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The world is not enough! Small open economies and regional dependence*

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Abstract

This paper bridges the new open economy factor augmented VAR (FAVAR) studies with the recent findings in the business cycle synchronization literature emphasizing the importance of regional factors. That is, we estimate and identify a three block FAVAR model with separate world, regional and domestic blocks and study the transmission of both global and regional shocks to four small open economies (Canada, New Zealand, Norway and UK). The results show that foreign shocks explain a major share of the variance in all countries, most so shocks that are common to the world. However, regional shocks also play an important role, explaining more than 20 percent of the variance in the variables. Hence in small open economies, the world is not enough. The regional factors impact the four countries differently, though, some through trade and some through consumer sentiment. Our findings of a strong transmission of both global and regional shocks to open economies are in sharp contrast to the evidence from recently developed open economy DSGE models.

JEL-codes: C32, E32, F41

Keywords: International transmission, world and region, small open economy, FAVAR, Business cycles

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1 Introduction

The last decades have been characterized as the globalization era. The share of total trade to world GDP has increased significantly, while liberalization of economic policies and financial markets have boosted financial integration. This has led to rapid economic growth in many regions of the world, starting with the US and Europe, extending now through much of Asia, parts of Africa and South America.

A long standing literature has investigated the patterns of globalization and regionalism, and their impact on business cycle synchronization, inflation and interest rates.[1] While studies such as Kose et al. (2003) seemed to confirm that world factors were indeed enough to describe the evolution of domestic business cycles, studies covering more recent periods find support for an increase in the role of regional factors. In particular, Clark and Shin (2000), Stock and Watson (2005), Moneta and Rüffer (2009) and Mumtaz et al. (2011) find that regional factors play a prominent role in explaining the evolution of the business cycle in different countries and regions, especially in North America, Europe and Asia.

For policy institutions in small open economies it is important to understand how international developments transmit into the domestic economy. The business cycle synchronization literature referred to above does not study this, as they leave the issue of identifying shocks unattended. On the other hand, models that analyze the transmission of international shocks to the domestic economy, such as open economy small-scale structural vector autoregressions (VARs) and factor augmented VAR (FAVAR) models, largely ignore the issue of globalization and regionalism. For instance, VAR models of the open economy such as Eichenbaum and Evans (1995) and Grilli and Roubini (1996), typically use a two country model to account for foreign influence, while open economy FAVAR models such as Mumtaz and Surico (2009), Boivin and Giannoni (2010) and Liu et al. (2011), identify shocks to common global factors, but do not discriminate between regional and world factors.[2]

We hypothesize that such a separation is important for identifying shocks that are common across the world and shocks that are region specific, affect-

[1] See e.g. Backus et al. (1995), Kose et al. (2003), Baxter and Kouparitsas (2005) and Kose et al. (2008) on business cycle synchronization and Mumtaz and Surico (2008), Monacelli and Sala (2009) and Ciccarelli and Mojon (2010) on co-movement of inflation rates.

[2] See also Eickmeier (2007) and Eickmeier et al. (2011) that study the transmission of US shocks to individual countries, the latter using a FAVAR model with time-variation.

ing in particular small open economies that trade within a certain geographical area.

In this paper we therefore bridge the new open economy FAVAR studies with the later findings in the business cycle synchronization literature and explicitly include both regional and world factors into a FAVAR model. More precisely, we extend the global FAVAR model proposed by Mumtaz and Surico (2009) to also include regional factors. To do so we estimate a three block FAVAR model with separate world, regional and domestic blocks. The analysis is applied to four small open economies; Canada, New Zealand, Norway and the UK, potentially affected differently by the various regions. The countries are chosen as they are somewhat peripheral to their respective geographical region. This is important as one can then disentangle the purely domestic factors from the regional factors, as well as identifying the corresponding shocks.

In addition to including regional factors, our FAVAR setup differs from Mumtaz and Surico (2009) in two other important aspect. First, we allow the dynamics of all the domestic variables to be a linear combination of both foreign (world and regional) and domestic factors. This implies that both domestic and foreign shocks may affect the domestic variables on impact, a plausible assumption in an integrated world, we believe. In contrast, Mumtaz and Surico (2009) restrict the domestic variables to be a linear combination of the domestic factors only. That way, the foreign shocks can only affect the dynamics in the individual domestic variables by first having an impact on the common domestic factors. We argue that this may undermine the importance of foreign driven shocks. Second, our domestic factors differ as we assume that they are orthogonal to the foreign factors. We argue that in this way we are able to more clearly distinguish the foreign impulses from the domestic impulses.

The modeling framework chosen is similar in spirit to the approach taken in Kose et al. (2003) of separating out the the effects of the world, region and the country specific factors, as well as the global VAR (GVAR) approach of Dees et al. (2007).[3] In contrast to the work by Kose et al. (2003) however, our FAVAR model will allow us to identify both price and activity shocks in addition to the domestic shocks. The shocks will be identified using two different identification schemes (recursive and sign restrictions). Finally, compared to the business cycle synchronization literature as well as the GVAR approach, the FAVAR approach utilizes a large domestic data set, which allows for a

[3]See also Pesaran et al. (2004) and Pesaran and Smith (2006) for more on the global VAR approach.

much richer description of the domestic responses to different world, regional and domestic shocks. In particular, while the business cycle synchronization literature tends to focus on synchronization from a perspective of trade, our FAVAR framework allows us to add variables that may capture consumers' expectations about the future, such as financial market prices (i.e. Beaudry and Portier (2006)), or survey measures of consumer confidence (i.e. Barsky and Sims (2009)). This is an important extension that allows us to investigate the channels behind the business cycle synchronization from a wide perspective.

