-free return. The risk-free return has a major impact on demand for all types of financial securities. When that risk-free return rises, money shifts from financial assets to the safety of guaranteed returns. For example, if the risk-free rate of return rises from 2% to 4%, a bond yielding 5% would become less attractive. The extra yield is not worth taking the risk. Demand for the bond decreases and the yield increases until supply and demand reach a new balance. This also applies to asset prices. Assets become less attractive when the risk-free alternative is better

financially interconnected countries - to both reduced capital flows to and higher yields and lower asset prices in foreign economies. These deteriorated financial conditions hamper foreign GDP growth (Ammer et al., 2016).

The net effect of US monetary policy on other countries, thus, hinges on the relative strength of these three channels. This depends on a number of factors such as the characteristics of the recipient country in question, the time span analyzed (especially financial spillovers tend to amplify as time goes by) and so on (Ammer et al., 2016). It has long been a popular belief that it is also important whether the policy of the originating country was conventional or unconventional. However, this claim has been rejected by many studies that have tested this (Ammer et al., 2016; Curcuru, De Pooter, & Eckerd, 2018; Curcuru, Kamin, Canlin, & Rodriguez, 2018).

The above classification of channels, of course, is a simplification and should only be considered as a guide. It may well be that the exchange rate channel matters but not via the classification here. For example, US monetary policy might have a substantial impact on the international market because import and export prices are expressed in US dollars, regardless of the exchange rate system (Iacoviello & Navarro, 2018; Gopinath, 2015).

Finally, measuring cross-border effects of monetary policy is not an easy task, as global shocks cause synchronized co-movements between countries that are unrelated to monetary policy (de Guindos, 2019).

The following subsections review some of the most important studies in the context of monetary policy spillovers. Since this is an empirical thesis, a greater emphasis is placed on the empirical literature.

2.2 Modelbased Literature

Early work, including, Lubik & Schorfheide (2005) , Tuesta & Rabanal (2006) and De Walque, Smets, & Wouters (2005), measured US monetary policy spillovers to the euro area based on two-country general equilibrium models using Bayesian techniques. Overall, these studies find that monetary policy shocks play only a small role in shaping the dynamics of the real exchange rate between the dollar and the euro and that the spillover effects of these shocks are relatively small.

However, Georgiadis and Jančoková (2017) argue that these studies do not measure correctly, because the New-Keynesian dynamic stochastic general equilibrium (DSGE) models used do not take sufficient account of the financial spill-over effects. Moreover, most of the models in this literature consist of two countries, which means that third country effects and spill-backs are not captured here. The paper by Dees, Pesaran, Smith, & Smith (2010) is an exception. The study attempts to estimate the global effects of US monetary policy using a multi-country New-Keynesian DSGE model that incorporates the insights of the GVAR approach. Their results clearly show the often-forgotten importance of indirect international connections via third country effects. In this way, they show that US monetary policy influences foreign output and inflation as much as it influences the US variables. So, ignoring these global interactions, as most models do, can lead to misleading conclusions.

In short, although earlier work considers only two-country models, the number of studies incorporating multiple countries is growing. The significance of the cross-border effects seems to depend on the chosen specification. Dees, et al. (2010) suggests that the low spillovers found in two-country models may well be the result of erroneously disregarding spill-backs and third country effects. Hence, the empirical studies will have to shed more light on this.

2.3 Empirical Literature

This empirical thesis is related to two strands of literature.

First, this thesis contributes to the growing number of studies on spillovers of US monetary policy shocks to global financial markets. Albagli, Ceballos, Claro, & Romero (2018), for instance, report significant effects of

remunerated. As a result, demand for assets decreases, and so do their prices.

US monetary policy to international bond markets by means of panel regressions. Their findings are threefold. First, the American monetary policy spillovers to long-term bond yields have increased substantially after the global financial crisis. Second, the US' spillovers are at least as large as domestic monetary policy on long-term yields after 2008. Finally, the spillovers operate through different channels and concentrate in risk-neutral rates (expectations of future monetary policy rates) for advanced countries.
Other studies that examine the effects on global financial markets such as foreign equity and bond markets, capital flows and exchange rates include Craine & Martin (2008); Ehrmann & Fratzscher (2009); Fratzscher, Lo Duca, & Straub (2018); Hausman & Wongswan (2011); Moore, Nam, Suh, & Tepper (2013); Neely (2012); Rogers, Scotti, & Wright (2014); Wongswan (2009). These studies find considerable financial cross-border effects stemming from US interest rate changes. Moreover, they show that the characteristics of the recipient country such as financial market structure and integration are key in explaining the cross-country heterogeneity.
This literature generally assumes that the financial spillovers from the ECB rates to US bond spreads or foreign equity markets are less impactful. The asymmetry in the international impact of the Fed and the ECB is said to be rooted in the dominant role of the US dollar in the global financial markets (de Guindos, 2019). However, recent research seems to contradict this view. Curcuru, De Pooter, et al. (2018) compare the cross-border effects between American and German bond markets after FOMC[4] and ECB meetings. The authors find that half of the reaction in German bond yields spill over to US yields after an ECB announcement, which is almost identical to the spillovers of US yields to German yields after a FOMC meeting. This result contrasts with the conventional wisdom that Fed decisions has an impact on other countries, but that there is not much effect in the other direction. In addition, like Albagli, Ceballos, Claro, & Romero (2018), the authors also find slightly higher financial spillovers after the recent crisis.

The second strand of literature focuses on output spillovers. Early work including, Bluedorn & Bowdler, (2011); Canova (2005); Faust & Rogers (2003); Faust, Rogers, Swanson, & Wright (2003); Kim (2001); Kim & Roubini (2000); Maćkowiak (2007); Nobili & Neri (2007), base their empirical findings on a two-country VAR model that involves the US and domestic macroeconomic variables of one additional economy. This literature suggests that US monetary policy spills over substantially to both advanced and emerging economies. For instance, Nobili & Neri (2007) examine the transmission of monetary policy shocks from the US to the euro are using a two-country structural VAR with no exogeneity assumption. They find that the euro immediately depreciates, in line with what the uncovered interest parity condition predicts. But then surprisingly the euro appreciates vis-à-vis the US dollar. Next, the authors report a temporary positive spillover to the euro area in the short-run, while a negative effect emerges in the medium-run. Third, the trade channel appears to contribute negligibly to the international transmission of monetary shocks. Finally, the pass-through of the depreciated euro onto European inflation is limited in the short-run and close to zero in the medium run. However, the aforementioned papers in this literature suffer from methodological constraints. In particular, as they build on two-country VAR models, they do not account for the multilateral nature of global interlinkages. That is, it might well be that spillovers from US monetary policy affect all economies and as such give rise to third-country effects and spill-backs that a bilateral model fails to capture.
By means of panel regressions for fifty advanced and emerging economies, Iacoviello & Navarro (2018) account for these multilateral interdependencies. They find that foreign GDP drops about as much as American output in response to US monetary tightening, and that economic activity shrinks more in emerging economies than in advanced economies.
Another interesting study with a multi-country setup is conducted by Kearns, Schrimpf, & Xia (2018). Their results suggest that there is no evidence that spillovers relate to real linkages such as trade flows. On the other hand, there is some indication that exchange rate regimes influence the extent of spillovers. But by far the strongest determinant of interest rate spillovers is financial openness. That is, stronger interest rate spillovers from the US occur to countries with tighter financial links to the US. Moreover, the spillovers are much more prevalent for long-term interest rates, while short rates do not consistently respond to foreign monetary policy shocks. This result suggests that central banks have been able to retain autonomy in their interest

[4] Federal Open Market Committee

rate policies (in line with Obstfeld (2015)), despite the forces of the global financial cycle. Interestingly, the authors show that the Fed is not the sole originator of spillovers, as they present also significant cross-border effects stemming from the ECB, albeit to a lesser extent. However, the foreign effects from other central banks such as the Bank of England and the Bank of Japan are mild.

A suitable tool for measuring all kinds of spillovers is the GVAR model. The GVAR literature is quickly expanding and has been applied in numerous settings (see Chudik & Pesaran (2016) for a survey). However, the number of studies that employ the GVAR approach to estimate US monetary spillovers is limited. Dees, di Mauro, Pesaran, & Smith (2007) touch briefly on this topic when analyzing international of the euro zone. For the DdPS version of the GVAR, covering 26 countries/regions over a period up to 2003, they find that the effects of an interest rate shock on euro area output and inflation are very small and statistically insignificant at all horizons. By contrast, the effects of long-term interest rates are positive and significant. The European short-term rate, on the other hand, is not affected. These findings reflect the weak interdependencies of the short rates across the two regions, and the stronger co-movement of the long-term yields globally.
Finally, Georgiadis (2016) employs an altered version of the GVAR framework that adds a mixed cross-sectional dimension to the model.[5] The paper estimates this model for a set of 61 countries over a rather limited timeframe from 1999 to 2009, and finds sizable output-spillovers to the rest of the world, when the Fed raises the interest rate. These effects on foreign output are found to be larger than the domestic effects in the US. The author identifies the receiving country's trade and financial integration, de jure financial openness, exchange rate regime, financial market development, labor market rigidities, industry structure and participation in global value chains as the determinants of the cross-border effects. However, this study identifies US monetary policy with sign restrictions, which are not uncontroversial in the context of spillovers.

[5] Georgiadis (2016) exploits the Mixed Cross-Sectional GVAR model proposed by Gross & Kok (2013) to model the common monetary policy in the euro area in a consistent way.

3 Empirical Approach: Global VAR

3.1 Motivation

This thesis employs the Global Vector Autoregression (GVAR) methodology to explore transmission of US monetary policy to European economies. The GVAR approach was developed by Pesaran, Schuermann, & Weiner (2004) in the aftermath of the 1997 Asian financial crisis to quantify the effects of macroeconomic developments on the losses of financial institutions. Although the GVAR approach was originally conceived as a tool for credit risk analysis, it soon became apparent that it has numerous other applications (Chudik & Pesaran, 2016).
The allure of the GVAR approach lies in its simple yet effective way of modelling interactions in a complex high-dimensional system. This feature is particularly appealing in the context of monetary policy spillovers. As a matter of fact, what makes evaluating cross-border effects difficult is that the interlinkages run through a complex net of transmission channels, which are, however, hard to model empirically. The empirical challenge lies in the so-called 'curse of dimensionality'. To see this, suppose there are N countries in the global economy. The aim is to model some country-specific variables such as real output, inflation, interest rates, real exchange rate and real equity prices over time t and across the N countries. Given the tight interlinkages present in the world economy, it is preferable that all country-specific variables are treated endogenously (Dees, di Mauro, Pesaran, & Smith, 2007). Attempting to do so, however, makes empirical estimation infeasible, as too many parameters are to be estimated with respect to the available observations. To overcome this curse of dimensionality, the GVAR framework imposes weak exogeneity of the foreign variables. This implies that foreign variables can influence domestic variables contemporaneously, and in its turn might be affected by lagged changes of the domestic and foreign variables, but are not affected by long-run disequilibria in the domestic economy. Intuitively, the assumption of weak exogeneity infers that each individual country is a relatively small economy with respect to the rest of the world. Thus, one single country does not determine the world economy. This assumption is seen to be a priori plausible considering that the size of most economies (perhaps with the exception of the US) is rather small compared to the global economy, usually not exceeding 5% of world GDP. However, since the assumption of weak exogeneity is key in the GVAR model, it is also empirically tested later in the GVAR procedure (di Mauro & Pesaran, 2013; Smith & Galesi, 2014).

Cut to the bone, the GVAR approach consists of two steps. In the first step, a number of country-specific augmented VAR models, commonly referred to as VARX* models, are estimated conditional on the rest of the world. These VARX* models feature domestic variables and weighted averages of foreign variables. The latter is also referred to as 'star variables' and are treated as weakly exogenous. In the second step, all country-specific VARX* models are stacked, using weights relating to international linkages of each country with the other countries in the sample, and solved simultaneously as one large Global VAR model. The solution can then be used for the analysis of the effects of a shock to the short-term interest rate in one country on the other economies in the model (Chudik & Pesaran, 2016).

3.2 Global VAR framework

Consider a set of N countries, indexed by $i = 1, 2, ..., N$, each featuring k_i variables, observed during the time periods $t = 1, 2, ..., T$. The aim is to combine all variables across N countries in one model, that allows to analyze the effects of a shock in one domestic variable of country i on the variables of other countries. The Global VAR is a useful and practical framework for conducting such analyses. The GVAR approach is set out below. For clarity of exposition, the common global variables and the dominant unit are omitted here. For a detailed explanation of how to include these in the model, the reader is referred to the appendix.

At the core of the GVAR model are country-specific augmented VAR models (i.e. VARX* models). The estimation of these individual VARX* models constitute the first step of the GVAR procedure.
These country-specific models include domestic as well as foreign variables. As discussed earlier, including every single foreign variable into each individual VARX* model will make empirical estimation infeasible

due to the curse of dimensionality. Therefore, the foreign 'star' variables are individually generated for each national VARX* model as weighted averages of the domestic variables. That is,

$$x^*_{it} = \sum_{j=0}^{N} w_{ij} x_{jt},\ w_{ii} = 0,$$

with w_{ij}, $j = 0, 1, ..., N$ a set of weights such that $\sum_{j=0}^{N} w_{ij} = 1$, constructed using data on bilateral foreign trade flows. The individual VARX* models, i.e. VAR models augmented by the vector of 'star' variables x^*_{it} and their lagged values, are expressed in their general form as

$$x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}x_{i,t-1} + ... + \Phi_{ip_i}x_{i,t-p_i} + \Lambda_{i0}x^*_{it} + \Lambda_{i1}x^*_{i,t-1} + ... + \Lambda_{iq_i}x^*_{i,t-q_i} + u_{it}, \tag{1}$$

for $i = 0, 1, 2, ..., N$. The lag orders p_i and q_i of the domestic and foreign variables respectively, is selected using the Akaike information criterion (AIC), computed as

$$AIC_{i,pq} = -\frac{Tk_i}{2}(1 + \log 2\pi) - \frac{T}{2}\log\left|\hat{\Sigma}_i\right| - k_i s_i, \tag{2}$$

The first two terms represent to the maximized value of the log-likelihood function with $\hat{\Sigma}_i = \sum_{t=1}^{T} \hat{u}_{it}\hat{u}'_{it'}/T$ computed based on the estimated residuals $\hat{u}_{it}$ of the individual VARX* models given by (1), T is the sample size, $|\cdot|$ is the determinant of $\hat{\Sigma}_i$, k_i and k^*_i are the number of domestic and foreign variables respectively in the individual models and $s_i = k_i p_i + k^*_i q_i + 2$. Thus in this specification of the criterion, the model with the *highest* AIC value is chosen.
For simplicity purposes, consider the VARX*(2,2) structure:

$$x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}x_{i,t-1} + \Phi_{i2}x_{i,t-2} + \Lambda_{i0}x^*_{it} + \Lambda_{i1}x^*_{i,t-1} + \Lambda_{i2}x^*_{i,t-2} + u_{it}, \tag{3}$$

The individual VARX* models are then transformed into the corresponding vector error correction form (VECMX*), which allows to distinguish between short-run and long-run relations and interpret long-run relations as cointegrating.[6]

$$\Delta x_{it} = c_{i0} - \alpha_i \beta'_i [z_{i,t-1} - \gamma_i(t-1)] + \Lambda_{i0}\Delta x^*_{it} + \Gamma_i \Delta z_{i,t-1} + u_{it}, \tag{4}$$

where $z_{it} = (x'_{it}, x^{*\prime}_{it})$, α_i is a $k_i \times r_i$ matrix of rank r_i containing the speed of adjustment coefficients, and β_i is a $(k_i + k^*_i) \times r_i$ matrix of rank r_i containing the cointegrating vectors.
Partitioning β_i as $\beta_i = (\beta'_{ix}, \beta'_{ix^*})'$, the r_i error correction terms defined by the above equation can be rewritten as

$$\beta'_i(z_{it} - \gamma_i t) = \beta'_{ix}x_{it} + \beta'_{ix^*}x^*_{it} - (\beta'_i\gamma_i)t,$$

allowing for the possibility of cointegration within x_{it} and between x_{it} and x^*_{it}, and therefore across x_{it} and x_{jt}, for $i \neq j$.
The country-specific VECX* models are estimated separately conditional on x^*_{it}, which are assumed to be weakly exogenous. The assumption of weak exogeneity in the context of cointegrating models implies no long-run feedback from the domestic variables, x_{it}, to the foreign variables, x^*_{it}, without necessarily ruling out any lagged short-run feedback between the two sets of variables. In this way, x^*_{it} is said to be 'long-run forcing'[7] for x_{it}. Technically, this means that that the error correction term of the country-specific VECMX* - which measure the extent of disequlibria in the domestic economy - does not affect x^*_{it} significantly (Granger & Lin,

[6] Cointegration of variables exists if their linear combination is stationary. This implies that the series are moving together in the long run, eventually establishing long-term or equilibrium related phenomena (Golitsis, 2018). In this way, the transmission channels are embedded in the GVAR model through the estimated cointegration vectors (Belke & Osowski, 2016).

[7] For example, oil prices are considered to be "long-run forcing" for outputlevels y_t, in the sense that changes in oil prices have a direct influence on y_t. By contrast, oil prices are on their turn not affected by directly influenced by changes in domestic economies (i.e. the presence of the error correction term in the individual country-models) (Garratt et al., 2006).

1995; Johansen, 1992; Garratt, Lee, & Pesaran, 2006). Thus, while fluctuations abroad (i.e. changes in x^*_{it}) have a direct influence on the domestic variables, x_{it}, they are not affected immediately by developments in the domestic economies. Intuitively, weak exogeneity imposes that all countries are small relative to the size of the whole set of countries in the model. This assumption is assessed by testing the joint significance of the estimated error correction terms in auxiliary equations for the country-specific 'star' variables x^*_{it} (Johansen, 1992; Harbo, Jansen, Nielsen & Rahbek, 1998; Smith & Galesi, 2014). In particular, for each l^{th} element of x^*_{it}, the following regression is carried out

$$\Delta x^*_{it,l} = a_{il} + \sum_{j=1}^{r_i} \delta_{ij,l} E\hat{C}M_{ij,t-1} + \sum_{s=1}^{p_i^*} \phi'_{is,l} \Delta x_{i,t-s} + \sum_{s=1}^{q_i^*} \psi'_{is,l} \Delta \tilde{x}^*_{it,t-s} + \eta_{it,l}$$

and the null hypothesis of weak exogeneity is tested,

$$H_0 : \delta_{ij,l} = 0 \text{ for every } j = 1, 2, .., N$$

Typically, the null hypothesis cannot be rejected, implying that the assumption of weak exogeneity is being met.
The estimation of the VECMX* is based on reduced rank regression and takes into account the cointegrating relations that might exist both within the domestic variables and across the domestic and foreign variables. In this fashion, the number of cointegrating relations, r_i, the speed of adjustment coefficients, α_i, and the cointegrating vector, β_i, are obtained for each country-specific-model.
After the estimation of the individual VECX* models, the coefficients of the corresponding VARX* models are easily recovered. This completes the estimation of the country-models in (1) – taking into account the cointegration within and across countries (through the 'star' variables). This concludes the first step of the GVAR approach.

The second step of the GVAR procedure consists of stacking the individual VARX* models, using weights relating to the international linkages of each country with the other countries in the sample, and solving simultaneously as one large Global VAR model.
Starting from the VARX*(p_i, q_i) model from (1) and assuming $p_i = q_i$ for ease of exposition:

$$A_{i0} z_{it} = a_{i0} + a_{i1} t + A_{i1} z_{i,t-1} + ... + A_{ip_i} z_{i,t-p_i} + u_{it},$$

where

$$z_{it} = (x_{it}, x^*_{it})'; A_{i0} = (I_{k_i}, -\Lambda_{i0}), A_{i1} = (\Phi_{ij}, \Lambda_{ij}), \text{for} j = 1, ..., p_i.$$

The so-called link matrix W_i with the trade weights w_{ij} allows the country-specific models to be written in terms of vector x_t, which contains all endogenous variables of the entire system:

$$z_{it} = W_i x_t, \tag{5}$$

where $x_t = (x'_{0t}, x'_{1t}, ..., x'_{Nt})'$ is the $k \times 1$ vector which collects all the endogenous variables of the system, and W_i is a $(k_i + k^*_i) \times k$ matrix. Using the identity given by (5),

$$A_{i0} W_i x_t = a_{i0} + a_{i1} t + A_{i1} W_i x_{t-1} + ... + A_{ip_i} W_i x_{t-p_i} + u_{it}, \text{ for } i = 0, 1, 2, ..., N,$$

The individual models are stacked to yield the model for x_t

$$G_0 x_t = a_0 + a_1 t + G_1 x_{t-1} + ... + G_p x_{t-p} + u_t, \tag{6}$$

where

$$G_0 = \begin{pmatrix} A_{00} W_0 \\ A_{10} W_1 \\ \vdots \\ A_{N0} W_N \end{pmatrix}, G_j = \begin{pmatrix} A_{0j} W_0 \\ A_{1j} W_1 \\ \vdots \\ A_{Nj} W_N \end{pmatrix} \text{for} j = 1, ..., p,$$

$$a_0 = \begin{pmatrix} a_{00} \\ a_{10} \\ ... \\ aN0 \end{pmatrix}, a_1 = \begin{pmatrix} Aa_{01} \\ a_{11} \\ ... \\ a_{N1} \end{pmatrix}, u_t = \begin{pmatrix} u_{0t} \\ u_{1t} \\ ... \\ u_{Nt} \end{pmatrix},$$

and $p = \max(\max p_i, \max q_i)$ across all i. Since G_0 is a known non-singular matrix that depends on the trade weights and parameter estimates, premultiplying (6) by G_0^{-1} leads to the GVAR(p) model

$$x_t = b_0 + b_1 t + F_1 x_{t-1} + ... + F_p x_{t-p} + \epsilon_t \tag{7}$$

where

$$b_0 = G_0^{-1} a_0, b_1 = G_0^{-1} a_1,$$
$$\mathrm{F}_j = G_0^{-1} G_j, j = 1, ..., p, \epsilon_t = G_0^{-1} u_t.$$

All variables are now combined into one system, which allows us to analyze the effects of, say, an American interest rate shock on the American economy as well as on other economies.

4 The Global VAR Model (1979Q2 – 2006Q4/2016Q4)

This section presents the estimation of the Global VAR models used to analyze the research question. As mentioned in the literature review, it is crucial in the context of spillovers to take into account third country effects and spill-backs. Ignoring these indirect global interactions can lead to misleading conclusions. It is therefore of the utmost importance not to narrow down the model to the countries under analysis (in this case the US and the European economies), but to aim at mapping out the entire world economy.
The setup proposed by Dees, di Mauro et al. (2007) (DdPS henceforth) is a fairly successful attempt in this respect. This thesis therefore builds on this DdPS-version of the model and adds a number of structural enhancements, following Smith & Galesi (2014), in order to more accurately reflect the influence of the US on the global commodity variables. The details hereof will be discussed below.

This section first describes the specific setup in 4.1. Then in 4.2, it discusses the construction of the foreign variables and the trade matrix used for this purpose. The latter already offers a peek into the trade channel. Next, subsection 4.3 examines the integration properties of the included variables, because if the variables are found to be I(1), we can allow for cointegration and distinguish between long-and short-run relationships. After completing the aforementioned steps, follows the estimation of the individual VECM* in 4.4. Finally, some validity checks are carried out in 4.5. The first two checks verify the assumption of weak exogeneity and parameter constancy, which are crucial for the initial implementation of the GVAR model. The last check verifies the extent to which the common factors that drive the global economy are filtered out, such that the estimated foreign changes following a US monetary policy shock can be effectively attributed to spillover effects of the policy.

4.1 The Setup of the Model

Following DdPS, the model includes 33 countries accounting for 90% of world GDP. Eight of these 33 countries are among the eleven countries that joined the euro area on January 1, 1999. However, modelling these countries separately is problematic. In fact, the GVAR model is not capable of modelling the ECB's common monetary policy and instead assumes that each euro zone country has sole control over its interest rate, which of course is no longer the case after 1999. In reality, it is the union-wide macroeconomic variables that shape the common policy rate. Recognizing this complication, the GVAR literature conventionally integrates the euro countries into one regional model. Though consistent with the institutional framework of monetary union, the aggregation of individual euro area countries into a single unit does not make it possible to analyze the heterogeneity of the spillovers across the euro area countries.
Figure 1 depicts the 33 countries included in the model. The eight euro countries (in blue) are grouped together and constitute the 'euro-area' regional model. The global model therefore comprises 26 countries/regions.

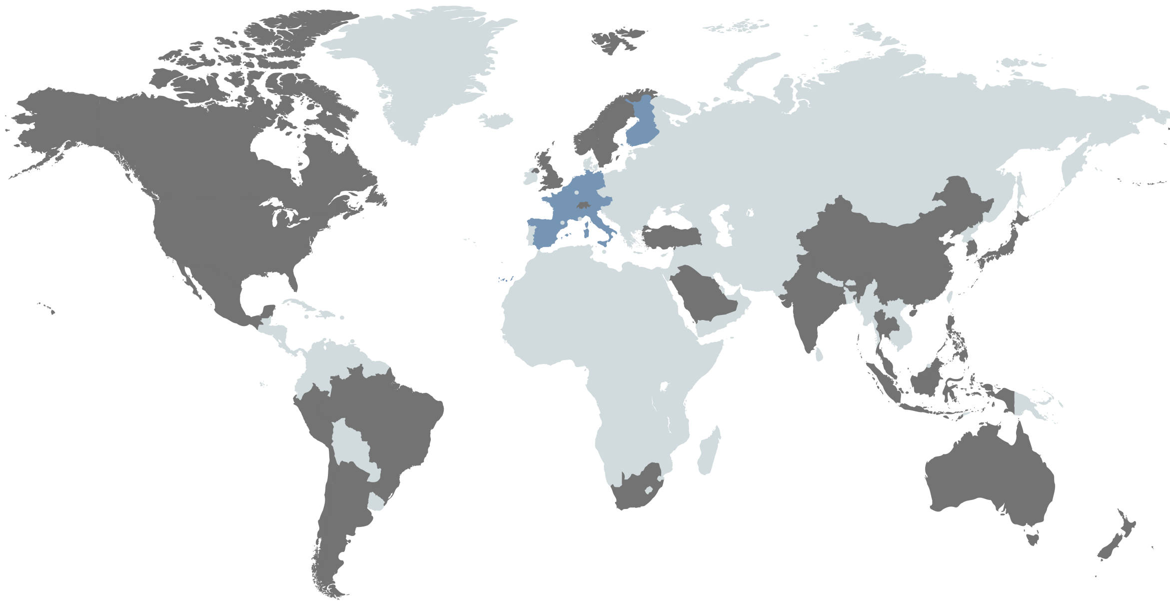
The central question of this thesis is whether the unilateral transmission of the US monetary policy to Europe has become stronger in the wake of the global financial crisis. To answer this question, two GVAR models

Table 1: Country-specific Variables

Real output	$y_{it} = ln(GDP_{it}/CPI_{it})$
Price level	$p_{it} = ln(CPI_{it})$
Real equity prices	$q_{it} = ln(EQ_{it}/CPI_{it})$
Real exchange rate	$e_{it} = ln(E_{it}) – p_{it}$
Short-term interest rate	$i^S_{it} = 0.25xln(1 + R^S_{it}/100)$
Long-term interest rate	$i^L_{it} = 0.25xln(1 + R^L_{it}/100)$
Inflation	$\pi_{it} = p_{it} - p_{i,t-1}$

Note: GDP_{it} is the nominal GDP, CPI_{it} the consumer price index, EQ_{it} the nominal equity price index, E_{it} the exchange rate in terms of US dollars, R^S_{it} the short-term interest rate, and R^L_{it} the long-term interest rate, for country I during the period t.

Figure 1: Included Countries



Note: Countries/regions in the model include USA, Argentina, Australia, Brazil, Canada, Chile, China, India, Indonesia, Japan, Korea, Malaysia, Mexico, New Zealand, Norway, Peru, Philippines, Saudi Arabia, Singapore, South Africa, Sweden, Switzerland, Thailand, Turkey, UK and the Euro-Area as a region. The Euro-Area region includes Austria, Belgium, Finland, France, Germany, Italy, Spain and the Netherlands.

are constructed and then compared. One models the world before the economy fell off the cliff in 2007 and spans the time period 1979Q2 - 2006Q4. The second model extends the period of the first model to 2016Q4 in order to cover the post-crisis years.[8]

As in the DdPS model, the variables included are real output, inflation, real exchange rate, real equity prices and both the short-term and the long-term interest rate, when available. To construct the euro zone variables, the data in Table 1 were collected separately for each country. They were then aggregated across the euro area countries according to the average purchasing power parity (PPP) of GDP.[9][10]
The incorporation of the real exchange rate allows examining the associated channel, while real equity prices and the long-term interest rate capture the financial channels via the stock market and the bond market respectively. In addition, the model contains so-called 'global variables' that also steer the economy. These are commodity prices, such as the price for oil, metal and raw materials. With regard to these variables, the model in this thesis differs greatly from the DdPS model. First, their model does not comprise the metal price and the raw material price, but only the oil price. Moreover, they include the oil price as an endogenous variable in the US model in an attempt to put more weight on the US in the development of these prices. This thesis, in contrast, presents a model that removes the oil price from the US model and instead integrates this variable into a so-called 'dominant unit' model along with the metal price and the raw material price. This dominant unit is no purely exogenous model, but takes into account the developments in the world

[8]Note that these time periods are considerably longer than the DdPS model, which is estimated over the period 1979Q2 - 2003Q4.

[9]For the 1979-2006 sample, the PPP over the period 2002-2004 were used, while for the 1979-2016 sample, the timespan of the PPP was set to 2012-2014

[10]Alternatively, the weights could be based on GDP in US dollars. But the PPP is thought to be a more reliable measure

economy through weighted feedback effects. The importance attributed to each country is based on that country's relative weight in world output measured in Purchasing Power Parity (PPP). In this way, the US, which accounts for 21% of the output produced in the 33-country model, still has the greatest influence on the global variables, while also taking into account other major economies such as China and the euro zone. These global variables (i.e. the oil price, p_t^{oil}, the metal price, p_t^{met}, and the raw material price, p_t^{mat}) along with the country-specific foreign variables (i.e. $y^*_{it}, \pi^*_{it}, q^*_{it}, i^{*S}_{it}, i^{*L}_{it}$) enter the separate VECX* models as weakly exogenous. Recall that the assumption of weak exogeneity implies that all countries are small relative to the world economy. Due to the dominant role that the US plays in the global economy, it was initially thought that the US-specific foreign output and inflation variables, $y^*_{US,t}$, and $\pi^*_{US,t}$, would not satisfy the assumption of weak exogeneity and were therefore not included in the US model by earlier GVAR models, such as Pesaran et al. (2004). However, by excluding these variables, any possible second round effects of external shocks on the US are lost. It is for this reason that these variables are included in the model presented here. Since the assumed weak exogeneity is crucial for the proper functioning of the GVAR model, it is of course tested in the validity checks. These tests confirm that the exclusion of $y^*_{US,t}$, and $\pi^*_{US,t}$ is unnecessary, since these variables are in fact weakly exogenous. However, the US financial foreign variables, $q^*_{US,t}$, $i^{*S}_{US,t}$, and $i^{*L}_{US,t}$ do not satisfy this assumption, and are therefore not included in the US model. Given the importance of the US in the global financial markets, this result does not come as a surprise.
Table 2 schematically illustrates the specification of the individual country models

Table 2: Country Specific Models

	Dominant Unit		USA		Other Countries	
Variables	endogenous	feedback	endogenous	foreign	endogenous	foreign
Real output	-	y^f	$y_{US,t}$	y^*_{USt}	y_{it}	y^*_{it}
Inflation	-	π^f	$\pi_{US,t}$	π^*_{USt}	π_{it}	π^*_{it}
Real equity prices	-	q^f	$q_{US,t}$	-	q_{it}	q^*_{it}
Real exchange rate	-	e^f	-	e^*_{USt}	e_{it}	-
Short-term interest rate	-	i^{Sf}	$i^S_{US,t}$	-	i^S_{it}	i^{S*}_{it}
Long-term interest rate	-	i^{Lf}	$i^L_{US,t}$	-	i^L_{it}	i^{L*}_{it}
Oil price	p^{oil}	-	-	p^{oil*}	-	p^{oil*}
Raw material price	p^{mat}	-	-	p^{mat*}	-	p^{mat*}
Metal price	p^{met}	-	-	p^{met*}	-	p^{met*}

The next subsections elaborate on the estimation of the GVAR models. Since displaying the estimation results of each of the 26 countries/regions takes up a lot of space, only the estimates of the relevant countries are reported here. These countries are the euro zone, Norway, Sweden, Switzerland, the UK and the USA. A complete overview of the estimates and tests are available on request.

4.2 Trade Weights

As described in the methodological section, the country-specific foreign variables, $y^*_{it}, \pi^{*}*_{it}, q^*_{it}, i^{*S}_{it}, i^{*L}_{it}$ are created using weights. Studies show that the use of trade weights is the most appropriate for constructing these variables. For example, Baxter and Kouparitsas (2004) identify bilateral trade as the main determinant of the international business cycle co-movement. This finding is further supported by Imbs, (2004). In his research on the effect of trade, finance and specialization on the synchronization of business cycles, the author finds that trade plays an important role. In addition, he observes that patterns of specialization also influence the business cycle and that strong financial interrelationships between countries also ensure that these countries are considerably more synchronized. These cross-country linkages in the financial markets are, however, also largely determined by direct trade, according to Forbes and Chinn (2003).
In view of these arguments, fixed trade weights based on the average trade flows calculated over 2002 - 2004

are used for the model that ranges up to 2006Q4 and the average trade flows of 2012 - 2014 for the post-crisis model.[11]

Table 3 lists the trade weights used to construct the country-specific foreign variables. In addition to the countries under analysis, both China's and Japan's trade shares are also displayed, as they belong to the main trading partners of the USA and Europe.

The trade matrix enables us to gain interesting insights into the trade channel. As pointed out in the literature review, if the trade channel indeed does have a key role in the international transmission of US monetary policy, a country with stronger trade linkages with the US would also face a greater downswing in output if the Fed decides to raise interest rates. However, the US trade share in the European economies in fact has fallen. Likewise, Europeans did also see their trade share in the US economy fall.
Also noteworthy is the very high shares of the euro area in the trade of the other European economies, i.e. Norway, Sweden, Switzerland and the UK. Although these shares decrease in the 1979 - 2016 model, they remain around 50%. This result suggests that other European economies contribute significantly to the transmission of shocks to a European economy through second-round effects. However, as mentioned above, these shares have also declined in the last decade.

Overall, the matrix reveals that in almost all focus countries there has been a reduction in the weight of formerly close trading partners - the US or the European economies - over the last decade to the benefit of China and the rest of the World. As has been mentioned repeatedly, the main finding of this thesis is that the transmission of US monetary policy to Europe has been intensified after the crisis. If the so-called trade channel lies behind this, then that should be reflected in closer trade relations between the US and the European economies in the post-crisis period. However, there seem to be no evidence to support this.

Table 3: Bilateral Trade Shares

	1979 - 2006								
	China	Euro-Area	Japan	Norway	Sweden	Switzerland	UK	USA	Rest World
China	0.00	0.17	0.22	0.00	0.01	0.01	0.03	0.22	0.35
Euro-Area	0.09	0.00	0.06	0.03	0.06	0.09	0.23	0.21	0.24
Japan	0.19	0.13	0.00	0.00	0.01	0.01	0.03	0.26	0.37
Norway	0.03	0.47	0.02	0.00	0.13	0.01	0.17	0.08	0.08
Sweden	0.03	0.54	0.03	0.10	0.00	0.02	0.10	0.10	0.09
Switzerland	0.02	0.68	0.03	0.00	0.01	0.00	0.06	0.10	0.09
UK	0.03	0.54	0.04	0.03	0.03	0.02	0.00	0.16	0.15
USA	0.11	0.16	0.10	0.00	0.01	0.01	0.05	0.00	0.56
	1979 - 2016								
	China	Euro-Area	Japan	Norway	Sweden	Switzerland	UK	USA	Rest World
China	0.00	0.16	0.12	0.00	0.01	0.02	0.03	0.20	0.47
Euro-Area	0.16	0.00	0.04	0.03	0.05	0.09	0.18	0.16	0.28
Japan	0.26	0.09	0.00	0.00	0.00	0.01	0.02	0.18	0.44
Norway	0.05	0.45	0.02	0.00	0.10	0.01	0.21	0.06	0.10
Sweden	0.06	0.54	0.02	0.13	0.00	0.01	0.09	0.06	0.10
Switzerland	0.06	0.52	0.02	0.00	0.01	0.00	0.11	0.10	0.17
UK	0.08	0.50	0.02	0.04	0.02	0.06	0.00	0.12	0.16
USA	0.18	0.14	0.07	0.00	0.00	0.02	0.03	0.00	0.56

Source: IMF Direction of Trade Statistics.

Note: An entry presents the share of trade (exports and imports) of the column country in total trade of the row country. The complete trade matrix is provided in the appendix.

[11] As an average over three years gives a better picture of the existing trade relations than a one-year snapshot, this is opted for to construct the tradeweights.