Specified this way, we can address the following questions. What is the role of global factors for developments in the domestic economy? To what extent does the region located close to the country matter? For instance, does the recent slow down in the Euro area affect countries close to the European region negatively, while countries located close to fast growing Asia are better off? Or doesn't location matter in an integrated world? And finally, how do the global and regional shocks affect the domestic economy? Primarily through trade, or through other channels such as consumers' anticipations of the future?

To our knowledge, this is the first paper to study and separate the effects of global and regional shocks to the domestic economy. Our main contributions and results are as follows:

First, foreign shocks explain a major share of business cycle fluctuations in small open economies. In particular, foreign shocks account for almost 50 percent of the variation in the domestic variables in all the four countries we are examining, increasing to 60-70 percent after two years. The impact is broadly felt in all components of output, prices and asset prices. Hence, we show that including foreign factors into a FAVAR model is an important extension of the standard FAVAR framework of Bernanke et al. (2005) to the open economy. The result contrasts findings in Mumtaz and Surico (2009) and Liu et al. (2011) of a weak impact of foreign (activity) shocks to the UK macroeconomy. We believe that the two key reasons for the difference in results are that Mumtaz and Surico (2009) and Liu et al. (2011) neglect the impact of regional factors and that they restrict the domestic variables to be a linear combination of the domestic factors only. As mentioned above, such a restriction may undermine the importance of foreign driven shocks.

Second, while shocks that are common to the world are the most important foreign shocks, regional shocks are far from trivial, and explain about 20 percent of the variance in the domestic variables in all the countries. Hence, for the small open economies analyzed here, the world is not enough! The regional factors impact the countries differently, though. In Canada and New Zealand, the regional activity shocks affect the domestic economy positively in particular through trade and employment. The effects of a regional activity shock in Norway and UK are also substantial, but the positive impact on trade is somewhat weaker. Instead, variables such as consumption, import, credit and house prices are directly affected, most likely through consumer sentiment.

We then do one major augmentation to our model setup by explicitly adding oil price to the model. Insofar as oil prices are globally determined, this should give us a better understanding of the foreign shocks. However, maybe even more important for our purpose is the fact that the small open economies we are analyzing are oil dependant, either as net oil exporters (Norway, Canada and previously the UK), or in their use of petroleum relative to the size of GDP (especially Canada and New Zealand). As such, our choice of countries can potentially bias the results against finding a role for regional factors. Explicitly including oil price to the model controls for this.

Accordingly, we find oil prices to account for 10-15 percent of the variation in the variables in all countries. However, the total variance explained by the foreign variables (including oil) remains much the same as before. We find that this is primarily due to the fact that the contribution from the world price factor decreases almost proportionably with the increased contribution from the oil price shock, while the regional and domestic factors remain very similar. Hence, the world price factor was also capturing the common responses to the oil price shocks.

A number of robustness checks leaves the general conclusions unaltered: Common world shocks affect small open economies significantly, and regional factors need to be accounted for. This holds after changing the composition of what defines the world factors, identifying the shocks employing sign restrictions (instead of recursive identification used in the baseline model), and changing the sample period.

Our results suggest that policymakers in small open economies need to understand how various foreign shocks transmit into the domestic economy and respond appropriately. In many policy institutions, Dynamic Stochastic General Equilibrium (DSGE) models play an important role for policy decisions. These models largely ignore foreign shocks, and of those that attempt to incorporate foreign shocks, there is little evidence of any significant foreign influence, see e.g. Galí and Monacelli (2005), Justiniano and Preston (2010) and Christiano et al. (2010).

Our findings of a strong transmission of both global and regional shocks to open economies are in sharp contrast to the evidence from recently developed open economy DSGE models. Yet, two common features of these DSGE models may explain why they find only trivial effects when adding foreign shocks. First, the transmission of foreign shocks in DSGE models often only go through one channel such as terms of trade. Here we have seen that trade is only one of several features where foreign shocks may affect the domestic economy. Second, foreign shocks do not affect the domestic economy directly in the DSGE models. The latter implies that these models do not allow for common shocks hitting both the foreign and the domestic economy at the same time. Our results do not support these restrictions as we show evidence of a direct effect on the domestic economy, as many variables such as credit, stock prices, investment, imports and consumption increase on impact from global and regional shocks.

The remainder of the paper is structured as follows: Section 2 describes the model, the identification scheme and the estimation procedure. In section 3 we report the results. We first describe the estimated factors and the contribution of these to the domestic variables. Then we give a detailed description of the impulse responses of the identified shocks in the model. Section 4 discusses robustness while Section 5 concludes.