4.3 Unit Root Tests

What makes the GVAR so appealing when analyzing cross-border effects, is that it allows to distinguish between short- and long-term relationships and to interpret the long-term relationships as cointegrating. To exploit this feature of the GVAR methodology, the variables included are assumed to be integrated of order one (i.e. I(1)).[12]

In the following, this assumption is examined by testing the included variables in levels and in differences for a unit root. The test used here is the weighted symmetric estimation of ADF type regressions (henceforth WS) introduced by Park & Fuller (1995). The WS test exploits the reversibility over time of stationary autoregressive processes to increase their power performance. As such, the WS test outperforms the traditional Dickey-Fuller test (DF), which has a widely accepted poor power performance. Moreover, the WS test performs better than the standard ADF test or the GLS-ADF test of Elliott, Rothenberg, & Stock (1996). Proof of this is provided by Leybourne, Kim & Newbold, (2005) and Pantula, Gonzalez-Farias, Wayne, & Fuller, (1994). The Akaike Information Criterion selects the lag length based on the ADF regressions for the WS unit root tests. Table 4 and 5 present the unit root tests based on the WS test statistics for the relevant subset of countries. All variables appear to be indeed integrated of order one. An exception to this is UK's output that is borderline I(1)/I(2) in the sample that reaches up to 2006. According to the standard ADF test, however, the variable in question is I(1). In addition the Swiss inflation also seems to be borderline I(0)/I(1) in the pre-crisis model. However, these two variables are I(1) in the model with the longer time span.

Table 4: Unit Root Tests: 1979 - 2006

	Unit Root Tests: levels														
	domestic						foreign						global		
	y	π	q	e	i^S	i^L	y^*	π^*	q^*	e^*	i^{S*}	i^{L*}	p^{oil}	p^{mat}	p^{met}
Euro-Area	1.27	-0.04	-0.28	-0.63	-1.67	-0.97	0.89	-1.61	0.14	0.28	-1.51	-0.69	–	–	–
Norway	1.67	-1.89	-0.37	0.00	-1.61	-1.09	0.79	-0.56	-0.01	-0.21	-1.31	-0.70	–	–	–
Sweden	1.68	-1.83	0.02	-1.33	-1.48	-0.63	1.21	-0.43	-0.03	-0.22	-1.20	-0.78	–	–	–
Switzerland	1.63	-3.06^o	-0.09	-0.51	-2.17	-1.51	1.16	-0.45	-0.12	-0.38	-1.24	-0.85	–	–	–
UK	-0.62	-0.77	-0.31	0.30	-1.70	-0.65	1.65	-0.40	0.01	-0.33	-1.27	-0.83	–	–	–
USA	1.52	0.36	-0.26		-1.94	-1.66	1.10	-1.36	-0.04	0.33	-1.03	-0.80	–	–	–
Dominant Unit	–	–	–	–	–	–	–	–	–	–	–	–	-1.70	-1.04	-1.39
	Unit Root Tests: first differences														
	domestic						foreign						global		
	y	π	q	e	i^S	i^L	y^*	π^*	q^*	e^*	i^{S*}	i^{L*}	p^{oil}	p^{mat}	p^{met}
Euro-Area	-3.65	-6.00	-6.49	-6.46	-3.60	-5.01	-4.18	-6.70	-6.67	-6.67	-10.11	-5.63	–	–	–
Norway	-6.55	-7.30	-7.23	-6.70	-8.21	-6.91	-3.77	-5.81	-6.57	-4.49	-5.24	-5.57	–	–	–
Sweden	-3.29	-6.57	-6.48	-4.18	-7.70	-6.70	-4.46	-7.37	-6.65	-6.55	-5.81	-5.41	–	–	–
Switzerland	-4.96	-10.72	-6.38	-7.11	-4.68	-5.80	-3.92	-6.12	-6.55	-4.63	-5.92	-5.29	–	–	–
UK	-2.13^h	-7.14	-7.23	-5.25	-6.28	-7.21	-4.31	-7.28	-6.57	-4.59	-5.78	-5.45	–	–	–
USA	-4.52	-8.11	-5.86		-3.54	-5.64	-5.60	-5.77	-6.42	-3.34	-11.46	-4.92	–	–	–
Dominant Unit	–	–	–	–	–	–	–	–	–	–	–	–	-8.46	-5.08	-4.35

Source: own calculations.

Note: The optimal number of lagged differences is determined by AIC. If the absolute value of an entry is greater than 2.55 (WS test statistic), a unit root is rejected at the 5% significance level. All variables are integrated of order 1 except for ^{o} integrated of order 0; ^{h} integrated of a higher order.

[12] However, the GVAR methodology can also be applied to stationary variables, but this would also entail a loss of information.

Table 5: Unit Root Tests: 1979 - 2016

	Unit Root Tests: levels														
	domestic						foreign						global		
	y	π	q	e	i^S	i^L	y^*	π^*	q^*	e^*	i^{S*}	i^{L*}	p^{oil}	p^{mat}	p^{metal}
Euro-Area	1.33	-0.56	-0.96	-0.88	-1.20	-0.64	1.47	-1.76	-0.22	-0.34	-1.53	-0.35	–	–	–
Norway	1.87	-2.19	-0.98	-0.58	-1.43	-0.79	1.00	-1.00	-0.48	-0.60	-0.95	-0.29	–	–	–
Sweden	1.25	-2.17	-0.07	-1.37	-1.29	-0.36	1.26	-1.03	-0.62	-0.62	-0.84	-0.45	–	–	–
Switzerland	1.27	-2.07	-0.44	-0.37	-1.98	-0.95	1.39	-0.90	-0.56	-0.54	-1.12	-0.49	–	–	–
UK	-0.29	-0.96	-0.61	-0.26	-1.13	-0.08	1.63	-0.83	-0.51	-0.63	-1.01	-0.54	–	–	–
USA	1.14	-0.14	-0.04		-1.33	-1.30	1.67	-1.53	-0.58	-0.02	-1.16	-0.51	–	–	–
Dominant Unit	–	–	–	–	–	–	–	–	–	–	–	–	-1.62	-1.24	-1.71
	Unit Root Tests: first differences														
	domestic						foreign						global		
	y	π	q	e	i^S	i^L	y^*	π^*	q^*	e^*	i^{S*}	i^{L*}	p^{oil}	p^{mat}	p^{metal}
Euro-Area	-4.80	-7.36	-5.75	-7.85	-4.48	-5.73	-5.46	-8.26	-7.95	-8.09	-11.76	-6.59	–	–	–
Norway	-6.13	-8.95	-6.21	-8.13	-9.26	-8.43	-5.18	-7.66	-7.97	-7.97	-10.22	-6.26	–	–	–
Sweden	-5.16	-7.50	-7.73	-7.70	-8.77	-7.63	-5.40	-7.18	-8.12	-7.98	-9.92	-6.02	–	–	–
Switzerland	-4.59	-8.50	-7.39	-8.44	-5.51	-6.63	-5.28	-7.15	-8.08	-7.94	-6.44	-5.98	–	–	–
UK	-3.71	-8.86	-8.14	-6.24	-7.33	-8.70	-5.33	-8.09	-8.00	-7.92	-7.14	-6.07	–	–	–
USA	-4.98	-10.57	-7.20		-4.13	-6.48	-6.19	-6.70	-8.11	-7.94	-13.08	-5.70	–	–	–
Dominant Unit	–	–	–	–	–	–	–	–	–	–	–	–	-9.94	-6.05	-5.49

Source: own calculations.

Note: The optimal number of lagged differences is determined by AIC. If the absolute value of an entry is greater than 2.55 (WS test statistic), a unit root is rejected at the 5% significance level. All variables are integrated of order 1 except for $^{o}integratedoforder0;^{h}integratedofahigherorder.$

4.4 Estimation of the Country-Specific Models

Now that the setup of the individual country-models has been specified, the country-specific foreign variables have been constructed and the integration properties of the variables have been examined, it is time to estimate the individual VECX* models. To this end, the first step is to select the order of the individual VARX*(p_i, q_i) models, where p_i denotes the lag order of the domestic variables and q_i denotes the lag order of the foreign ('star') variables. The Akaike information criterion selects a p_i of at most two, while the q_i, with the exception of the US and EA, is fixed at one owing to data limitations (Dees, di Mauro, et al., 2007). The selected lags are shown in Table 6. Next, the cointegration relationships are determined according to Johansen's trace statistic, which is known to yield better results than the maximum eigenvalue statistic in small samples. The number of cointegration relationships is further adjusted using both the eigenvalues which contain information about the stability of the GVAR model as a whole, and the persistence profiles (PPs) which refer to the time profiles of the effects of variable-specific shocks on the cointegrating relations. Thus, PPs allow us to verify the convergence behavior of the assumed cointegration relationships in each individual VECX* model and to adjust them when needed.

As an additional check, each individual VECX* model is subjected to the F-version of the LM test for residual serial correlation. This test reveals that there is overall weak evidence of serial correlation in the residuals for the chosen specification.

Table 6: VARX* Order and Number of Cointegration Relationships

	1979 - 2006			1979 - 2016		
	VARX*(p_i, q_i)		Rank	VARX*(p_i, q_i)		Rank
	p_i	q_i		p_i	q_i	
Euro-Area	2	2	2	2	1	1
Norway	2	1	2	2	1	3
Sweden	2	1	3	2	1	2
Switzerland	1	1	3	1	1	3
UK	2	1	3	1	1	2
USA	2	2	2	2	1	2

Note: A complete overview of the selected lags and ranks is provided in the appendix

4.5 Validity Checks

The modelling exercise begun under the assumption that country-specific 'star' variables are weakly exogenous, and that the individual models' parameters are stable over time. These assumptions are crucial for the initial implementation of the GVAR model and thus their validity is examined in 4.5.1 and 4.5.2. Moreover, what makes the GVAR model particularly appealing in the context of spillovers, is that it claims to capture the common effects that drive the world economy. That is, by conditioning the country-specific variables on weakly exogenous foreign variables and commodity prices, viewed as proxies for the common 'global' factors, the GVAR approach contends that the remaining correlation of the shocks across countries will be weak (Dees, di Mauro, et al., 2007). These residual interdependencies can therefore be interpreted as policy spillovers. It is exactly this what this thesis aims to capture, and thus this key-assumption will be tested in 4.5.3.

4.5.1 Testing Weak Exogeneity

Section 3.2 on the Global VAR framework provides a formal way of testing the assumption that country-specific foreign variables are weakly exogenous with respect to the long-run parameters. The test results indicate that the weak exogeneity assumption could not be rejected for most of the variables.

Table 7 summarizes the F-test results for the set of focus countries and shows that the exogeneity hypothesis is only rejected for UK's output in the 1979-2006 model. A greater concern would be, if weak exogeneity were rejected in the US or euro area models. However, the tests reveal that the euro area's foreign variables can be considered weakly exogenous, which is not self-evident after grouping the euro-members into one single unit. Also, the included US foreign variables turn out to be weakly exogenous. As expected, US foreign real equity prices and foreign interest rates fail the test and are therefore not included in the model for the USA.

Table 7: F-statistics for Testing the Weak Exogeneity of the Foreign and Global Variables

		y^*	π^*	q^*	e^*	i^{S*}	i^{L*}	p^{oil}	p^{mat}	p^{met}
1979 - 2006										
Euro-Area	F(2,76)	0.62	0.45	2.30		0.62	1.90	0.81	1.04	0.39
Norway	F(2,84)	0.67	0.10	0.42		1.75	1.38	0.62	0.65	0.69
Sweden	F(3,83)	0.80	0.48	1.71		1.54	1.32	0.96	0.22	0.75
Switzerland	F(3,90)	0.61	1.56	1.07		0.28	0.03	0.16	0.36	0.11
UK	F(3,83)	1.97	4.27*	0.09		1.32	0.18	1.84	1.32	1.49
USA	F(2,82)	2.19	1.98		2.61			0.11	2.10	0.67
1979 - 2016										
		y^*	π^*	q^*	e^*	i^{S*}	i^{L*}	p^{oil}	p^{mat}	p^{met}
Euro-Area	F(1,125)	0.31	1.11	0.08		1.03	0.49	0.00	0.56	2.78
Norway	F(3,123)	1.66	1.36	1.07		1.11	2.09	0.08	0.24	0.73
Sweden	F(2,124)	0.74	0.43	0.02		0.22	0.30	0.74	0.21	1.73
Switzerland	F(3,130)	1.88	0.79	1.79		0.59	0.30	1.12	0.81	0.42
UK	F(2,131)	2.74	0.55	0.06		0.70	0.86	0.98	2.23	0.92
USA	F(2,128)	0.69	1.89		0.44			1.28	2.74	2.78

Source: own calculations.

*Note: * rejected at the 5% significance level.*

4.5.2 Testing for Structural Breaks

One of the most feared problems in macro-econometric modelling is the potential presence of structural breaks. This problem can arise especially in the case of emerging economies, since these countries often undergo significant political changes. While structural breaks are the subject of much research, it remains unclear how to deal with it.[13]

The GVAR model too is not completely immune to this issue, although it does alleviate the problem. Indeed, as the country-specific models are conditional on foreign variables, a global crisis can be confined to the model of the originating country. For instance, when the US housing market collapsed in 2007, the subsequent crash of the American stock market had strong spillovers to the rest of the world. Since the other country models are specified conditional on the US equity returns they need not to be subject to similar breaks. Thus, the GVAR model accommodates this so-called 'co-breaking' (Hendry & Mizon,1976). This way, the VECX* models that lie at the core of the GVAR might be robust to the possibility of structural breaks.

Table 8 presents the results of the structural stability tests included in the analysis. Among the considered tests are the maximal OLS cumulative sum (CUSUM) statistic, proposed by Ploberger & Kramer (1992). This test is denoted by PK_{sup} and its mean square variant PK_{msq}. The table also lists the Nyblom-test and its robust variant, which tests for parameter constancy against non-stationary alternatives (Nyblom, 1989). Other tests included are the Wald-type tests of a one-time structural change at an unknown change point. These are the Wald form of Quandt's (1960) likelihood ratio statistic (QLR), the mean Wald statistic (MW) proposed by Hansen (1992) and Andrews & Ploberger (2006), as well as the Wald statistic based on the exponential average (APW) also introduced by Andrews & Ploberger (2006). The 90%-critical values are computed under the null of parameter stability and calculated using sieve bootstrap samples from the GVAR solution given by equation (6).[14]

What is striking from the table, is that the results seem not to vary much across variables, whereas they do significantly across the tests. The rejection rate seems to depend greatly on whether heteroskedasticity-robust versions of these tests are used. This finding suggests that once allowing for possible changes in error variances, the parameter coefficients appear to be reasonably stable. At least, based on the robust-version of the tests, the hypothesis of coefficient stability seem to hold for 85% of the cases. The rejection rate is, however, much higher in the non-robust version of the Nyblom, QLR, MW and APW tests. These rejections seem to be driven by the breaks in error variances and not the parameter coefficients, as the test outcomes of the robust-versions of the tests reveal. This view is underpinned by studies, such as Watson & Stock (2002), Artis, et al. (2004) and Cecchetti, Flores-lagunes, & Krause (2005) that find statistically significant evidence of changing volatility.

In sum, the evidence of structural instability seems to be mainly driven by error variances. To account for this problem of changing error variances, robust standard errors are employed when analyzing the contemporaneous effects of the foreign variables on the domestic counterparts in section 5.1, while bootstrap means and confidence bounds provide the basis of the impulse response analysis in section 5.2.

[13] Although in-sample breaks could be identified with Bayesian or classical procedures, there is no way to allow for the possibility of future breaks in policy analysis and forecasting (Clements & Hendry, 1998; Clements, & Hendry, 1999; Pesaran, Pettenuzzo, & Timmermann, 2006; Stock & Watson, 1996).

[14] The critical values in Stock & Watson (1996) are not applicable in the GVAR setting, as they assume predetermined regressors.

Table 8: Tests for Parameter Constancy per Variable Across the Country-Specific Models

	Domestic variables						Numbers	%
	y	π	q	e	i^S	i^L		
	[26]	[26]	[19]	[25]	[25]	[13]		
Pk_{sup}	2	2	0	0	2	0	6	4.5
PK_{msq}	2	1	0	1	0	0	4	3
robust-Nyblom	0	0	0	4	2	1	7	5.2
QLR	9	14	8	7	13	10	61	45.5
robust-QLR	0	4	2	8	4	2	20	14.9
MW	4	4	3	7	7	6	31	23.1
robust-MW	0	5	2	9	2	3	21	15.7
APW	9	14	7	8	13	10	61	45.5
robust APW	0	5	3	9	4	2	23	17.2

Source: own calculations.

Note: number of rejections of the null of parameter constancy per variable across the country-specific models at the 1% level. Statistics with the prefix 'robust' denote the heteroskedasticity-robust version of the tests. All tests are implemented at the 1% significance level.

4.5.3 Average Pair-Wise Cross-Section Correlations

When analyzing impulse responses from one country to another, the 'idiosyncratic' shocks of the individual countries are ideally weakly correlated across countries/regions. This ensures that the common factors that drive the global economy are filtered out. That way, any remaining residual interdependencies reflect policy spillover effects, which is exactly what this thesis aims to estimate.

The weak exogeneity tests performed in 4.4.1 indirectly support the view that idiosyncratic shocks could only be weakly correlated. However, a direct and simple diagnostic test of this key-assumption is analyzing the average pairwise cross-section correlations. The premise of this test is that by conditioning the individual VECX* models on weakly exogenous foreign variables - which serve as proxies for the common factors- the correlation of the remaining shocks across countries is likely to be limited. This degree of correlation is computed for the levels and first differences of the endogenous variables, as well as for the residuals of the estimated VECX* models. If the GVAR model indeed manages to filter out the common factors such that the individual models are indeed cross-sectionally weakly correlated, then this should be reflected in greatly reduced pair-wise correlations of the VECX* residuals.
Table 9 shows that the average cross-sectional correlations are high for the endogenous variables in levels, ranging from roughly 40% to 95%. These correlations fall after first differencing, but remain quite high. The VECX* models, however, seem to have filtered out most of the common global factors, as the correlation of the residuals drop significantly. The degree of correlation lies close to zero with the exception of real exchange rates. Dees, di Mauro, et al. (2007) find similar results.
Overall, the results underline the importance of conditioning individual models on country-specific foreign variables in dealing with often significant global interdependencies.

In summary, the two main assumptions of the GVAR model - the weak exogeneity and the parameter stability - have been verified and found valid. This ensures a correct initial implementation of the model. The third validity check examines whether the model also estimates what it needs to estimate, namely policy spillover effects. In other words, the shocks must be weakly correlated across countries. A direct diagnostic test shows that this is indeed the case, as the common factors that drive the world economy have been successfully filtered out in the GVAR model.

Table 9: Average Pair-Wise Cross-Section Correlations of All Variables and Residuals

	1979 - 2006			1979 - 2016		
	Real output					
	Levels	First Diff.	VECMX* Residuals	Levels	First Diff.	VECMX* Residuals
Euro-Area	0.96	0.15	-0.04	0.96	0.26	-0.02
Norway	0.96	0.08	-0.01	0.97	0.10	-0.01
Sweden	0.95	0.13	0.03	0.97	0.19	0.02
Switzerland	0.95	0.14	0.02	0.97	0.20	0.01
UK	0.96	0.10	0.01	0.97	0.18	-0.01
USA	0.96	0.15	-0.03	0.97	0.21	-0.04
	Inflation					
Euro-Area	0.45	0.12	0.03	0.48	0.16	0.05
Norway	0.38	0.08	0.05	0.38	0.08	0.03
Sweden	0.45	0.07	0.04	0.48	0.10	0.06
Switzerland	0.38	0.06	0.03	0.43	0.10	0.05
UK	0.45	0.05	0.00	0.47	0.11	0.00
USA	0.42	0.14	0.03	0.44	0.19	0.07
	Real equity prices					
Euro-Area	0.77	0.49	-0.08	0.77	0.56	-0.12
Norway	0.79	0.40	0.06	0.80	0.49	0.05
Sweden	0.75	0.44	-0.02	0.78	0.51	0.00
Switzerland	0.77	0.48	0.00	0.79	0.53	-0.01
UK	0.78	0.49	-0.02	0.77	0.56	-0.01
USA	0.77	0.45	-0.02	0.78	0.54	0.00
	Real exchange rate					
Euro-Area	0.65	0.30	0.25	0.80	0.36	0.28
Norway	0.66	0.30	0.23	0.82	0.40	0.27
Sweden	0.63	0.27	0.20	0.78	0.36	0.23
Switzerland	0.66	0.27	0.23	0.83	0.31	0.26
UK	0.65	0.27	0.18	0.79	0.33	0.19
USA	-	-	-	-	-	-
	Short-term interest rate					
Euro-Area	0.57	0.16	0.05	0.69	0.18	0.08
Norway	0.50	0.03	-0.02	0.65	0.05	0.01
Sweden	0.59	0.08	-0.02	0.71	0.10	0.00
Switzerland	0.40	0.08	0.00	0.57	0.09	0.00
UK	0.57	0.13	0.01	0.70	0.15	0.04
USA	0.47	0.11	0.04	0.63	0.11	0.04
	Long-term interest rate					
Euro-Area	0.77	0.40	-0.06	0.85	0.43	-0.09
Norway	0.75	0.25	0.01	0.85	0.31	0.01
Sweden	0.80	0.32	0.04	0.88	0.37	0.01
Switzerland	0.67	0.34	0.02	0.80	0.37	0.01
UK	0.77	0.34	0.01	0.86	0.39	-0.01
USA	0.73	0.35	-0.02	0.84	0.39	0.00

Source: own calculations.

5 Results

The results section is split up in a static and a dynamic part.
It first examines the contemporaneous effects of foreign variables on their domestic counterparts within the same quarter. This gives a (static) picture of the existing global interlinkages for a particular variable.
Then, the section discusses the results from the impulse response analysis, which simulates the dynamics in the world economy over time after a positive shock to US interest rates.[15] Finally, it checks the robustness of the results.

5.1 Contemporaneous Effects of Foreign Variables on Their Domestic Counterparts

Table 10 displays the effects of the foreign variables on their domestic counterparts within the same quarter. The significance of these estimates is based on White's heteroskedastic-robust t-ratios to account for error variances (cfr. 4.5.2 Testing for Structural Breaks). These effects can be regarded as impact elasticities between domestic and foreign variables, and are informative as regards the international linkages.

Table 10: Contemporaneous Effects of Foreign Variables on Their Domestic Counterparts

		Domestic Variables				
		y	π	q	i^S	i^L
Euro Area	1979-2006	0.65***	0.14	1.01***	0.10**	0.60***
	1979-2016	0.54***	0.15**	1.10***	0.05**	0.68***
Norway	1979-2006	0.45	0.64*	0.99***	0.05	0.68***
	1979-2016	0.58**	0.76***	0.98***	0.05	0.74***
Sweden	1979-2006	1.23***	0.61**	1.27***	0.31*	0.96***
	1979-2016	1.27***	0.67***	1.08***	0.28*	0.92***
Switzerland	1979-2006	0.69***	0.31**	0.95***	0.18*	0.55***
	1979-2016	0.33**	0.15	0.92***	0.19***	0.56***
UK	1979-2006	0.39**	0.59***	0.86***	0.19	0.89***
	1979-2016	0.60***	0.59***	0.79***	0.16	0.82***
USA	1979-2006	0.56***	0.03	_	_	_
	1979-2016	0.52***	0.07	_	_	_

Source: own calculations.

*Note: significance * 5%; ** 1%; *** 0.1% based on White's heteroskedastic-robust t-ratios*

In line with the expectations, most elasticities turn out to be positive and highly significant. For instance, changes in foreign output affect domestic activity significantly. What stands out, is the estimate for Sweden that is greater than one, which implies that Swedish output tends to overreact to changes in foreign GDP. This is to a great extent a reflection of the high degree of trade openness of the Swedish economy.
Domestic prices, on the other hand, appear to be less influenced by foreign inflation in most countries. The table shows even a zero-effect of foreign prices on American inflation.
Turning to the equity markets, the degree of interlinkages is striking. The elasticities are close to one and for the Euro-Area and Sweden, they are even greater than one, implying that these equity markets are much more volatile.

[15] The impulse response analysis should be seen as a counterfactual dynamic simulation. For instance, the responses of Swedish output do not only take into account the direct effect of higher US interest rates (the shocked variable), but also the indirect effects. That is, the analysis also includes the change in Swedish output coming from fluctuations in all variables of all countries over time (e.g. Swedish real equity prices, Chinese inflation, oil prices, Mexican interest rates etc.) resulting from a positive US interest rate shock.

The elasticity-estimates of interest rates reveal a very interesting picture. While impact-elasticities of short-term interest rates are rather limited, those of the long-term yields are sizable and highly significant. Moreover, the interdependencies on the bond markets increased over the last decade for most countries. This result supports the view in the literature that while relationships across short-term rates are weak, the linkages across long-term rates are very high, significant and strengthening.

In sum, the estimates of the impact elasticities demonstrate the significance of the global interlinkages across all variables with the exception of short-term interest rates. Moreover, the financial linkages are likely to be particularly strong through the equity and bond market channels. Finally, in line with the literature reviewed in section 2 these results support the view that while the linkages between bond markets are strong, the interdependencies between monetary policy reactions are not.

5.2 Impulse Response Analysis

Impulse response functions visualize the timeline of all variables in the dynamic system after a variable-specific shock (such as changes in oil prices, short-term interest rates etc.) or an identified shock. Examples of such an identified shock are changes in monetary policy, demand or technology. The identification is based on suitable economic theory.
An interest rate shock differs from an identified monetary policy shock in that it does not provide information about the causal relationships between the variables *in the country of origin.* However, such analyses may be informative regarding the propagation mechanisms of shocks *between different countries* (Ricci-Risquete & Ramajo-Hernández, 2015). This is exactly why the impulse responses of such unidentified shocks are still instructive in the context of spillover effects.

In the following, the responses to a variable-specific shock - a hike in the US short-term interest rates - are examined first. Then follows the identification of a US Monetary Policy shock. This is done using an ordering of variables that is standard in the literature. Since responses might be sensitive to how the shock is identified, the robustness of the results is tested against an alternative identification in section 6.

5.2.1 GIRF: Shock to US Short-Term Interest Rate

Typically the GVAR framework relies on Generalized Impulse Response Functions (GIRF) for the impulse response analysis. These GIRFs, advanced by Koop, Pesaran, & Potter (1996) and further developed by Pesaran & Shin, (2002), offer an alternative to the Orthognalized Impulse Response Functions (OIRF) of Sims (1980), which suffers from the so-called Wold-Ordering problem. This issue is already present in small, simple VARs, but becomes even more problematic in the GVAR framework (Kim, 2009).[16] As it is, the OIR requires an ordering of all variables in the system, which is not evident in a global setting. Even if one can find an appropriate ordering of the variables based on economic theory or a priori reasoning, it is not clear how one should order countries (Belke & Osowski, 2016). Moreover, the OIR are very sensitive to this predetermined order. For example, an alternative order can lead to dramatically different responses (Lütkepohl, 1991).[17] Given this problem, a number of authors have adopted the sign restriction approach[18] as an alternative to identify shocks (Canova & Nicoló (2002); Canova & Pina (2000); Faust (1998); Inoue & Kilian (2013); Mountford & Uhlig (2009); Uhlig (2005) in the VAR literature and Georgiadis (2016) in the GVAR literature). However, the sign approach is not uncontroversial. Because the responses are restricted by their sign, little insight can be gained (Hebous & Zimmermann, 2012). The purpose of this thesis is precisely to determine the magnitude and sign of monetary policy spillovers that have their origins in the

[16]The OIRF recursively identifies the structural shocks through Choleski decomposition of the covariance matrix. This decomposition results in a unique lower triangular matrix, which states that the variable that is ordered first in the VAR is not affected by all other variables.

[17]A clever solution, used in section 5.2, is partial ordering. A country is placed first, with its variables ordered internally. The order of the other countries and the relative order of their variables are irrelevant

[18]This approach imposes restrictions by limiting the sign of the responses. For example, a monetary tightening would be identified by the following constraints: inflation cannot rise, while short-term interest rates cannot fall during k periods after the shock (Uhlig, 2005).

US and in that way offer insights into the various channels that are at work.
Unlike the sign approach and the OIRF, the GIRF does not aim to identify shocks by some kind of canonical system or a priori economic theory, but instead offers a counterfactual exercise in which the historical correlations of shocks are considered to be given (Belke & Osowski, 2016). As a result, in contrast to the OIR, the GIRF remains unchanged in the ordering of the variables and the countries in the model, which is after all an important consideration as discussed above.
The drawback though is that because the shocks have not been identified, the GIRFs do not provide any insight into the causal relationships between American variables (Ricci-Risquete & Ramajo-Hernández, 2015). However, the GIRF may provide useful information on interest rate changes. Although the GIRFs do not report on the reasons for the changes in the US, they can still be fairly informative about the dynamics of the transmission of the shocks from the US to European countries (Dees, di Mauro, et al., 2007).
For the econometric explanation of the workings behind the GIRF, I refer to the appendix.

In discussing the results, the emphasis is placed on the first two years after the shock occurred. This seems to be a reasonable time horizon for reliable results. In the representation of the impulse responses, however, I opt for a longer time horizon of 20 quarters, which corresponds to five years. This is purely to illustrate the convergence properties of the model. The GIRFs settle quite quickly, suggesting that the GVAR model is stable.[19]
Figures 2, 3 and 4 report the impact of an American interest rate hike in a system before the crisis (1979-2006 model in blue) and a system that includes the post-crisis (1979-2016 model in red). The size of the shock on US interest rates is one standard error, which is equal to 0.13% on a quarterly basis in both the pre-crisis system and the post-crisis system.[20] The shaded area around the GIRFs represents the 70% confidence bounds. Note that 70% confidence bounds are standard in the macro-economic literature. A total of 2500 bootstraps were computed each time for the estimation of the GIRFs and the confidence bounds.

Since the purpose of this thesis is to find out whether the Fed has (unintentionally) strengthened its grip on the European economies over the last ten years, the main variable, i.e. output, will be examined first. Surprisingly, the US economy appears to be growing significantly right after a rise in interest rates both before and after the crisis – an effect that disappears within a year. However, Dees, di Mauro, et al., (2007) come to a similar conclusion for a GVAR model that stretches to 2003. This significant American expansion does not seem to be spreading to the European economies though. On the contrary, while the effect of increased US interest rates was still uncertain before 2007, the impact is negative and quickly significant after the crisis. What is even more startling, is that after one year – when the US economy is already shrinking - the European output has dropped by as much or even more than US domestic activity. This observation also applies to the quarters after the first year. However, Norway is an exception in Europe. The country does not seem to suffer from a rise in US interest rates both before and after the crisis. So, the GIRF suggest that before the crisis, the European countries in question were still able to shield their economies from the influence of US interest rate hikes. However, they seem to have lost this ability after the crisis. Moreover, it seems that the European economies are being hit just as hard, if not harder, than the American one.[21]

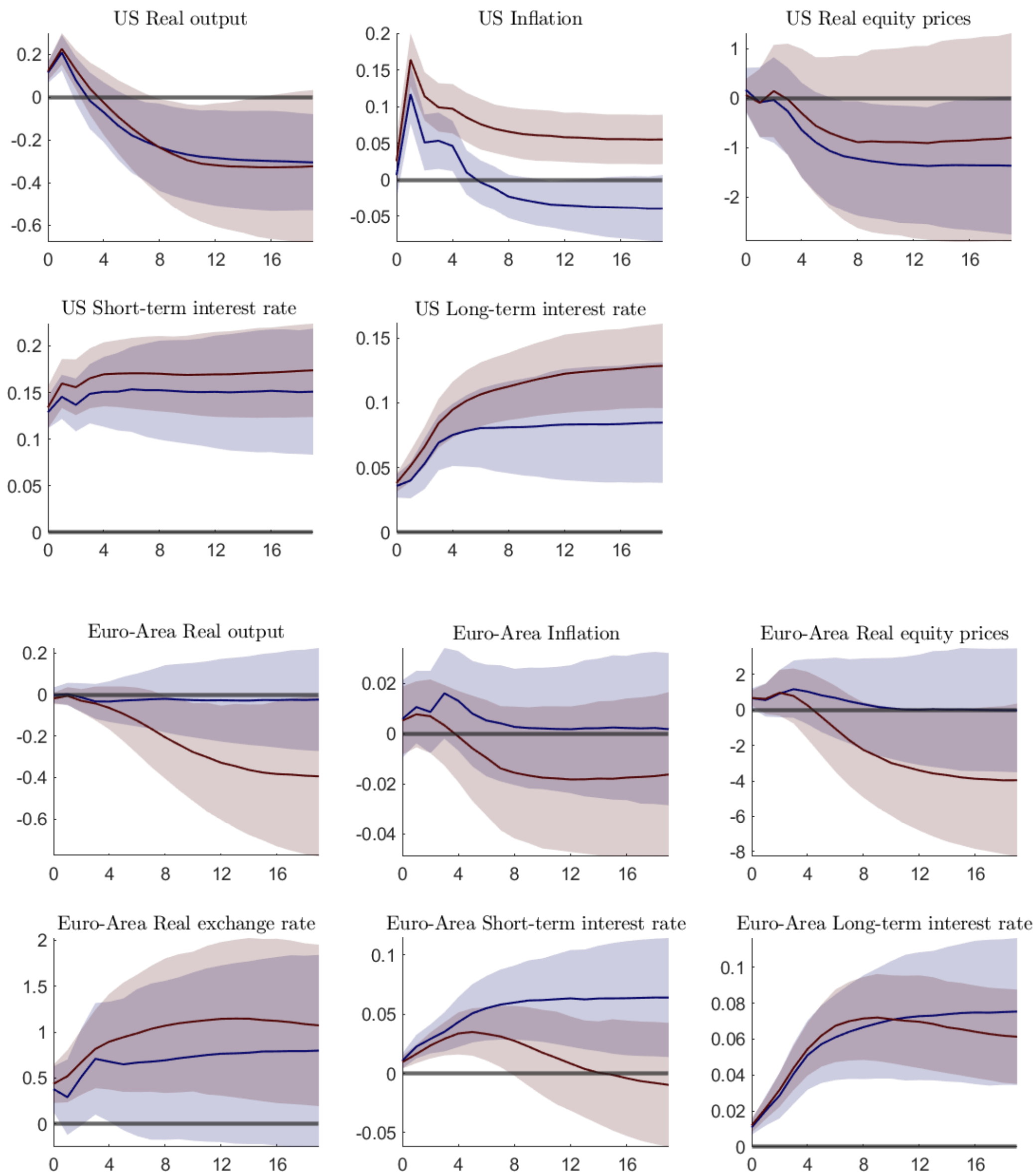
The question now arises as to how these interest rate effects travel to Europe. Providing a conclusive answer to this question is not an easy undertaking. As is common practice in this literature, the analysis consists of educated conjectures. Based on the available information, I will discuss the plausibility of whether a particular channel is the main contributor to the increased spillover effects to Europe. To this end, I examine the GIRF graphs of the European countries that are experiencing a negative impact (i.e. all European

[19] The eigenvalues contain valuable information to further investigate the stability of the specified GVAR models. According to the theorem in Pesaran et al. (2004) the GVAR must have at least $0.5 \times \lambda R$ eigenvalues falling on the unit circle, where λ is the total number of eigenvalues and R the sum of all cointegration relationships across all individual country models. This condition is met in both the 2006 model and the 2016 model. The other eigenvalues have a moduli less than unity (Dees, di Mauro, et al., 2007).

[20] Also in the structural impulse response analysis and robustness checks that follow, this 1 standard error shock is equal to 0.13%.

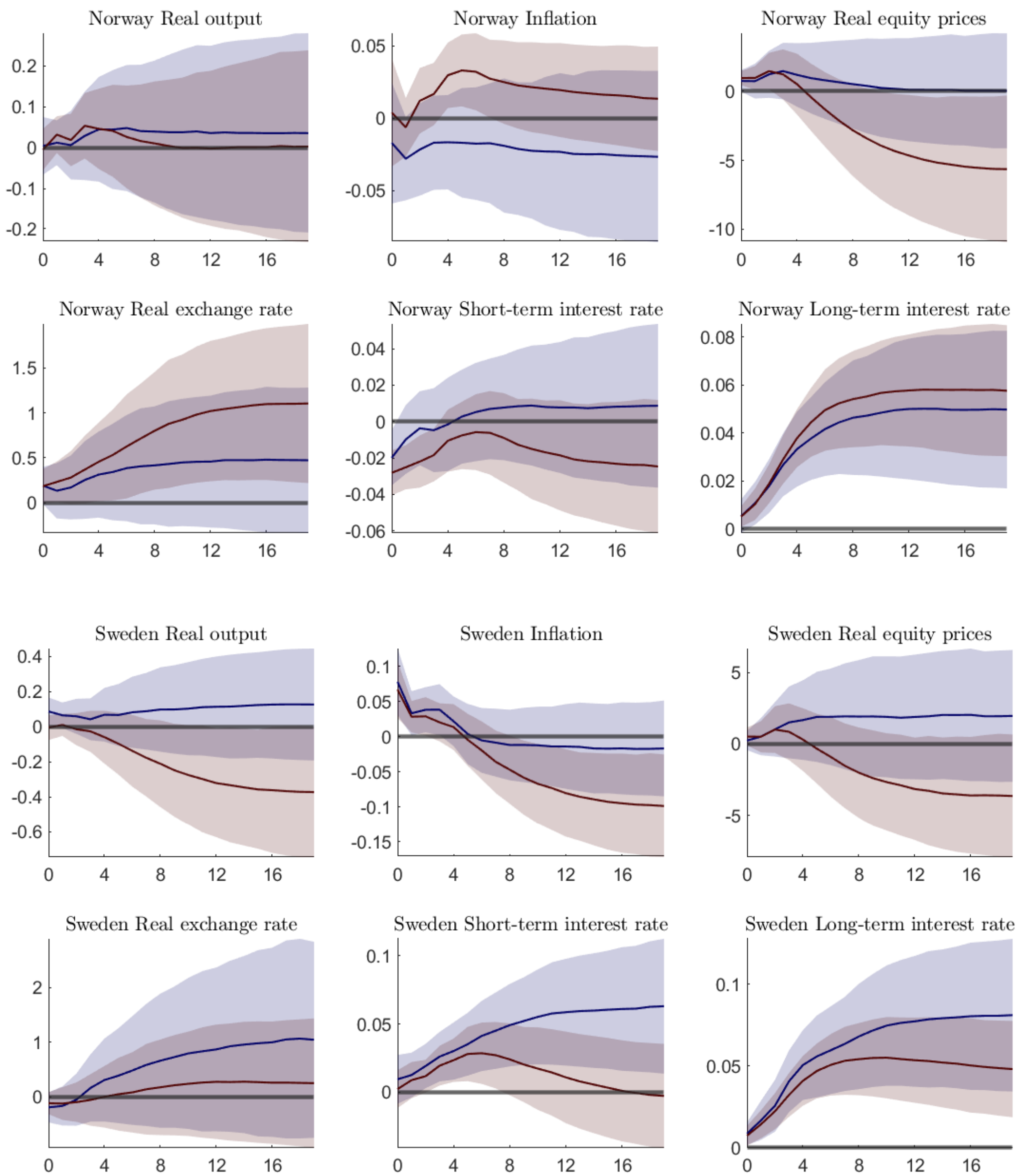
[21] Noteworthy, the estimates of US output before and after the crisis have remained virtually unchanged, following a positive shock to US interest rates. This is finding is in line with a recent paper ”On the Empirical (Ir)Relevance of the Zero Lower Bound Constraint” by Debortoli, Galí, & Gambetti (2019).