2 The model

Our factor augmented vector autoregressive (FAVAR) model follows the general setup in Bernanke et al. (2005), and extended to the international economy by Mumtaz and Surico (2009). A fundamental assumption in our analysis is the belief that the dynamics of domestic variables can be captured by some common world and regional unobserved factors in addition to a set of purely domestic factors (including domestic monetary policy). Based on the evidence from the international business cycle literature we have chosen to categorize the world and regional factors into world activity and price factors, and regional activity, price and interest rate factors.[4]

The factors are generally unobserved, and have to be estimated from the data. Thus, the model can naturally be represented in a state space form. We specify the transition equation as:

[4] We include a regional interest rate into the analysis to control for the possible influence of the monetary policy setting in the region on the domestic economies.

$$\begin{bmatrix} F_t \\ R_t \end{bmatrix} = \beta(L) \begin{bmatrix} F_{t-1} \\ R_{t-1} \end{bmatrix} + u_t, \tag{1}$$

where $F_t = \begin{bmatrix} F_t^* & F_t^{**} & F_t^D \end{bmatrix}'$ is a set of world, regional and domestic factors, and R_t is an observed domestic interest rate factor. $\beta(L)$ is a conformable lag polynomial of order p and u_t is the reduced form disturbances. The structural disturbances follow $u_t = \Omega^{1/2}\varepsilon_t$, with $\varepsilon \sim N(0,1)$ and $\Omega = A_0(A_0)'$.

The observation equation of the system is:

$$X_t = \Lambda^F F_t + \Lambda^R R_t + e_t, \tag{2}$$

where X_t is a $N \times 1$ vector of variables, Λ^F and Λ^R are $N \times K$ and $N \times 1$ matrices of factor loadings. Finally e_t is a $N \times 1$ vector of idiosyncratic, zero mean, disturbances.

2.1 Identifying the factors

To estimate equation (1), we first need to extract the unobserved factors. We assume two world factors, $F_t^* = \begin{bmatrix} F_t^{act*} & F_t^{pri*} \end{bmatrix}$, representing respectively global co-movements in real activity and prices, and three regional factors $F_t^{**} = \begin{bmatrix} F_t^{act**} & F_t^{pri**} & R_t^{**} \end{bmatrix}$, representing respectively regional co-movements in real activity and prices and an observed regional interest rate. In addition to the global and regional factors we will assume three domestic factors, $F_t^D = \begin{bmatrix} F_t^{D_1} & F_t^{D_2} & F_t^{D_3} \end{bmatrix}$, and a domestic interest rate R_t.[5] Note that in our model the derived domestic factors, F_t^D, have not been given any economic interpretation and hence they are not identified.[6]

To identify the unobserved factors, the X matrix in the observation equation is partitioned into blocks. Each block consists of either world, regional or domestic data. By restricting the different data blocks in X_t, we argue that

[5] The choice of three domestic factors have been made based on two informal criteria. First, including additional purely domestic factors increases the variance explained by the factors only marginally. Second, including less than three domestic factors could potentially bias our results towards the foreign factors such that almost all of the variance explained by the model is attributed to the foreign factors and shocks.

[6] Restricting the domestic factors to rely on specific variables, and thereby identify them as for example real activity or price factors could have been done. However, such additional identifying restrictions would have limited the potential heterogenous responses of the domestic variables to shocks in the transition equation.

we can identify the unobserved factors, or the underlying driving forces of the world, regional and domestic economy. Appendix A describes the estimation procedure in detail. Here it is sufficient to note that the unobserved factors are essentially estimated by principal components, block by block.

A potential problem when identifying the factors block by block, is that the regional and domestic factors may span the same space as the world factors. To further separate the world factors from regional factors, we therefore follow Kose et al. (2003), and impose the restriction that the world activity and regional activity factors are orthogonal.[7] Likewise, a similar restriction is imposed for the world price and regional price factors. In this way, the regional activity/price factor will capture common co-movements in the regional activity/price variables that cannot be explained by the world activity/price factor. Similarly, we separate the domestic factors from the world and regional factors, by assuming they are orthogonal to both regional and global factors.[8]

Having properly identified the unobserved factors in equation (1), the factors will be related to the domestic variables such that each domestic series is a linear combination of both the domestic factors as well as the global and regional factors. We emphasize that this loading structure relates closely to our underlying identification scheme, and that the loading structure permits both domestic and foreign shocks to affect the domestic variables on impact.

To sum up, we separate the domestic factors from the world and the regional factors by imposing the restriction that the domestic factors are orthogonal to both regional and global factors. At the same time, we allow the dynamics of each domestic series to be a linear combination of both the domestic factors as well as the global and regional factors. This differs from the approach taken in Mumtaz and Surico (2009), where the structural factors are identified by only imposing restrictions on the loading matrix. In particular, they restrict the dynamics of each domestic series to be a linear combination of the domestic factors only, implying that their international factors cannot affect the domestic variables directly. However, as the international factors are linked to the domestic factors via the transition equation (1), they can affect the domestic variables indirectly (or via a lag). We believe such a restriction is neither innocuous nor necessary to identify the foreign impulses. Furthermore, we believe it may undermine the effect of international impulses to the domestic economy.

[7] A similar setup is also chosen when identifying world and regional factors in Karagedikli and Thorsrud (2011).

[8] See Appendix A for a more detailed explanation of how we construct the factors.

2.2 Identifying the shocks

To identify the structural shocks, we apply two different identification schemes for the transition equation. The first (and baseline) is a standard recursive ordering of the variables (Cholesky identification), and the second is a combination of recursive restrictions and sign restrictions. For both identification schemes we assume a block exogenous structure in the transition equation. That is, the $\beta(L)$ term from equation (1) is restricted so that the domestic factors (F) do neither affect the regional nor the world factors (F^{**} and F^{*}) at any horizons. The regional factors can affect the domestic factors contemporaneously and the global factors only with a lag.

For the recursive identification scheme activity factors are ordered before price and interest rate factors within each block, a common assumption in SVAR analysis. The global factors are ordered before the regional factors, and the domestic factors are ordered last. As such, impulse responses and variance decompositions can be computed using standard VAR techniques. The implementation of the sign restrictions assumes the same ordering of the variables as in the recursive identification scheme and follows the approach in Mumtaz and Surico (2009). However additional restrictions are imposed in order to identify world and regional demand and supply shocks. This is explained in detail in Appendix A.

Given the identification of the factors, we argue that we can uncover six different structural shocks using the Cholesky ordering, namely world activity and price shocks, regional activity, price and interest rate shocks, and also a domestic monetary policy shock. Note that since we let all the domestic variables load contemporaneously on the interest rate factor, we potentially allow any fast moving variables ordered above the interest rate factor in the transition equation, e.g. exchange rates, to actually react contemporaneously to interest rate shocks.[9]

2.3 Data and estimation

In total, we include variables from 32 different countries in the FAVAR. The data include variables from the US, UK, Switzerland, Netherlands, Japan, Italy, France, Finland, Denmark, Sweden, Norway, Spain, Germany, Belgium, Luxembourg, Canada, Chile, Peru, South Africa, Brazil, Argentina, Mexico,

[9]Thereby avoiding imposing a puzzle from the outset, see Bjørnland (2009) for a further discussion.

Korea, China, Malaysia, India, Taiwan, Hong Kong, Thailand, Singapore, Australia and New Zealand.[10] We use primarily real activity and price series from the G20 countries to construct respectively global activity and price factors. Note, however, that we do not have data for Russia, Indonesia, Turkey and Saudi Arabia.

The regional activity and price factors are constructed using activity and price variables from the respective geographical regions. For Norway and UK, the regional block consists of data from European countries, while for Canada and New Zealand the regional block consists of data from respectively North America and Asia. As for regional monetary policy, we select the Euro Area interest rate as regional interest rate for Norway and UK, the US interest rate as regional interest rate for Canada and the Australian interest rate as regional interest rate for New Zealand.

To establish to what extent the chosen geographical regions are also important for trade, we report export and import shares for the main trading partners of the different countries, see Table 4 in Appendix B. The table suggests that the US is by far the most important trading partner for Canada, accounting for about 75 percent of all exports and more than 50 percent of all imports. The European Union as a whole is the most important trading partner for both Norway and UK accounting for respectively 80 and 55 percent of the countries exports and 66 and 53 percent of the countries' imports.[11] For New Zealand the picture is somewhat more diverse. Their main trading partner is Australia, but they also have substantial trade with the European Union (mostly UK), US, China and Japan. Together, however, Australia and Asian countries account for more than 50 percent of both exports and imports to New Zealand. Hence, the geographical regions are also where the main trading partners of each country are located.

Since we are mainly interested in investigating how the different world and regional shocks affect the four domestic economies, the variables entering into the domestic block is collected from a much wider pool of series, than the global and regional factors.We have tried to make the four domestic data sets as balanced and similar as possible. In total we include respectively 92, 89, 94 and 88 data series for Canada, New Zealand, Norway and UK. Each data set covers a broad range of aggregated and disaggregated macroeconomic

[10]Compared to the data set used by Mumtaz and Surico (2009), our data set includes a larger share of variables from the emerging and developed Asian economies. We believe this is important to capture the unobserved world factors.

[11]Note, that the US is also an important trading partner for UK both in terms of exports and imports.

variables.[12]

The model is estimated on quarterly observations from 1992Q2 to 2009Q4. Some monthly series are included in the model; these are aggregated to quarterly series by taking the mean. Variables that are assumed to be non-stationary are in quarterly growth rates, while variables affected by seasonality are seasonally adjusted using the X12 ARIMA procedure. To make the estimation of the factors invariant to scale, all variables are standardized prior to estimation.

Finally, we estimate the system in equation (1) and (2) in a two step procedure: The unobserved factors are first estimated by principal components block by block and then identified. Then, after the factors are identified and estimated, we estimate equation (1) as a Bayesian VAR. Appendix A gives a detailed description of the two step estimation procedure.

3 Results

In the following we first present the identified world and regional factors, and some statistics highlighting their relevance. Thereafter we investigate the impulse responses to the world and regional shocks in detail.

3.1 Identified factors

The estimated factors are unobserved and represent the "underlying" driving forces in the economy. To gain some insight into what the factors are capturing, Figure 1 graphs the estimated world factors (activity and price), followed by the regional factors (activity and price) in Europe, Asia, and North America respectively.[13]

The world activity factor (left column) captures the important features of the world business cycle the last 20 years. It resembles well the factor identified in Mumtaz and Surico (2009), although our sample covers more years at the end, including the period of the financial crisis. Several periods stand out. In particular, the Asian led crisis by the end of the 1990s (see the discussion for Asia) which induced a brief downturn in the world business cycle. The world

[12] Appendix B gives a more detailed description of some of the variables entering into the model.

[13] We do not show the three estimated domestic factors, as we do not identify them.

activity factor also captures the global effect of the 2001 slowdown following the bursting of the dot-com bubble. Finally, the recession following the financial crisis is by far the deepest recession in our sample period. However, note that as a global phenomenon, the impact of the recession was short lived.