Figure 2: Positive Shock to US Interest Rates (GIRF): US and Euro-Area



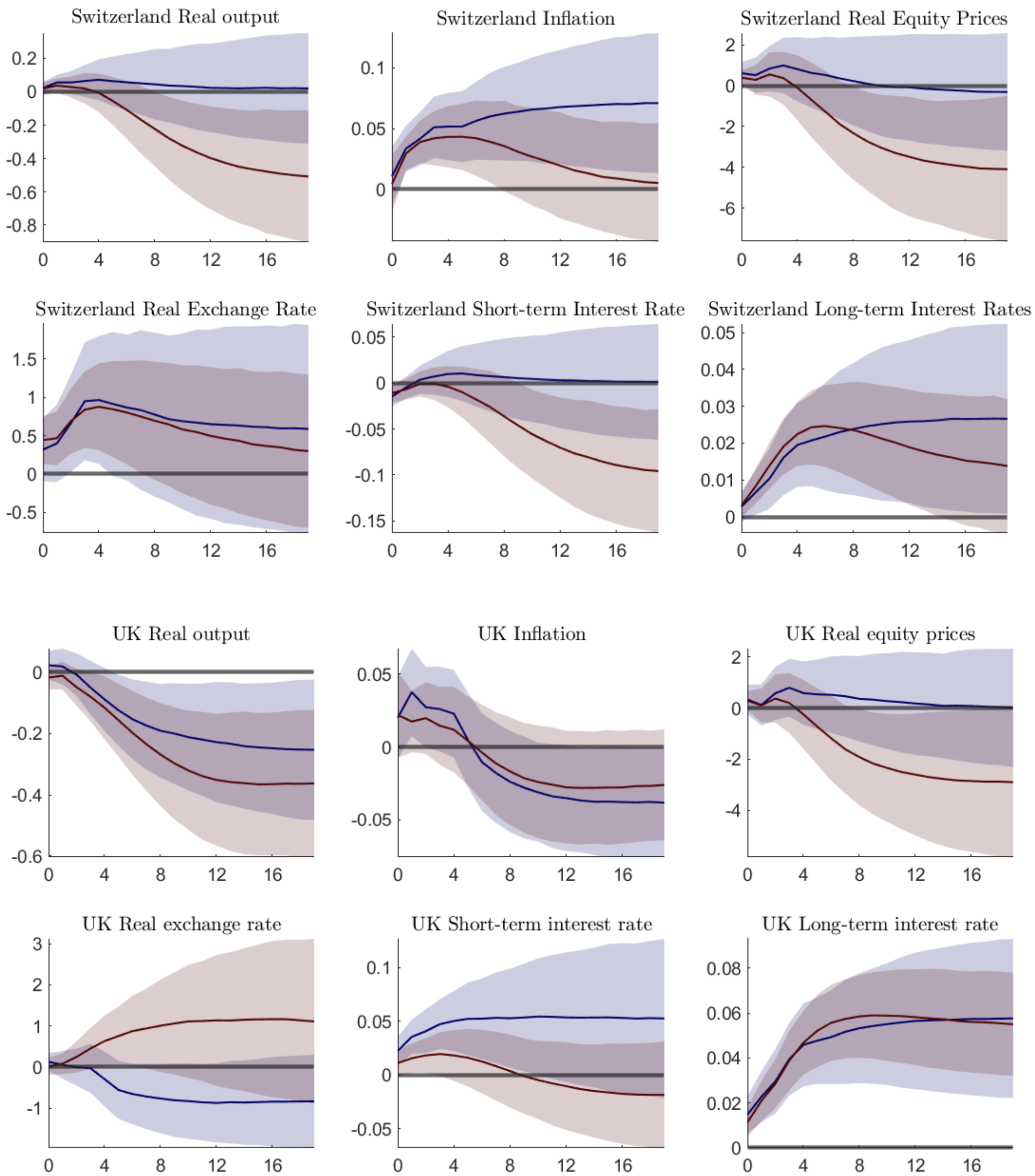
Note: The Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US interest rates (0.13%). The shaded area represents the 70% confidence bounds.

Figure 3: Positive Shock to US Interest Rates (GIRF): Norway and Sweden



Note: The Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US interest rates (0.13%). The shaded area represents the 70% confidence bounds.

Figure 4: Positive Shock to US Interest Rates (GIRF): Switzerland and UK



Note: The Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US interest rates (0.13%). The shaded area represents the 70% confidence bounds.

economies except the Norwegian one) reported in Figures 2, 3 and 4, the impact elasticities between domestic and foreign variables in Table 10, and the trade matrix in Table 3.

Reexamining the GIRFs of output of the US and the European economies in Figures 2, 3 and 4 confirms somewhat the earlier suspicion (which emerged from the trade matrix) that the *trade channel* is unlikely to be behind the strengthened spillovers to Europe.[22] Recall that the trade channel assumes that a drop in American output after the Fed decides to raise the interest rates, results in reduced demand for foreign goods which would hurt the close trading partners of the US. On the contrary, if American output and thus demand for foreign goods were to increase, the trade channel predicts the European output to expand as well. Thus, a dominant trade channel would at least manifest itself in a similar output pattern between the two regions. However, the output GIRFs (Figures 2, 3 and 4) show different patterns for the US and European economies. Here the American economy grows significantly right after the interest rate hike, which would according to the trade channel also result in European growth during the first quarters, which is not the case. Hence, the trade channel seems unlikely to be the dominant mechanism behind the strengthened cross-border effects. Nobeli & Neri, (2007) and Kearns, Schrimpf, & Xia, (2018) arrive at a similar conclusion.

Another variable that might drive the drop in European output is the *exchange rate*. Recall that according to the uncovered interest rate parity, the dollar should appreciate and the European currencies[23] depreciate against the dollar. This would then result in a gained competitiveness and a boost for European economies. But the GIRFs show a different story. Like Nobeli & Neri (2007), some European countries find their currency appreciated against the dollar, contrary to what the exchange rate channel predicts. Such a stronger European currency could partly explain the output losses owing to reduced competitiveness. However, the exchange rate alone is not a sufficient explanation of the contraction in the European economies, as countries such as Sweden do not see its currency appreciate and yet do see their output decline.

Next, consider the responses of the *short-term interest rates* in Figures 2, 3 and 4. Although positive and temporarily significant in some countries, the impact is much smaller after the crisis than before. This observation suggests that central banks in Europe have been better able to retain their autonomy over the past decade. This is also in line with the earlier finding from Table 10 that impact elasticities between domestic and foreign short-term interest rates are limited. Thus, the increased sensitivity to US interest rates does not stem from strengthened interdependencies of the short rates across the two regions.

The literature already tipped off the *financial channels* as the main drivers behind the spillover effects of American interest rates to the rest of the world. Two variables in the GVAR model relate to these channels, i.e. the real share prices that depict the stock market situation and the long-term interest rates that reflect the bond markets.
First, the *real equity prices* seem to be telling a strange story. After the crisis, the negative effect on the US stock market diminishes and the significant effect that was found before the crisis disappears. The European stock markets, on the other hand, reverse the story. That is, European countries now experience a significant negative effect on their equity markets, while that effect did not exist prior to 2007. This observation could partly explain the larger drop in European output after the recent financial crisis, as a deteriorated stock market situation hampers the economy.[24]
Second, the GIRFs reveal a highly significant effect on *long-term interest rates* all over Europe, following an American interest rate hike. In most countries, this effect is even amplified after the global financial crisis. The worsened financial conditions then impede the European economy.

[22]That is, if the trade channel were the main driver behind this, one would expect an increase in the trade intensity between Europe and the US in the last decade. The trade matrix, however, shows the opposite.

[23]All European currencies have a floating exchange regime with the US

[24]However, it is conjecture as to why European stock markets react significantly to a hike in US interest rates, while US stock markets seem to be quite insensitive to it. Part of the explanation probably lies in the increasingly globalized nature of these stock markets. That way, the American interest rate defines the risk-free return not only in the US but also in Europe, and therefore reduces not only the American equity prices but also the European ones. Yet, Table 10 in section 5.1 shows that European equity markets are more volatile. This results in European equity prices falling by more than American equity prices, which then makes the latter still attractive to foreign investors.

In order to evaluate this channel, its mechanism is split up in two parts.

(i) The American long-term interest rates spill over to European long-term interest rates

(ii) The European long-term interest rates worsen the European economy

To examine the first point, let us have a look at Table 10 in section 5.1. It is apparent from this table that the impact elasticities between European and foreign long-term interest rates are highly significant and (in most European countries) stronger after the crisis than before. This suggests that developments in foreign bond markets immediately affect European bonds in a very significant way and that this effect has strengthened in the last decade. Thus, there is reason to think that American long-term interest rates spill over to European ones.
For the second point, I rely on qualitative arguments from the literature. The literature hints that the presence of the zero-lower bound in the post-crisis sample might have amplified the effects of domestic long-term yields on output. As a matter of fact, when the monetary policy rates hit zero in the wake of the global financial crisis, central banks started to aim at influencing long-term rates with forward guidance.[25] As such, the bond yields became increasingly important over the last decade to steer the economy. This led to an increased sensitivity of domestic activity to bond yields, especially in Europe where policy rates have been virtually zero for an extensive time (Albagli et al., 2018).

Finally, the GIRFs also show a peculiarity with regard to inflation. The graph suggests that inflation rises in the US in response to higher interest rates, which is counterintuitive. However, this result occurs in many VARs and GVARs, and is commonly referred to as the prize puzzle. The next section on Structural GIRFs will come back to this point.

To summarize, the GIRFs demonstrate that European economies have become more sensitive to American interest rate spillovers over the last decade. The impulse responses for output together with the trade matrix suggest that the trade channel does not play a role in this. On the other hand, the graphs hint that increased sensitivity might be driven by stronger financial channels. As the GIRFs show, the reactions of the long-term yields and the real equity prices have increased substantially after the recent global crisis.

5.2.2 SGIRF: Shock to US Monetary Policy

Although the GIRFs provide a first glimpse into spillovers from the US to Europe, it is not a sufficient analysis. These impulse responses provide useful information on changes in interest rates, but the approach is silent as to reasons behind these changes. An identification of the shock is necessary to attribute the changes to consequences of US monetary policy.

As discussed in section 5.2.1, structural identification is not self-evident, as it requires an ordering of all variables and countries. However, there is no economic theoretical support for such ordering. A clever solution to this problem is a partial ordering. A Monetary policy shock originating in the US can thus be identified by placing the US as the first country in the system. Within the US model one can consider alternative sequences of the variables (Sims, 1980). Economic theory can serve as a good guideline. The ordering of the remaining variables and countries, however, does not matter as long as no short-term overidentifying restrictions are imposed in the model. The sequencing of the US variables considered here is proposed by Christiano, Eichenbaum, & Evans (1998) and is standard in the literature. It is based on the premise that monetary policy does not affect the other macro-economic variables (e.g. output, inflation, bond yields etc.) within the same quarter. Thus, the ordering considered here is given by

$$S = (\underbrace{p^{oil}, p^{mat}, p^{met}}_{\text{dominant unit}}, \underbrace{i^L, q, \pi, y, i^S}_{\text{US model}}) \tag{8}$$

At first glance, the SGIRFs seem similar to the GIRFs. However, a major difference is that the significance of the negative effect on real equity prices disappears in the US and all European economies.

[25] Forward guidance refers to communicating the intentions to keep rates at zero for an extended time

Moreover, the output spillovers – though still significant – are reduced in magnitude. Given that the standard GIRFs simulate any increase in US interest rates, while the SGIRFs only capture changes in intended monetary policy, these reduced estimates are not surprising.
In addition, the long-term rates remain very statistically significant. These findings might indicate that it is the strong spillovers to the bond market that cause the European output to drop after a US monetary tightening, especially after the financial crisis. The increasing importance of that channel after the recent crisis is not unexpected, as the conduct of monetary policy in Europe has changed in important ways since then. As a matter of fact, when central banks all over Europe faced the dreaded zero-lower bound, the focus shifted towards influencing bond yields through forward guidance and large scale asset purchase programs. As such, the bond yields became an increasingly important tool to steer the economy (Albagli et al., 2018). Moreover, as the impact elasticities of the long-run rates take sizable values (cfr. section 5.1), spillovers from US bond markets to European bond yields are likely to be strong.

The SGIRFs also show that the prize puzzle persists. The monetary tightening causes the prices to go up, which is counterintuitive according to the standard transmission mechanism. However, this result often occurs in VARs and GVARs. The reason as to why this is the case is not clear. In the setting of VARs, Sims (1992) conjectured that this puzzle might be driven by mismeasurement. For simple VARs, he argues that the estimates are based on specifications of the information matrix at time t that does not include information about future inflation, which is, however, available to the Fed. Thus, the price puzzles are actually confounded with non-policy disturbances that signal future increases in prices. To this end, Sims proposes including commodity prices which signal future inflation increases. However, in view of Sims' arguments the GVAR model presented here includes commodity prices, namely prices for oil, metal and raw materials. Nevertheless, the price puzzle persists.

In sum, the SGIRFs confirm largely the conclusions drawn from the GIRFs, although the spillover effects are found to be slightly smaller. Moreover, the significance of the impact on real equity prices vanishes, when the interest rate changes are attributed to monetary policy. This suggests that monetary policy spillovers propagate mostly through the bond markets.

5.3 Robustness Check

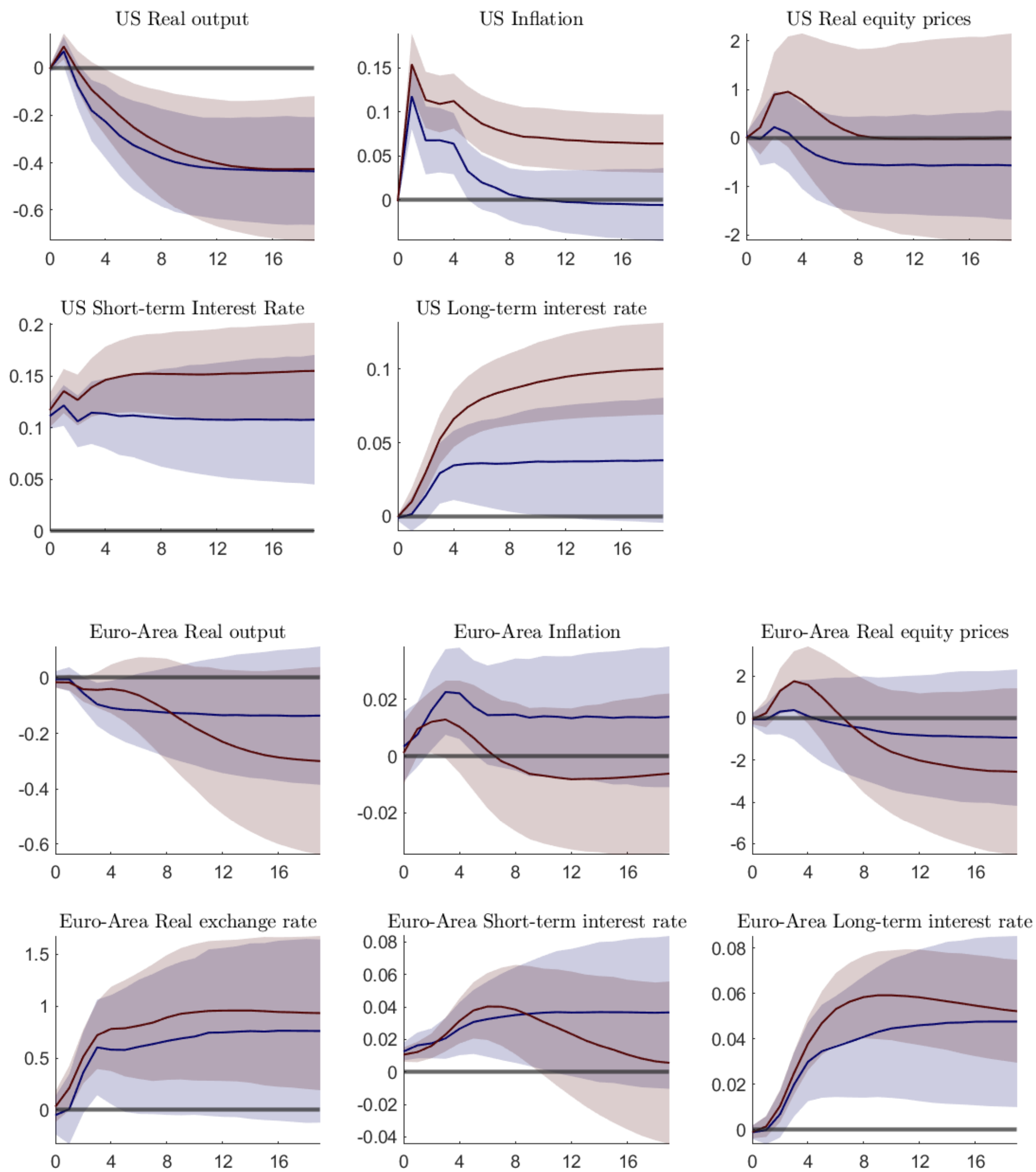
To account for the possibility that the impulse response analysis is sensitive to the adopted identification, another ordering is considered. In light of the arguments advanced in Sims & Zha (2006), the short-term interest rate is this time placed ahead after the dominant unit.

$$R = (\underbrace{p^{oil}, p^{mat}, p^{met}}_{\text{dominant unit}}, \underbrace{i^S, i^L, q, \pi, y}_{\text{US model}}) \tag{9}$$

The graphs of the impulse response functions under this ordering can be consulted in the appendix. The resulting SGIRFs are found to be rather similar to the previous identification, and almost identical to the GIRFs. Hence, the results obtained above appear to be robust.

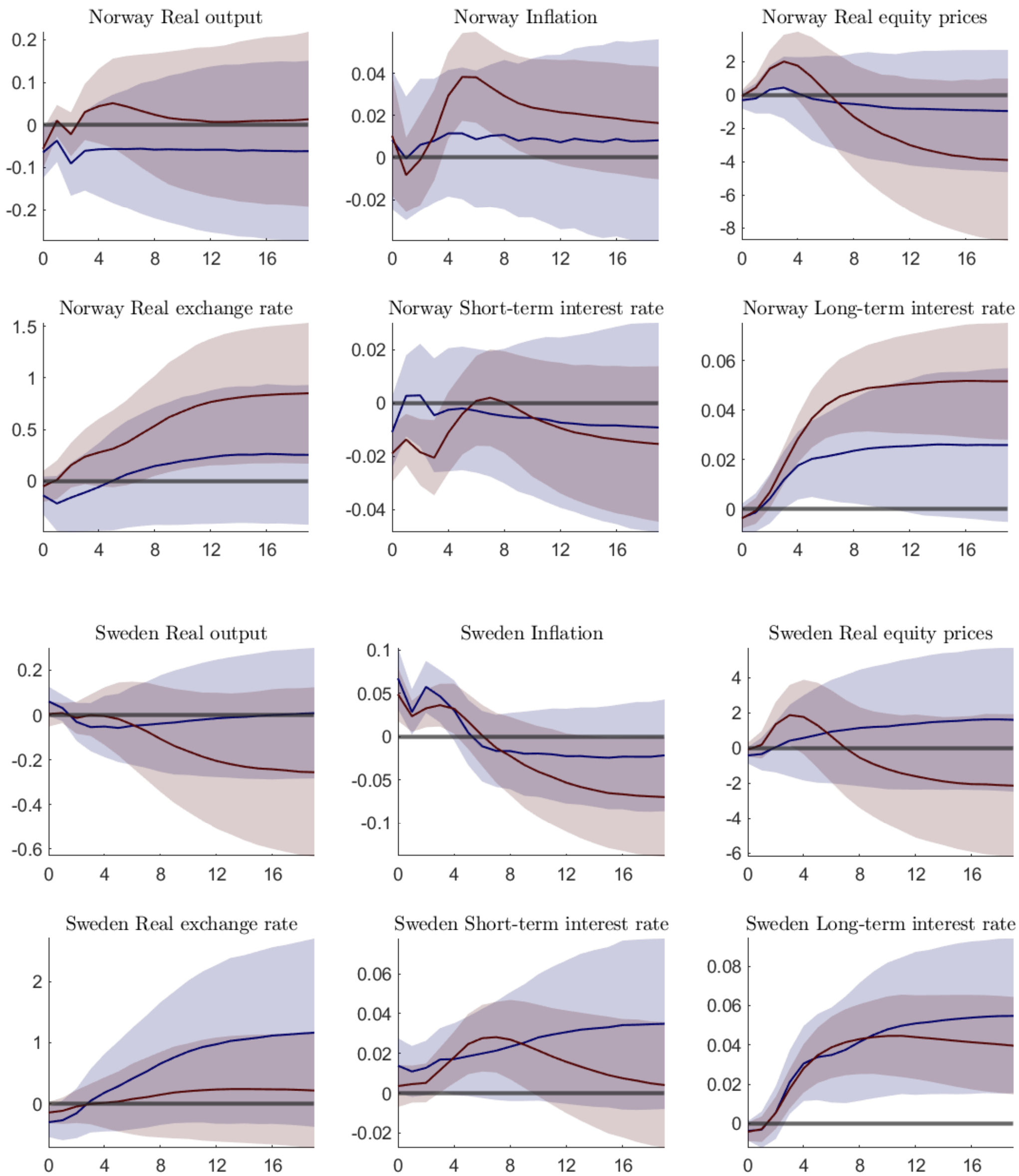
As regards US inflation, the price puzzle persists and has even amplified in this identification compared to the previous identification. Christiano, et al., (1998) show that this can be expected when output is placed after monetary policy.

Figure 5: Positive Shock to US Monetary Policy (SGIRF): US and Euro-Area



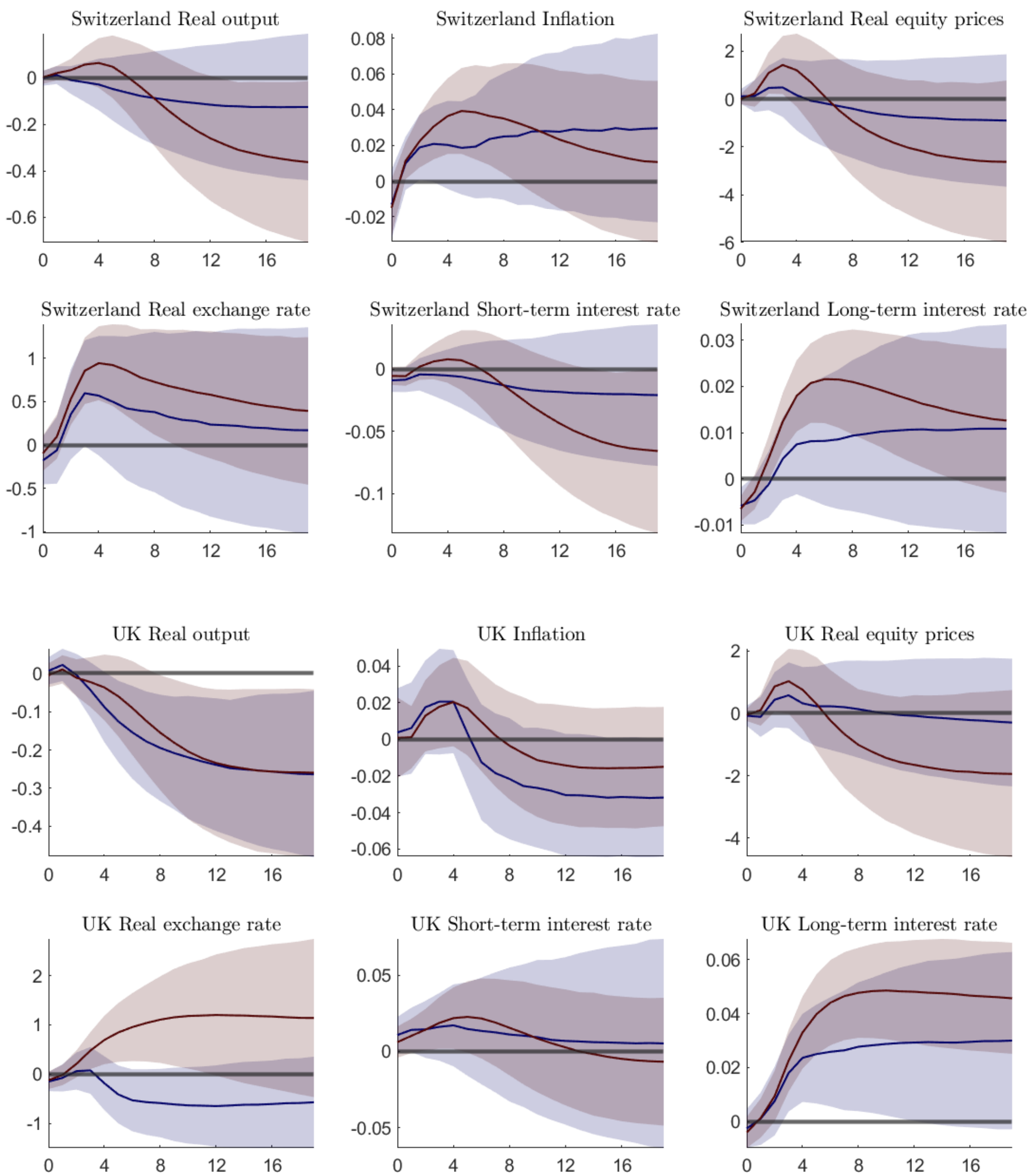
Note: The Structural Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US monetary policy (0.13%). The ordering is given by $S = (p^{oil}, p^{mat}, p^{met}, i^L, q, \pi, y, i^S)$ *The shaded area represents the 70% confidence bounds.*

Figure 6: Positive Shock to US Monetary Policy (SGIRF): Switzerland and UK



Note: The Structural Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US monetary policy (0.13%). The ordering is given by $S = (p^{oil}, p^{mat}, p^{met}, i^L, q, \pi, y, i^S)$ *The shaded area represents the 70% confidence bounds.*

Figure 7: Positive Shock to US Monetary Policy (SGIRF): Switzerland and UK



Note: The Structural Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US monetary policy (0.13%). The ordering is given by $S = (p^{oil}, p^{mat}, p^{met}, i^{L}, q, \pi, y, i^{S})$ *The shaded area represents the 70% confidence bounds.*

6 Conclusion

This thesis started with a brief overview of the literature on US monetary policy spillovers. A growing number of studies have investigated the financial spillovers from a hike in US interest rates. These studies show that the impact on the European bond and equity markets is substantial, significant and strengthened over the past ten years. By contrast, the number of papers studying the impact on European production is limited. Moreover, the few studies do not include the period after the global financial crisis. This thesis fills this gap in the literature by analyzing the effects of US monetary policy on European production before and after the crisis.

To this end, a suitable approach, the Global VAR, is employed. The model aims at mapping out the dynamics of the global economy, by comprising 33 countries covering 90% of total world output. As such, the model accounts for possible third country effects and spill-backs. The specification of the model builds on the DdPS version of the GVAR model, and adds a number of enhancements following Smith & Galesi, (2014). That is, this model comprises not only oil prices but also metal and raw material prices. Including these prices enables us to control for global supply shocks that are common to all countries. Moreover, commodity prices contain information on future inflation. Furthermore, while DdPS includes the oil prices as an endogenous variable in the US model in an attempt to reflect the dominant weight of the US economy in the development of these prices, I have placed commodity prices in a separate so-called 'dominant unit model'. The dominant unit model is not purely exogenous, but accounts for weighted feedback effects from the individual countries. That way, the model allows the US to play an important role in influencing these commodity prices, while it does also account for other major economies such as the euro zone and China.
Since the main question of the thesis is whether and how US monetary policy spillovers differ before and after the crisis, this model is estimated over a period from 1979Q2 to 2006Q4 and extended to 2016Q4. The results are then compared across these two estimation periods.
As a correct initial implementation of the model relies on two key assumptions i.e. weak exogeneity of the country-specific foreign variables and the absence of structural breaks, I carry out tests to check their validity and find evidence that these assumptions hold. However, although that the test for structural breaks shows that parameter coefficients are stable, it suggests that error variances are not. To account for this feature, robust standard errors are employed when analyzing the contemporaneous effects of foreign variables on their domestic counterparts, while bootstraps means and confidence bounds provide the basis of the impulse response analysis.
In addition, I show that by conditioning the individual VARX* models on weakly exogenous country-specific foreign variables, the GVAR model is successful at filtering out the common shocks and factors that drive the world economy. As such, the results can be correctly interpreted as spillover effects.

After the model is specified, the estimation is carried out, and the validity of the key assumptions is checked, the thesis proceeds with the analysis of the results. The results section consists of two parts. The first part estimates the contemporaneous effects of foreign variables on their domestic counterparts. These coefficients are instructive on the global connections that exist within one variable. The estimates reveal that, while strong international interlinkages are found in both the equity and bond markets, the interdependencies between monetary policy reactions are weak.
The second part analyzes the impulse responses of a US interest rate or identified monetary policy shock. The results indicate that US monetary policy spillovers to European economies have strengthened substantially after the global financial crisis. Indeed, a tightening of US monetary policy elicits virtually no effect in the sample ranging up to 2007 but impinges European economies significantly after the crisis. What is more, European output drops by as much or even more than the US economy in the second sample.

Through what channels do these effects travel to Europe? Based on the bilateral trade shares and the impulse responses, I conclude that direct trade does not play a role. The counterintuitive appreciation of most European currencies in response to US monetary tightening might contribute somewhat to the drop in European output. But by far the most important channel appears to be the financial one. Indeed, this thesis confirms the findings in the literature that European bond and equity markets are increasingly more

sensitive to a hike in US policy rates.
The bond markets, in particular, seem to be the one to blame. This result is not very surprising. On the one hand, the European yields have become more susceptible to contagion from foreign bond markets. On the other hand, the literature suggests that domestic activity is increasingly subject to developments in the bond markets. This not surprising. When the economy fell off the cliff in 2007 and central banks all over Europe soon faced the effective zero lower bound, the focus was shifted to influencing the long-term yields as a tool to steer the economy.

Some improvements can be done to the empirical analysis of this thesis and there are many opportunities for further research.
The major shortcoming of the approach employed in this thesis, is that it is ill-suited for modelling a monetary union. If the euro countries were to be included separately, the GVAR model would incorrectly assume that each of these countries has sole control over its interest rate, which is of course no longer the case after 1999. Therefore, in line with the GVAR literature, this thesis aggregates the euro countries into one single unit. Though consistent with the institutional framework of a monetary union, the grouping of individual euro area countries makes it impossible to analyze the heterogeneity of the spillovers across these countries. The consistent modelling of a monetary union in the Global VAR framework is, therefore, an interesting avenue for future research.
This thesis also does not address a relevant policy question that arises here, namely how can European countries limit these cross-border effects? Although the analysis shows that US monetary policy spillovers have increased in the last decade and that these are spreading mainly through financial channels to Europe, it does not provide clear information on measures that European countries can take to shield their economy. To provide an answer to this question, the characteristics of the countries should be examined and compared. In order to do this, one should ideally have enough countries in analysis. However, as mentioned above, the GVAR is not capable to model euro countries separately in a consistent way.

Appendices

A Technical Appendix

A.1 Modelling the Dominant Unit and Common Variables

This section deals with the inclusion of the dominant unit and the common variables in the GVAR model, as set out in section 3.

The dominant unit acts as a dynamic factor in the regressions of the other country-models, which are non-dominant units (Chudik & Pesaran, 2013). Therefore, the individual country-models should be conditioned not only on the foreign variables, but also on both current and lagged values of the dominant variables. In contrast, the dominant unit includes only the lagged values of the dominant variables (Smith Yamagata, 2011). However, the dominant unit is no purely exogenous model. The model includes also lagged feedbacks from the rest of the countries in the GVAR model. The influence that a specific country exerts on the dominant unit and as such on the common variables depends on the relative size of its economy. That way, the dominant variables account more for (lagged) developments in the US, the euro area and China than for changes in the Swedish or Swiss economy.

Consider $m_\omega \times 1$, a vector containing the variables ω_t of the dominant unit. The first stage is testing for possible cointegrating relations amongst the elements ω_t. For this purpose, consider the following VAR(p_ω) specification for the dominant unit, where the lag order p_ω is determined by the AIC. The dominant unit acts as a dynamic factor in the regressions of the other country-models,

$$\omega_t = \mu_0 + \mu_1 t + \Phi_1 \omega_{t-1} + ... + \Phi_{p_\omega} + \omega_{tp_\omega} + \eta_t \tag{10}$$

Accounting for cointegration among the integrated American observables ω_t, yields the error correction representation of (10).

$$\Delta\omega_t = c - \alpha_\omega \beta'_\omega [\omega_{t-1} - \kappa(t-1)] + \sum_{j=1}^{p_\omega - 1} \Gamma_j \Delta\omega_{t-j} + \eta_t \tag{11}$$

where α_ω and β_ω are $m_\omega \times r_\omega$ vectors, and r_ω denotes the number of cointegrating relations. Denote the $r_\omega \times 1$ vector of error correction terms by $\xi_{\omega,t-1} = \beta'_\omega[\omega_{t-1} - \kappa(t-1)]$, and its estimate by $\hat{\xi}_{\omega,t-1} = \hat{\beta}'_\omega[\omega_{t-1} - \hat{\kappa}(t-1)]$. Applying OLS to $\Delta\omega_t = c + \delta\hat{\xi}_{\omega,t-1} + \sum_{j=1}^{p_\omega-1} \Gamma_j \Delta\omega_{t-j} + \eta_t$, where $\hat{\xi}_{\omega,t-1}$ is taken as given, yields consistent estimates of the remaining parameters in (10).