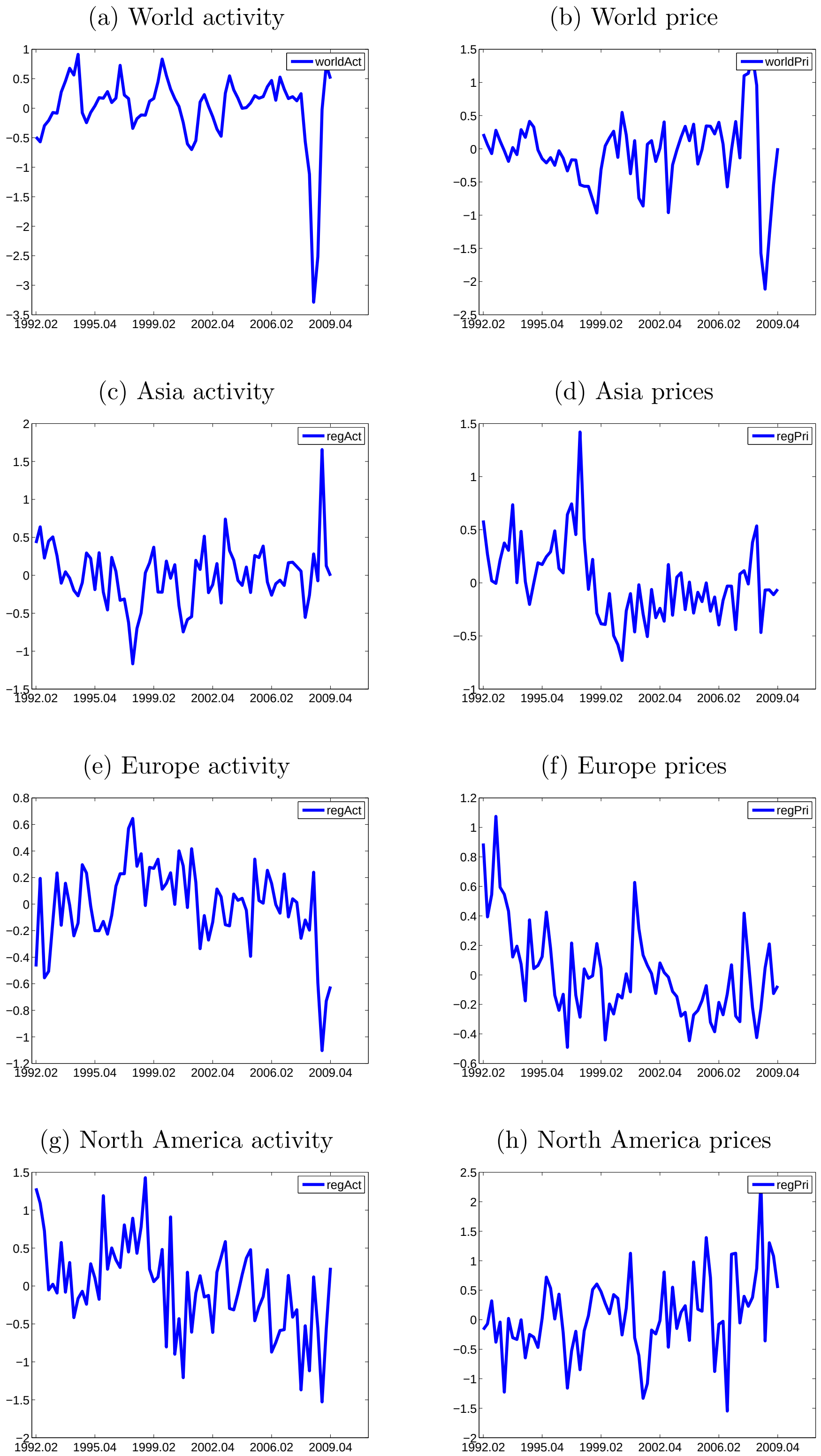
The regional factors are by construction (contemporaneously) orthogonal to the world factor. Hence, we are identifying the common underlying driving forces that originate in each region. The Asian factor captures several distinct characteristics of the Asian business cycles. In particular, the Asian crisis in the latter part of the 1990's appears to be more severe than the following downturn in the world activity factor. Further, after the huge drop in economic activity following the global financial crisis, the Asian activity factor has recovered much better than the world activity factor, which at the end of 2009 is still hardly above zero.

Early studies of regional business cycles find little evidence of a synchronized business cycle in Europe, see for instance Kose et al. (2003) covering data until 1990. When extending the data sample until 2009, we still find that the regional factor in Europe is noisy, reflecting the diversity in the European countries. However, in periods there is clear evidence of an European business cycle. By the end of the 1990s, there is an European boom corresponding to the period when a single monetary policy was introduced under the authority of the ECB. There is a European led recession in 2001/2002 and again in the latter part of the sample. The last recession started a few periods into the global financial crisis, but has turned out to be much more severe than the recession experienced in the other regions. By the end of the period (2009), the European recession had not yet ended.

The North American factor captures the downturn in the US in 2001 following the bursting of the dot-com bubble. The recession that started in 2007 is also clearly visible. Interestingly this recession precedes the world recession, and is hence a genuine North American recession, not observed in the world factor. The dates correspond well with the dates defined by the NBER when dating the recession.