In the second stage, lagged changes of the variables in the rest of the GVAR model can be included in the error correction model specification above. The first step is to construct a set of global variables defined by $\tilde{x}_t = \tilde{W} x_t$, where x_t is the $k \times 1$ vector of the variables included in the models for the non-dominant units, and $\tilde{W}$ is an $m_{\tilde{x}} \times k$ matrix of weights used in constructing the global variables, $\tilde{x}_t$. To this end, the PPP-GDP weights are used. Evidently, the contemporaneous values of $\tilde{x}_t$ cannot be included in the model for the dominant unit model, as $\tilde{x}_t$ is not weakly exogenous for the parameters of the dominant unit model. The inclusion of lagged changes of $\tilde{x}_t$ in modelling ω_t might seem redundant at first glance. Indeed, if ω_t is truly dominant, then $\tilde{x}_t = \tilde{W} x_t$ and ω_t are highly correlated for sufficiently large sample sizes through the inclusion of ω_t and its lagged values in the models for x_{it}. However, for small samples, improvements can be made by including $\Delta\tilde{x}_{t-s}$ for s = 1,2,... in the above error correction model specification for the dominant unit. Hence,

$$\Delta\omega_t = c + \delta\hat{\xi}_{\omega,t-1} + \sum_{j=1}^{\tilde{p}-1} \Gamma_j \Delta\omega_{t-j} + \sum_{j=1}^{\tilde{q}-1} \Theta_j \Delta\hat{x}_{t-j} \eta_t \tag{12}$$

Conditional on $\delta\hat{\xi}_{\omega,t-1}$, previously computed from (11), equation (12) can be consistently estimated by OLS. Note that not only a lag order needs to be determined for $\Delta\tilde{x}_{t-j}$, but also a new order needs to be selected for $\Delta\omega_{t-j}$. Denote these lag orders as $\tilde{q}$ and $\tilde{p}$ respectively. Augmenting (11) with $\Delta\tilde{x}_{t-j}$ is likely to alter the order of the lags of $\Delta\omega_{t-j}$. After estimating the parameters in (12), the error correction model representation can be converted back into

$$\omega_t = \mu_0 + \mu_1 t + \Phi_1\omega_{t-1} + ... + \Phi_{\tilde{p}}\omega_{t-\tilde{p}} + \Lambda_1\tilde{x}_{t-1} + ... + \Lambda_{\tilde{q}}\tilde{x}_{t-\tilde{q}} + \eta_t \tag{13}$$

Below the GVAR is solved in presence of a dominant unit, where () will be used to establish the dynamic properties of the global model.
Consider first the non-dominant country-specific VARX*(p_i, q_i) for $i = 0, 1, \ldots, N$.

$$\begin{aligned} x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}x_{i,t-1} + ... + \Phi_{ip_i}x_{i,t-p_i} + \Lambda_{i0}x^*_{i,t} + \Lambda_{i1}x^*_{i,t-1} + ... + \Lambda_{iq_i}x^*_{i,t-q_i} \\ + \Psi_{i0}\omega_t + \Psi_{i1}\omega_{t-1} + \Psi_{iq_i}\omega_{t-q_i} + u_{it} \end{aligned} \tag{14}$$

The dominant variables ω_t are treated as foreign variable and thus share the same lag order, q_i. To ensure the estimation of long-run (cointegrating) relations in the non-dominant country models through the use of VECM*, the foreign variables, x^*_{it}, and the dominant variables, ω_t, are treated as weakly exogenous. Similar to the tests of weak exogeneity applied to the foreign variables in the GVAR, the weak exogeneity assumption of the dominant variables in the non-dominant models, ω_t has to be checked afterwards. After the estimation of the country-specific models, the global variable $k \times 1$ vector $x_t = (x'_{0t}, x'_{1t}, ..., x'_{Nt})'$ is solved for by stacking the individual country equations and 'dispensing' with the foreign variables x^*_{it} through the identity $z_{it} = W_i x_t$, with $z_{it} = (x'_{it}, {x^*}'_{it})'$, where W_i are the link matrices defined by the trade weights w_{ij}. However, because ω_t does not enter as a domestic variable in any country-specific model x_{it}, one cannot 'dispense' with this via the link matrices. When expressing (14) in terms of z_{it} and assuming that $p_i = q_i$(for simplicity reasons), then

$$G_{i0}z_{it} = a_{i0} + a_{i1}t + G_{i1}z_{i,t-1} + ... + G_{ip_i}z_{i,t-p_i} + \Psi_{i1}\omega_{t-1} + ... + \Psi_{iq_i}\omega_{t-q_i} + u_{it}, \tag{15}$$

with $G_{i0} = (I_{k_i}, -\Lambda_{i0})$ and $G_{ij} = (\Phi_{ij}, \Lambda_{ij})$, for $j = 1, ..., p_i$. With the identity $z_{it} = W_i x_t$ (15) can be rewritten as

$$G_{i0}W_i x_t = a_{i0} + a_{i1}t + G_{i1}W_i x_{t-1} + ... + G_{ip_i}W_i x_{t-p_i} + \Psi_{i0}\omega_t + \Psi_{i1}\omega_{t-1} + ... + \Psi_{iq_i}\omega_{t-q_i} + u_{it}.$$

These individual models are then stacked to yield the equivalent of equation (6) in section 3.

$$G_0 x_t = a_0 + a_1 t + G_1 x_{t-1} + ... + G_p x_{t-p} + \Psi_0\omega_t + \Psi_1\omega_{t-1} + ... + \Psi_2\omega_{t-q} + u_t, \tag{16}$$

with $p = max(p_i)$ and $q = max(q_i)$and

$$G_0 = \begin{pmatrix} G_{00}W_0 \\ G_{10}W_1 \\ \vdots \\ G_{N0}W_N \end{pmatrix}, G_j = \begin{pmatrix} G_{0j}W_0 \\ G_{1j}W_1 \\ \vdots \\ G_{Nj}W_N \end{pmatrix}, j = 1, ..., p,$$

$$a_0 = \begin{pmatrix} a_{00} \\ a_{10} \\ \vdots \\ a_{N0} \end{pmatrix}, a_1 = \begin{pmatrix} a_{01} \\ a_{11} \\ \vdots \\ a_{N1} \end{pmatrix}, u_1 = \begin{pmatrix} a_{0t} \\ a_{1t} \\ \vdots \\ a_{Nt} \end{pmatrix}$$

Note that now both the contemporaneous and lagged values of ω_t appear on the right hand side of equation (16).
Introducing the $(k + m_\omega) \times 1$ vector $y_t = (x'_t, \omega'_t)'$and assuming $p = \tilde{p} = \tilde{q} = q$, equations (A.1) and (16) can be written as

$$H_0 y_t = h_0 + h_1 t + H_1 y_{t-1} + ... + H_p y_{t-p} + \zeta_t, \tag{17}$$

where

$$H_0 = \begin{bmatrix} G_0 & -\Psi_0 \\ \mathbf{0}_{m_\omega \times k} & I_{m_\omega} \end{bmatrix}, h_0 = \begin{bmatrix} a_0 \\ \mu_0 \end{bmatrix}, h_1 = \begin{bmatrix} a_1 \\ mu_1 \end{bmatrix}$$

$$H_j = \begin{bmatrix} G_j & \Psi_j \\ \Lambda_j W_j & \Phi_j \end{bmatrix}, j = 1, ..., p, \qquad \zeta_t = \begin{bmatrix} u_0 \\ \mu_t \end{bmatrix}$$

or

$$y_t = c_0 + c_1 t + C_1 y_{t-1} + ... + C_p y_{t-p} + H_0^{-1} \zeta_t, \tag{18}$$

with

$$c_j = H_0^{-1} h_j, j = 0, 1; \qquad C_j = H_0^{-1} H_j, j = 1, ..., p.$$

Generally, the lag order of y_t will be determined by the maximum lag order $\max(\max(p, \tilde{p}), \max(q, \tilde{q}))$. The process y_t determines the properties of the global model. These include the impulse response functions, that are set out below. Also, the bootstrapping is performed in terms of ζ_t innovations.

A.2 Impulse Response Functions

A.2.1 Generalized Impulse Response Functions

First, define the infinite moving average representation of (18) by

$$y_t = d_t + \sum_{s=0}^{\infty} B_s \epsilon_{t-1} = \epsilon_t + B_1\epsilon_{t-1} + B_2\epsilon_{t-2} + ... \tag{19}$$

where d_t represents the deterministic component of y_t. $\epsilon_t = H_0^{-1}\zeta_t$ and B_s can be derived recursively as

$$B_s = C_1 B_{s-1} + C_2 B_{s-2} + ... + C_p B_{s-p}, \quad s = 1, 2, ... \tag{20}$$

with $B_0 = I_{k+m_\omega}, B_s = 0$, for $s < 0$. Using this infinite moving average representation, the generalised impulse reponse function (GIRF) of (18) for a one standard error shock defined by $v_t = b'\zeta_t$ at time t over the horizon $h = 0, 1, 2, ...$ is given by

$$\mathcal{GIRF}(h, y_t; v_t) = E(y_{t+h}|v_t = \sqrt{b'\Omega b}, \mathcal{I}_{t-1}) - E(y_{t-h}|\mathcal{I}_{t-1}) \tag{21}$$

where b is $(k + m_\omega) \times 1$ selection vector of the PPP-GDP weights with non-zero values only for the element associated with the variable to be shocked. This vector is then rescaled such that its sum equals unity. The $\mathcal{I}_{t-1}$ represents the information set up to time $t-1$. Assuming that ζ_t has a multivariate normal distribution, the GIRF is derived as

$$\mathcal{GIRF}(h, y_t; v_t) = \frac{B_h H_0^{-1}\Omega_\zeta b}{\sqrt{b'\Omega_\zeta b}}, \quad h = 0, 1, 2, ...$$

where the B_h are computed according to ().

A.2.2 Structural Impulse Response Functions

In the structural impulse response analysis, the dominant unit is placed first followed by the country of interest, the US. For identifying the shock, the dominant unit and the US are considered as a single 'block'. As discussed in section 5.2.2, the results are invariant to the sequencing of the rest of the countries. Consider the dominant unit model, specified as

$$\omega_t = \mu_0 + \mu_1 t + \Phi_1\omega_{t-1} + \Lambda_1\tilde{x}_{t-1} + \eta_t,$$

and the US model

$$x_{0t} = a_{00} + a_{01}t + \Phi_{01}x_{0,t-1} + \Phi_{02}x_{0,t-2} + \Lambda_{00}x^*_{0t} + \Lambda_{01}x^*_{0t-1} + u_{0t}. \tag{22}$$

Consider the $(m_\omega + k_0) \times 1$ vector

$$\dot{x}_t = \dot{a}_0 + \dot{a}_1 t + \dot{\Phi}_1\dot{x}_{t-1} + P\dot{h}i_2\dot{x}_{t-2} + \dot{\Lambda}_0\dot{x}^*_0 + \dot{\Lambda}_1\dot{x}^*_{0,t-1} + \dot{u}_t, \tag{23}$$

where the $(m_\omega + k_0) \times 1$ vector $\dot{x}_t = (\omega'_t, x'_{0t})$ and

$$\dot{a}_0 = \begin{pmatrix} \mu_0 \\ a_{00} \end{pmatrix}, \dot{a}_1 = \begin{pmatrix} \mu_1 \\ a_{01} \end{pmatrix}, \dot{\Phi}_1 = \begin{pmatrix} \Phi_1 & \mathbf{0} \\ \mathbf{0} & \Phi_{01} \end{pmatrix}, \dot{\Phi}_2 = \begin{pmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \Phi_{02} \end{pmatrix},$$

$$\dot{\Lambda}_0 = \begin{pmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \Lambda_{00} \end{pmatrix}, \dot{\Lambda}_1 = \begin{pmatrix} \Lambda_1 & \mathbf{0} \\ \mathbf{0} & \Lambda_{01} \end{pmatrix}, \dot{u}_t = \begin{pmatrix} \eta_t \\ u_{0t} \end{pmatrix}$$

First, define the structural shocks $\dot{v}_t$ as

$$\dot{v}_t = P\dot{u}_t,$$

where P is a $(m_\omega + k_0) \times (m_\omega + k_0)$ matrix of coefficients to be identified. Following the triangular approach of Sims (1980), such identification requires $\Sigma_{\dot{v}} = Cov(\dot{v}_t)$ to be diagonal and P to be lower triangular. With Q the upper Cholesky factor of $\Sigma_{\dot{u}} = Cov(\dot{u}) = Q'Q$, the covariance matrix $\Sigma_{\dot{v}} = P\Sigma_{\dot{u}}P'$, with $P = (Q')^{-1}$. As such, $Cov(\dot{v}_t) = I_{(m_\omega + k_\omega)}$.
Next, premultiply the GVAR model in (17) by

$$P_{H_0} = \begin{pmatrix} P & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & I_{k_1} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \ddots & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & I_{k_N} \end{pmatrix}$$

Then, it follows that

$$P_{H_0} H_0 y_t = P_{H_0} H_1 y_{t-1} + P_{H_0} H_2 y_{t-2} + v_t,$$

where $v_t = (\dot{v}_t', u_{1t}', ..., u_{Nt}')'$ and

$$\Sigma_v = Cov(v_t) = \begin{pmatrix} V(\dot{v}_t) & Cov(\dot{v}_t, u_{1t}) & \cdots & Cov(\dot{v}_t, u_{Nt}) \\ Cov(u_{1t}, \dot{v}_t) & V(u_{1t}) & \cdots & Cov(u_{1t}, u_{Nt}) \\ \vdots & \vdots & & \vdots \\ Cov(u_{Nt}, \dot{v}_t) & Cov(u_{Nt}, u_{1t}) & \cdots & V(u_{Nt}) \end{pmatrix}$$

with

$$V(\dot{v}_t) = \Sigma_{\dot{v}} = P\Sigma_{\dot{u}}P', Cov(\dot{v}_t, u_{jt}) = Cov(P\dot{u}_t, u_{jt}) = P\Sigma_{\dot{u},j}$$

For structurally identified shock, v_{lt}, such as a US monetary policy shock, the impulse response function is given by

$$\mathcal{SGIRF}(y_t; v_{lt}, n) = E(y_{t+n}|\mathcal{I}_{t-1}, e_l' v_t = \sqrt{e_l'\Sigma_v el}) - E(y_{t+n}|\mathcal{I}_{t-1}) = \frac{e_j' B_n (P_{H_0} H_0)^{-1} \Sigma_v e_l}{\sqrt{e_l' \Sigma_v e_l}}, \quad h = 0, 1, 2, ...$$

where $e_l = (0, 0, \cdots, 0, 1, 0, \cdots, 0)'$ is a selection vector with unity on the l^{th} element that corresponds to the US, and $e_j = (0, 0, \cdots, 0, 1, 0, \cdots, 0)'$ is a selection vector with unity on element j that refers to the variable shocked, i.e. the short-term interest rate. The Σ_v represents the covariance matrix of the structural shocks and $P_{H_0} H_0$ is the identification scheme to identify the shocks.

B Tables and Graphs

Table 11: Complete Overview of VARX* Order and Number of Cointegration Relationships

	1979 - 2006			1979 - 2016		
	VARX*(p_i, q_i)		Rank	VARX*(p_i, q_i)		Rank
	p_i	q_i		p_i	q_i	
Argentina	2	1	2	2	1	2
Australia	1	1	4	1	1	3
Brazil	2	1	1	2	1	2
Canada	1	1	4	2	1	3
China	2	1	1	2	1	2
Chile	2	1	2	2	1	2
Euro-Area	2	2	2	2	1	1
India	2	1	2	2	1	2
Indonesia	2	1	3	2	1	3
Japan	1	1	4	2	1	2
Korea	2	1	4	2	1	3
Malaysia	2	1	1	1	1	2
Mexico	1	1	3	1	1	2
Norway	2	1	2	2	1	3
New-Zealand	2	1	3	2	1	3
Peru	2	1	3	2	1	2
Philippines	2	1	2	2	1	3
South Africa	2	1	1	2	1	2
Saudi Arabia	2	1	1	2	1	1
Singapore	2	1	3	2	1	1
Sweden	2	1	3	2	1	2
Switzerland	1	1	3	1	1	3
Thailand	1	1	3	2	1	2
Turkey	2	1	1	2	1	1
UK	2	1	3	1	1	2
USA	2	2	2	2	1	2

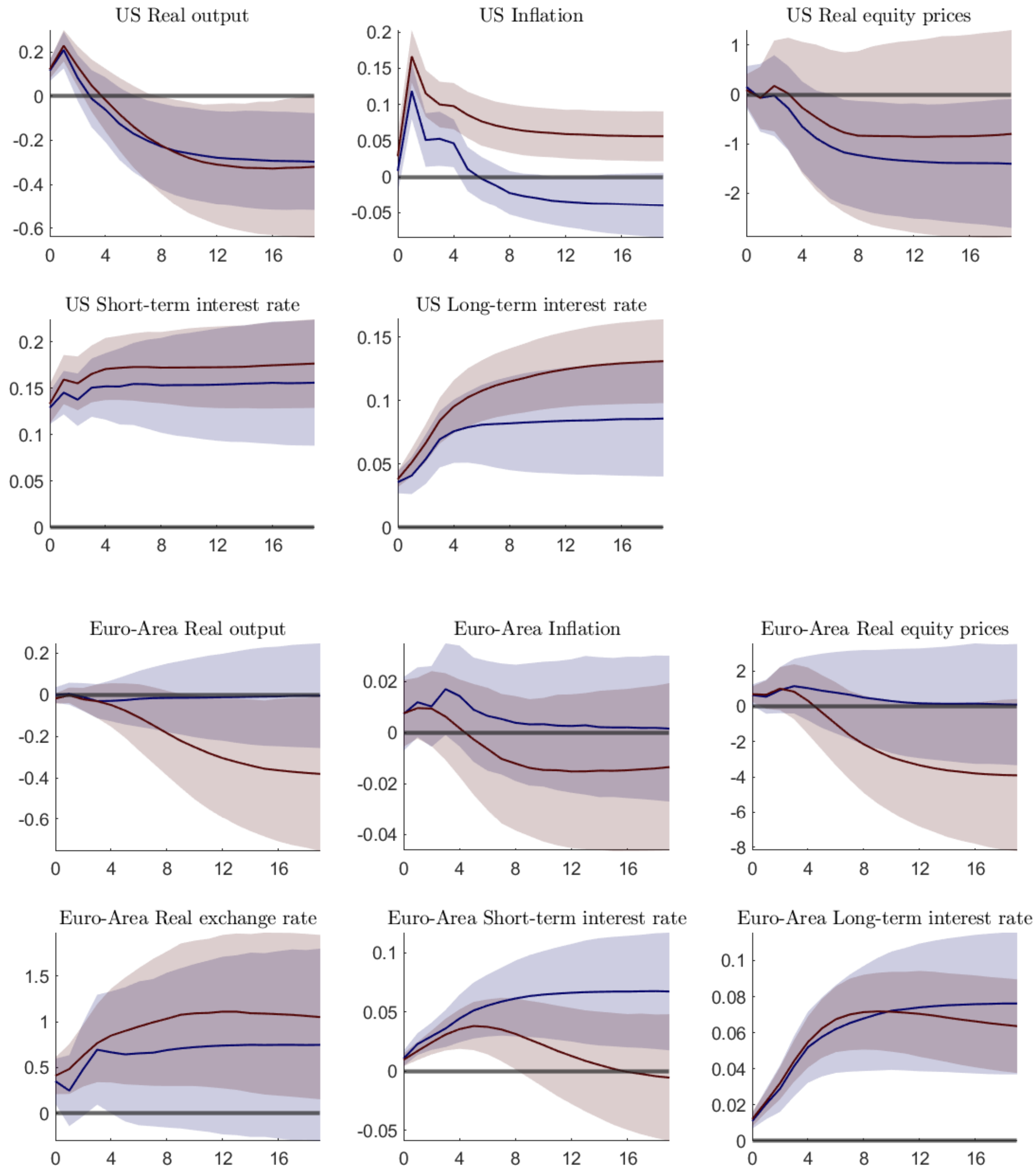
Table 12: Complete Overview of Bilateral Trade Shares

1979 - 2006	Argentina	Australia	Brazil	Canada	China	Chile	Euro-Area	India	Indonesia	Japan	Korea	Malaysia	Mexico	Norway	New-Zealand	Peru	Philippines	South-Africa	Saudi Arabia	Singapore	Sweden	Switzerland	Thailand	Turkey	UK	USA
Argentina	0.00	0.00	0.27	0.01	0.08	0.10	0.20	0.02	0.01	0.02	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.02	0.16
Australia	0.00	0.00	0.00	0.02	0.12	0.00	0.13	0.02	0.03	0.17	0.06	0.03	0.00	0.00	0.06	0.00	0.01	0.01	0.01	0.04	0.01	0.01	0.03	0.00	0.05	0.15
Brazil	0.09	0.01	0.00	0.02	0.07	0.03	0.26	0.01	0.01	0.05	0.02	0.01	0.04	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.03	0.28
Canada	0.00	0.00	0.00	0.00	0.04	0.00	0.05	0.00	0.00	0.03	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.78
China	0.00	0.02	0.01	0.02	0.00	0.01	0.17	0.01	0.02	0.22	0.11	0.03	0.01	0.00	0.00	0.00	0.02	0.01	0.01	0.03	0.01	0.01	0.02	0.00	0.03	0.22
Chile	0.11	0.01	0.09	0.02	0.10	0.00	0.20	0.01	0.01	0.09	0.05	0.00	0.04	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.03	0.19
Euro-Area	0.01	0.01	0.02	0.02	0.09	0.01	0.00	0.02	0.01	0.06	0.02	0.01	0.01	0.03	0.00	0.00	0.01	0.02	0.02	0.02	0.06	0.09	0.01	0.03	0.23	0.21
India	0.01	0.03	0.02	0.02	0.08	0.00	0.24	0.00	0.03	0.05	0.04	0.03	0.01	0.00	0.00	0.00	0.01	0.02	0.03	0.05	0.01	0.03	0.02	0.01	0.07	0.20
Indonesia	0.00	0.04	0.01	0.01	0.09	0.00	0.12	0.03	0.00	0.22	0.07	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.11	0.00	0.00	0.04	0.00	0.02	0.13
Japan	0.00	0.04	0.01	0.02	0.19	0.01	0.13	0.01	0.03	0.00	0.08	0.03	0.01	0.00	0.01	0.00	0.02	0.01	0.03	0.03	0.01	0.01	0.04	0.00	0.03	0.26
Korea	0.00	0.03	0.01	0.02	0.20	0.01	0.11	0.01	0.03	0.18	0.00	0.03	0.01	0.00	0.00	0.00	0.02	0.00	0.04	0.03	0.00	0.01	0.02	0.01	0.02	0.21
Malaysia	0.00	0.03	0.00	0.01	0.09	0.00	0.10	0.02	0.03	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.19	0.00	0.01	0.05	0.00	0.02	0.20
Mexico	0.00	0.00	0.01	0.03	0.03	0.00	0.06	0.00	0.00	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.77
Norway	0.00	0.00	0.01	0.04	0.03	0.00	0.47	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.13	0.01	0.00	0.01	0.17	0.08
New Zealand	0.00	0.25	0.00	0.02	0.08	0.00	0.13	0.01	0.02	0.13	0.04	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.02	0.00	0.05	0.15
Peru	0.02	0.01	0.05	0.02	0.08	0.07	0.18	0.01	0.00	0.04	0.03	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.06	0.34
Philippines	0.00	0.02	0.00	0.01	0.08	0.00	0.11	0.01	0.02	0.22	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.00	0.00	0.04	0.00	0.02	0.24
South-Africa	0.01	0.03	0.02	0.01	0.06	0.00	0.35	0.02	0.01	0.10	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.01	0.02	0.01	0.01	0.12	0.13
Saudi Arabia	0.00	0.02	0.02	0.01	0.07	0.00	0.20	0.02	0.02	0.17	0.09	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.04	0.01	0.01	0.02	0.01	0.04	0.21
Singapore	0.00	0.03	0.00	0.00	0.09	0.00	0.11	0.02	0.07	0.11	0.05	0.19	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.01	0.05	0.00	0.03	0.16
Sweden	0.00	0.01	0.01	0.01	0.03	0.00	0.54	0.01	0.00	0.03	0.01	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.01	0.10	0.10
Switzerland	0.00	0.01	0.01	0.01	0.02	0.00	0.68	0.01	0.00	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.06	0.10
Thailand	0.00	0.03	0.01	0.01	0.09	0.00	0.11	0.01	0.03	0.24	0.04	0.07	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.08	0.00	0.01	0.00	0.00	0.03	0.17
Turkey	0.00	0.01	0.01	0.01	0.04	0.00	0.58	0.01	0.01	0.03	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.00	0.02	0.04	0.00	0.00	0.09	0.09
UK	0.00	0.01	0.01	0.02	0.03	0.00	0.54	0.01	0.00	0.04	0.01	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.02	0.01	0.01	0.00	0.16
USA	0.00	0.01	0.02	0.23	0.11	0.00	0.16	0.01	0.01	0.10	0.04	0.02	0.14	0.00	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.00	0.05	0.00

1979 - 2016	Argentina	Australia	Brazil	Canada	China	Chile	Euro-Area	India	Indonesia	Japan	Korea	Malaysia	Mexico	Norway	New-Zealand	Peru	Philippines	South-Africa	Saudi Arabia	Singapore	Sweden	Switzerland	Thailand	Turkey	UK	USA
Argentina	0.00	0.01	0.30	0.02	0.14	0.04	0.16	0.02	0.02	0.02	0.02	0.01	0.03	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.12
Australia	0.00	0.00	0.00	0.01	0.31	0.00	0.09	0.03	0.03	0.15	0.07	0.04	0.01	0.00	0.03	0.00	0.01	0.01	0.01	0.05	0.01	0.01	0.04	0.00	0.03	0.09
Brazil	0.09	0.00	0.00	0.02	0.22	0.02	0.21	0.03	0.01	0.04	0.04	0.01	0.03	0.00	0.00	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.17
Canada	0.00	0.00	0.01	0.00	0.08	0.00	0.06	0.01	0.00	0.03	0.01	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.68
China	0.01	0.05	0.03	0.02	0.00	0.01	0.16	0.03	0.03	0.12	0.11	0.04	0.02	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.01	0.02	0.03	0.01	0.03	0.20
Chile	0.04	0.01	0.07	0.02	0.25	0.00	0.14	0.02	0.00	0.08	0.05	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.20
Euro-Area	0.01	0.01	0.03	0.02	0.16	0.01	0.00	0.03	0.01	0.04	0.02	0.01	0.02	0.03	0.00	0.00	0.00	0.01	0.02	0.02	0.05	0.09	0.01	0.04	0.18	0.16
India	0.00	0.03	0.02	0.01	0.15	0.01	0.16	0.00	0.04	0.04	0.04	0.03	0.01	0.00	0.00	0.00	0.00	0.03	0.10	0.04	0.01	0.06	0.02	0.01	0.03	0.14
Indonesia	0.01	0.03	0.01	0.01	0.16	0.00	0.08	0.05	0.00	0.15	0.08	0.07	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.14	0.00	0.00	0.05	0.01	0.01	0.08
Japan	0.00	0.06	0.01	0.02	0.26	0.01	0.09	0.01	0.04	0.00	0.08	0.04	0.01	0.00	0.00	0.00	0.02	0.01	0.05	0.02	0.00	0.01	0.05	0.00	0.02	0.18
Korea	0.00	0.04	0.02	0.01	0.29	0.01	0.08	0.02	0.03	0.12	0.00	0.02	0.02	0.01	0.00	0.00	0.02	0.01	0.06	0.04	0.00	0.00	0.02	0.01	0.02	0.14
Malaysia	0.00	0.04	0.01	0.01	0.18	0.00	0.10	0.04	0.05	0.12	0.05	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.16	0.00	0.01	0.07	0.00	0.01	0.10
Mexico	0.00	0.00	0.01	0.03	0.10	0.00	0.07	0.01	0.00	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.68
Norway	0.00	0.00	0.01	0.02	0.05	0.00	0.45	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.10	0.01	0.00	0.01	0.21	0.06
New Zealand	0.00	0.20	0.00	0.01	0.21	0.00	0.10	0.01	0.02	0.08	0.05	0.04	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.04	0.00	0.00	0.03	0.00	0.03	0.11
Peru	0.03	0.00	0.06	0.05	0.22	0.05	0.14	0.02	0.00	0.05	0.04	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.01	0.01	0.23
Philippines	0.00	0.02	0.00	0.01	0.15	0.00	0.11	0.01	0.04	0.18	0.08	0.04	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.09	0.00	0.01	0.06	0.00	0.01	0.15
South-Africa	0.01	0.02	0.02	0.01	0.19	0.00	0.26	0.06	0.01	0.07	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.06	0.02	0.01	0.02	0.02	0.01	0.05	0.10
Saudi Arabia	0.00	0.01	0.01	0.01	0.17	0.00	0.13	0.10	0.01	0.14	0.11	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.04	0.00	0.01	0.03	0.01	0.01	0.14
Singapore	0.00	0.04	0.01	0.00	0.16	0.00	0.10	0.04	0.11	0.07	0.07	0.16	0.01	0.00	0.01	0.00	0.02	0.00	0.03	0.00	0.00	0.01	0.04	0.00	0.02	0.11
Sweden	0.00	0.01	0.01	0.01	0.06	0.00	0.54	0.01	0.00	0.02	0.01	0.00	0.00	0.13	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.09	0.06
Switzerland	0.00	0.01	0.01	0.01	0.06	0.00	0.52	0.04	0.00	0.02	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.02	0.01	0.00	0.01	0.02	0.11	0.10
Thailand	0.00	0.04	0.01	0.01	0.18	0.00	0.08	0.02	0.05	0.18	0.04	0.07	0.01	0.00	0.01	0.00	0.02	0.01	0.03	0.05	0.00	0.03	0.00	0.00	0.02	0.11
Turkey	0.00	0.01	0.01	0.01	0.13	0.00	0.46	0.03	0.01	0.02	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.03	0.00	0.02	0.04	0.01	0.00	0.07	0.09
UK	0.00	0.01	0.01	0.02	0.08	0.00	0.50	0.02	0.00	0.02	0.01	0.01	0.00	0.04	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.06	0.01	0.02	0.00	0.12
USA	0.00	0.01	0.02	0.20	0.18	0.01	0.14	0.02	0.01	0.07	0.03	0.01	0.16	0.00	0.00	0.01	0.01	0.00	0.02	0.02	0.00	0.02	0.01	0.01	0.03	0.00

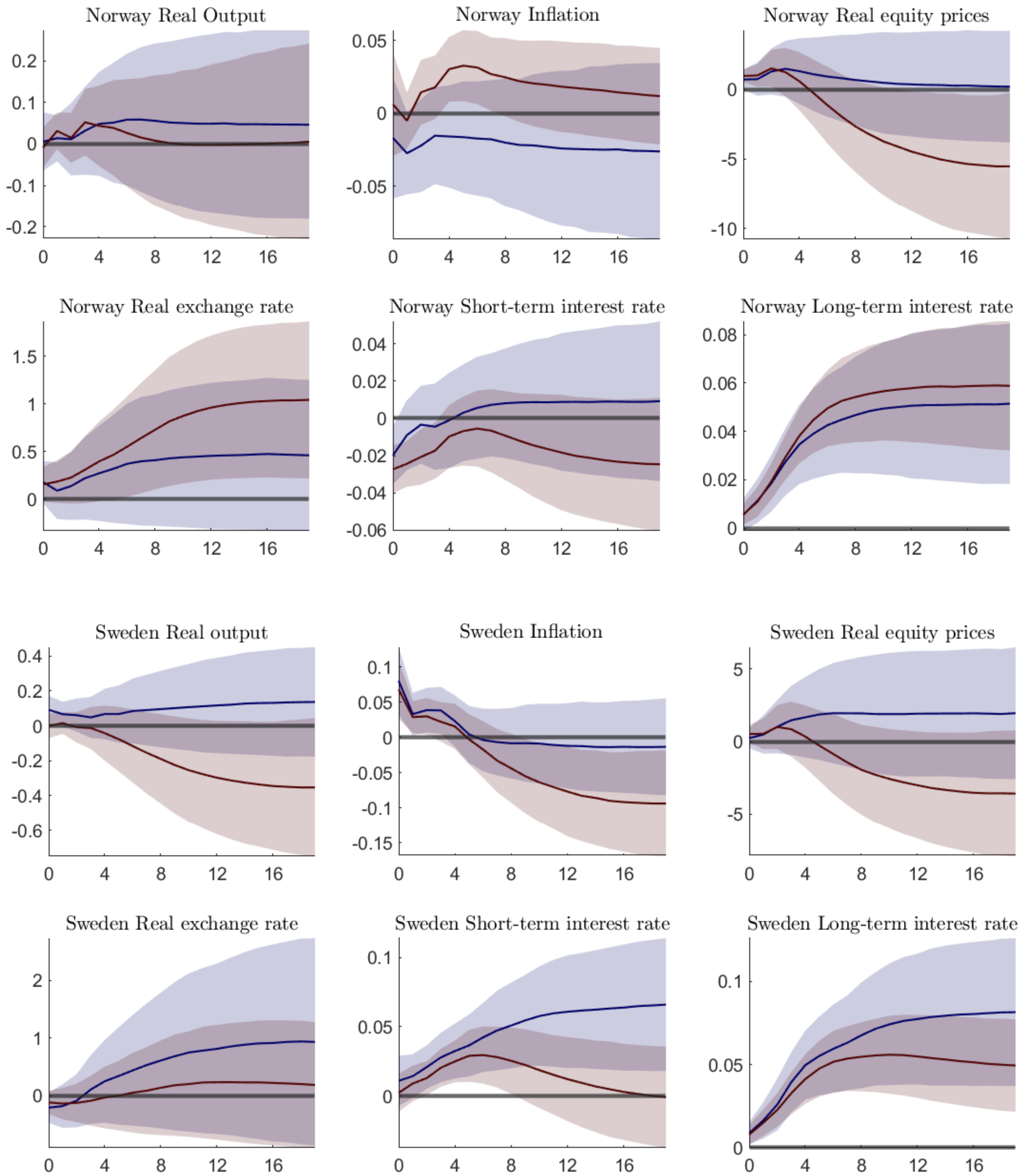
Source: IMF Direction of Trade Statistics

Figure 8: Positive Shock to US Monetary Policy (Robustness Check): US and Euro-Area



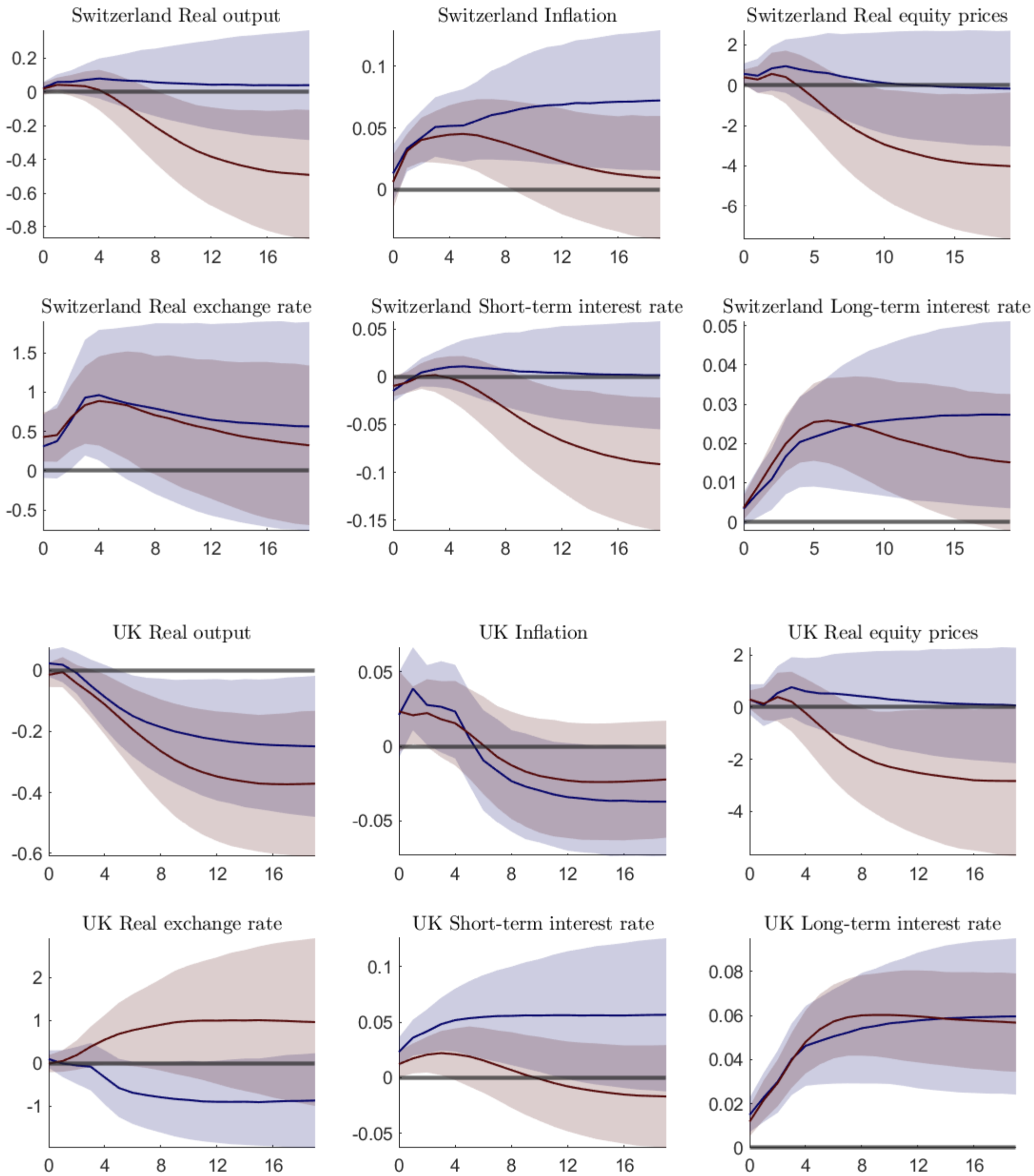
Note: The Structural Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US monetary policy (0.13%). The ordering is given by $S = (p^{oil}, p^{mat}, p^{met}, i^S, i^L, q, \pi, y)$ *The shaded area represents the 70% confidence bounds.*

Figure 9: Positive Shock to US Monetary Policy (Robustness Check): Norway and Sweden



Note: The Structural Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US monetary policy (0.13%). The ordering is given by $S = (p^{oil}, p^{mat}, p^{met}, i^S, i^L, q, \pi, y)$ *The shaded area represents the 70% confidence bounds.*

Figure 10: Positive Shock to US Monetary Policy (Robustness Check): Switzerland and UK



Note: The Structural Generalized IRFs for the 1979Q2-2006Q4 model (blue) and for the 1979Q2-2016Q4 (red), resulting from a positive one s.e. shock to US monetary policy (0.13%). The ordering is given by $S = (p^{oil}, p^{mat}, p^{met}, i^S, i^L, q, \pi, y)$ *The shaded area represents the 70% confidence bounds.*

C Data Description

The dataset employed in this thesis, covering the period 1979Q1 - 2016Q4, is an updated version of the database provided by Smith & Galesi (2014) that spans from 1979Q1 to 2013Q1. On their turn, Smith and Galesi extended and revised the dataset used in Dees, di Mauro et al. (2007), reaching up to 2003Q4.

Like the Smith & Galesi (2014) database, the construction of the variables relies on the International Financial Statistics (IFS) database, the Inter-American Development Bank Latin Macro Watch (IDB LMW) database, and data from Bloomberg. The data for the variables are compiled on quarterly basis, and thus need to be controlled for seasonality. To this end, a joint significance test of seasonal effects is carried out for all the variables. The variables that fail the test, are adjusted with the method described in Smith & Galesi (2014) that makes use of the X-12 method.

For constructing the country-specific foreign variables, a trade matrix needs to be constructed. For this purpose, the IMF Direction of Trade statistics was used.
The PPP-GDP data employed for the feedback weights are obtained from the World Development Indicator database of the World Bank.

For a detailed description of the dataset, I refer to Smith & Galesi (2014).

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