The world price factor (right column) inhabits the global co-movement in inflation rates across the world found in earlier studies, such as Mumtaz and Surico (2009) and Ciccarelli and Mojon (2010). Particularly striking is the significant upturn at the end of the sample, probably representing a hike in commodity prices. We note that the regional factors show a declining pattern when most countries went through a period of disinflation, in particular in Europe and in Asia in the late 1990s.

Figure 1: **Identified factors**



Note: The factors are estimated using data from 1991:Q4 to 2009:04.

Having examined the factors visually, we can also examine to what extent the various countries are highly correlated with the factors. Here we summarize the findings. The correlation coefficients between the factors and either output growth or inflation in all countries are graphed respectively in Table 7 and Table 8 in Appendix C. The results suggest that the world activity factor is positively correlated with output growth in all countries. As such, the world activity factor is a global factor in the sense that the foreign shocks identified will be common across the world. Regarding inflation, the world price factor is also highly correlated with individual inflation rates across the world, except for countries in South America.

For the regional activity and price factors the correlation patterns are more mixed, indicating that countries in the region are not always strongly correlated. This is in particular the case for the regional price factors, as the correlation coefficients are lower and vary for the countries in the region. Yet, the correlation coefficients do still support the presence of a common regional activity and price factor in Asia, Europe and North America.[14]

Finally we examine the relevance of these factors for the domestic data sets, see Table 1. The table emphasizes that the average variance explained by all the factors for each country (R^2) is approximately 50 percent, which is consistent with other FAVAR studies (see e.g. Bernanke et al. (2005)). The partial R^2 numbers suggest that including global and regional factors to the model increases the proportion of explained variance in all the four domestic data sets.[15] Note, however, that Table 1 suggests that the partial R^2 and the percentage of significant factor loadings are smaller for the regional factors than for the global factors. This follows almost by construction from the way we have identified the factors, i.e. the orthogonality restrictions. Still, the numbers highlight that the regional factors are far from trivial, and significant for between 20-40 percent of the variables in the domestic data sets.

In sum, the properties of the identified factors, the correlation numbers and the factor statistics suggests that the factor model is capturing well world and regional driving forces in the economy.

[14] The countries most correlated with the European activity factor are France, Netherlands and Spain, while China, Hong Kong, Singapore and Taiwan have the highest correlation with the Asian factor. Regarding the regional price factor, Italy, UK, and Germany are highly correlated to the European price factor, while Malaysia, Thailand and South Korea are the countries most correlated to the Asian price factor.

[15] The partial R^2 measures the mutual relationship between two variables y and x when other variables (z, u, v...) are held constant with respect to the two variables involved y and x. As such it allows to directly estimate the proportion of unexplained variation in the domestic variables that becomes explained with the addition of the regional factors.

Table 1: **Factor statistics**

			World		Region			Domestic
			Act.	**Price**	**Act.**	**Price**	**R**	**R**
Canada	R^2	0.56	0.15	0.11	0.07	0.04	0.05	0.14
	Sf		0.56	0.44	0.30	0.24	0.32	0.36
New Zealand	R^2	0.53	0.12	0.09	0.06	0.06	0.03	0.08
	Sf		0.56	0.36	0.38	0.27	0.19	0.22
Norway	R^2	0.46	0.09	0.09	0.05	0.03	0.05	0.06
	Sf		0.52	0.39	0.24	0.15	0.28	0.23
UK	R^2	0.56	0.19	0.14	0.10	0.04	0.08	0.04
	Sf		0.67	0.47	0.43	0.26	0.30	0.24

Note: For each country we report the average variance explained by the model, partial R^2 for each identified factor (first row for each country), and the fraction of significant factor loadings (Sf) at the 5 percent significance level (second row for each country). The average total R^2 are presented in column 3, while columns 4 to 9 report the average partial R^2 and the fraction of significant factor loadings. Act. and R are abbreviations for activity and interest rate.

3.2 Variance decompositions - the world is not enough

One of the main motivations for separating between world and regions in our FAVAR model, is to examine *if* and *how* common world and region specific shocks transmit into the domestic economies. From the business cycle literature, important papers such as e.g Frankel and Rose (1998) argue that trade is the most important channel transmitting foreign shocks (thereby making the countries that trade together more synchronized). An alternative view advocated by Imbs (2004) among others, is that business cycle resemblance does not require much trade between countries. Instead, common shocks across the world, to e.g. consumer sentiments, industries, or financial markets, are what is driving the business cycles. This view of the business cycle gives a central role to anticipations; Consumers and firms continuously receive information about the future. Based on this information, they then decide on spending which affects output and hence business cycle synchronization in the short run, see e.g. Blanchard et al. (2009).[16]

By having a large and similar data set for each country, containing financial and survey data, in addition to the traditional national accounts and pricing

[16] The fact that Kose et al. (2003) find clear evidence of a world business cycle despite little trade between many of the countries in their sample, could be an indication of this.

series, we are able to investigate to what extent the shocks affect these countries directly through trade, or through other channels, such as consumer sentiment. This is an important extension to the traditional business cycle literature, that focuses on synchronization of output and price variables, but does not investigate the channels behind the synchronization.

Table 2: **Variance decomposition: International and domestic contributions**

	Horizon	**World**	**Region**	**Domestic**
Canada	1	0.30	0.19	0.52
	8	0.48	0.21	0.31
New Zealand	1	0.31	0.19	0.50
	8	0.38	0.20	0.41
Norway	1	0.28	0.22	0.50
	8	0.37	0.25	0.37
UK	1	0.35	0.19	0.47
	8	0.58	0.18	0.24

Note: Variance decomposition for all domestic variables (average) divided into world, regional and domestic contributions.

We now turn to analyze the relative contribution of the world, regional and domestic factors for aggregate behavior in the countries. That is, Table 2 displays the contribution from all the shocks to the world factors (world activity and price factors), the regional factors (regional activity, price and monetary policy factors) and the domestic factors (domestic unidentified factors and domestic monetary policy) on all domestic variables in Canada, New Zealand, Norway and the UK after one and eight quarters.

Table 2 emphasizes that there is a large contribution from the foreign factors in small open economies. Taking the world and the regional factors together, 60-75 percent of the variation in the variables are explained by the foreign factors after two years in all countries.

Of these, shocks that are common to the world explain the largest proportion of the variance in the domestic variables, thus extending the results commonly found in earlier business cycle studies, e.g. Kose et al. (2003) to more recent time, new countries and additional variables. In particular, approximately 30 percent of the variation in all domestic variables are explained by shocks to the world factors on impact, increasing to 40-55 percent after two years. The contribution is in particular large for the UK, where 55 percent of the variation in domestic variables are explained by shocks to the world factors. This can in part be explained by the large contribution of the US to the world factor, but also that the UK has trading partners spread across the world, see the discussion in Section 2.3.

However, regional factors are also non-trivial, explaining approximately 20 percent of the variance in domestic variables on impact. Hence in all countries, the world is not enough! In contrast to the shocks to the world factors, however, the contribution from the regional shocks does not increase much over time, and remains at approximately 20-25 percent after eight quarters.

How does our result so far compare to previous studies that analyze the importance of international factors on domestic variables? Mumtaz and Surico (2009) and Liu et al. (2011) specify a FAVAR model with international activity and price factors for the UK, but find only a weak impact of international shocks to the macroeconomy. In fact Liu et al. (2011) using a time-varying VAR, find a weaker impact of international shocks on the UK economy after the 1990s.

We believe there are two main reasons for the discrepancy between their and our results. First, we include regional shocks, which account for another 20 percent of the variance in the UK macroeconomy.

Second, in contrast to us, Mumtaz and Surico (2009) and Liu et al. (2011) restrict the domestic variables to be a linear combination of domestic factors only. This implies that the foreign factors can only affect the common dynamics in the domestic variables through their impact on the domestic factors in the transition equation. Our results do not support these features as we will show evidence of a direct effect on the domestic economy, as stock prices, investment and consumption increases on impact from global and regional shocks. Hence, we believe that such a restriction may explain why they undermine the importance of foreign driven shocks compared to what we find here.

A related argument, highlighted by Reichlin (2010), is that any observed domestic variables in an open economy will be the result of a general equilibrium process that reflects changes in both domestic and foreign forces. Domestic dynamics, therefore, incorporates the effect of foreign forces. The only way to disentangle domestic and foreign forces is to identify domestic and foreign shocks separately. Once these shocks are identified, the dynamics of the domestic variables will be a linear combination of both domestic and foreign forces.

3.3 World and regional activity and price shocks

Having established the importance of world and regional shocks in small open economies, we now turn to describe and investigate in detail the transmission mechanisms of the foreign shocks into the domestic economy.

Figures 2, 3, 4 and 5 graph respectively the effects of a (one unit deviation) shock to world activity, world price, regional activity and regional price on ten selected variables; GDP, investment, export, import, employment, inflation, stock prices, house prices, the exchange rate and terms of trade.[17] In the next section we discuss the effects of regional monetary policy, c.f. Figure 6.[18] Variance decomposition for a selection of variables is displayed in Appendix D, and will be discussed where relevant.

World activity shock. A positive shock to the world activity factor increases GDP and inflation gradually in all countries, but most notably in Canada and the UK. An important channel for which the world activity shock affects these countries could be through trade. That is confirmed here, as export gradually increases in all countries. However, import also increases in all countries, most notably in Norway. To the extent that the effect on imports are stronger than those on exports, the beneficiary net effect on GDP becomes smaller. This is clearly seen in Norway and to a certain extent in New Zealand (see the variance decomposition in Appendix D). Interestingly, terms of trade in these two countries are also less positively affected than in Canada and the UK.

Yet, the world activity shock has also direct positive effects on investment and stock prices (as well as a variety of other asset prices not displayed here) in all countries. For UK, almost 80 percent of investment activities are explained by world shocks on impact, declining only slightly after two years (again, see the variance decomposition in Appendix D).[19] However, also in Canada and Norway, do investment activities increase substantially, and almost 50 percent of the variance is explained by world shocks after two years. The effect on the exchange rate, however, is neutral, suggesting only

[17] Where relevant, we will comment on the responses of other variables, which can be obtained at request.

[18] Note that all the shocks are normalized to one. For shocks to the observable factors the normalization is adjusted by the standard deviation of the actual variable. However, for all variables except for the observable factors the impulse responses are displayed in standard deviation units, i.e. we have not scaled up the responses with the standard deviation of the different variables.

[19] This is not very surprising, as UK was the second largest recipient of foreign direct investment in 2009.

a slight appreciation of the currency in all countries, which is consistent with this being a shock common to the world.

Higher overall activity increases demand for labour and employment. The impulse responses and the variance decomposition (again see Appendix D) indicate that employment in Canada and the UK is in particular stimulated by the world activity shocks. As discussed above, this is most likely due to the fact that the stimulus comes through both trade and direct investment activities. In New Zealand and Norway, however, the increased demand for labour seems to increase real wages rather than employment to a larger extent.[20]

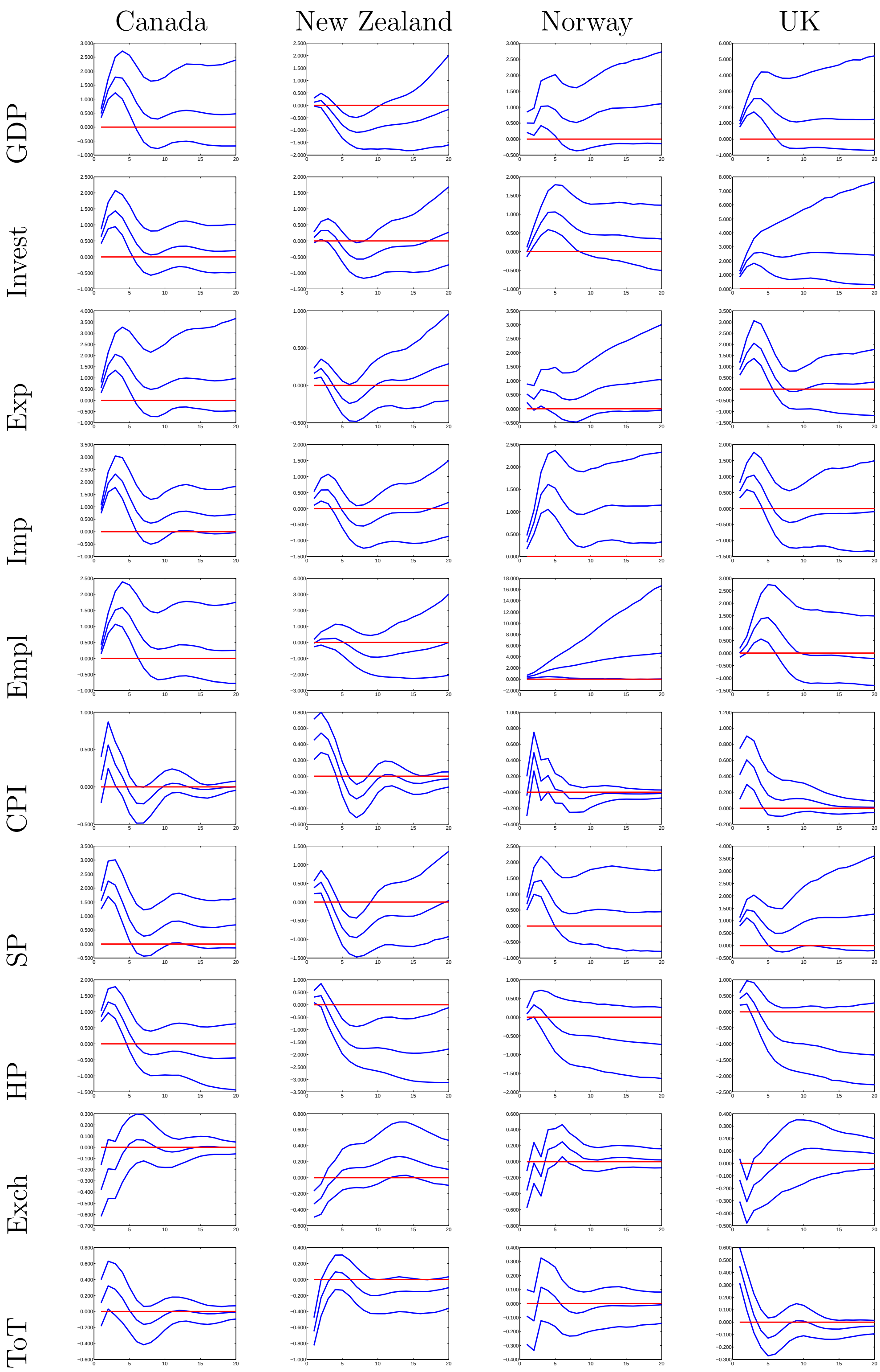
Hence, the world activity shock has characteristics of a positive aggregate demand shock, stimulating the components of output, employment, wealth and prices in all countries, although to a varying degree. Although trade is an important channel for which the global activity shock affects the domestic economies positively, all countries are also affected directly through for instance increased investment demand and higher valued asset prices (that increases collateral). This suggests that expectations about the future is an important channel for the international driven business cycles.

World price shock. A world price shock (that increases world inflation) reduces the components of output substantially while inflation picks up briefly in all countries. As a consequence, export, import, employment and asset prices gradually fall in all countries. Hence, the world price shock can be interpreted as an adverse aggregate supply shock.

Terms of trade, on the other hand, increases temporarily in all countries due to higher export prices. In Canada and Norway, the exchange rate also appreciates significantly. This could very well be due to the fact that Canada and Norway are net oil and gas exporters. If the adverse supply shock has characteristics of an adverse oil price shock that increases oil prices, the response in these two countries may well be that of an exchange rate appreciation. Consistent with this interpretation, investment also picks up substantially in Canada and Norway as demand for investment activities increases with higher energy prices. We will discuss this further in Section 3.5 when we augment the model to include oil prices.

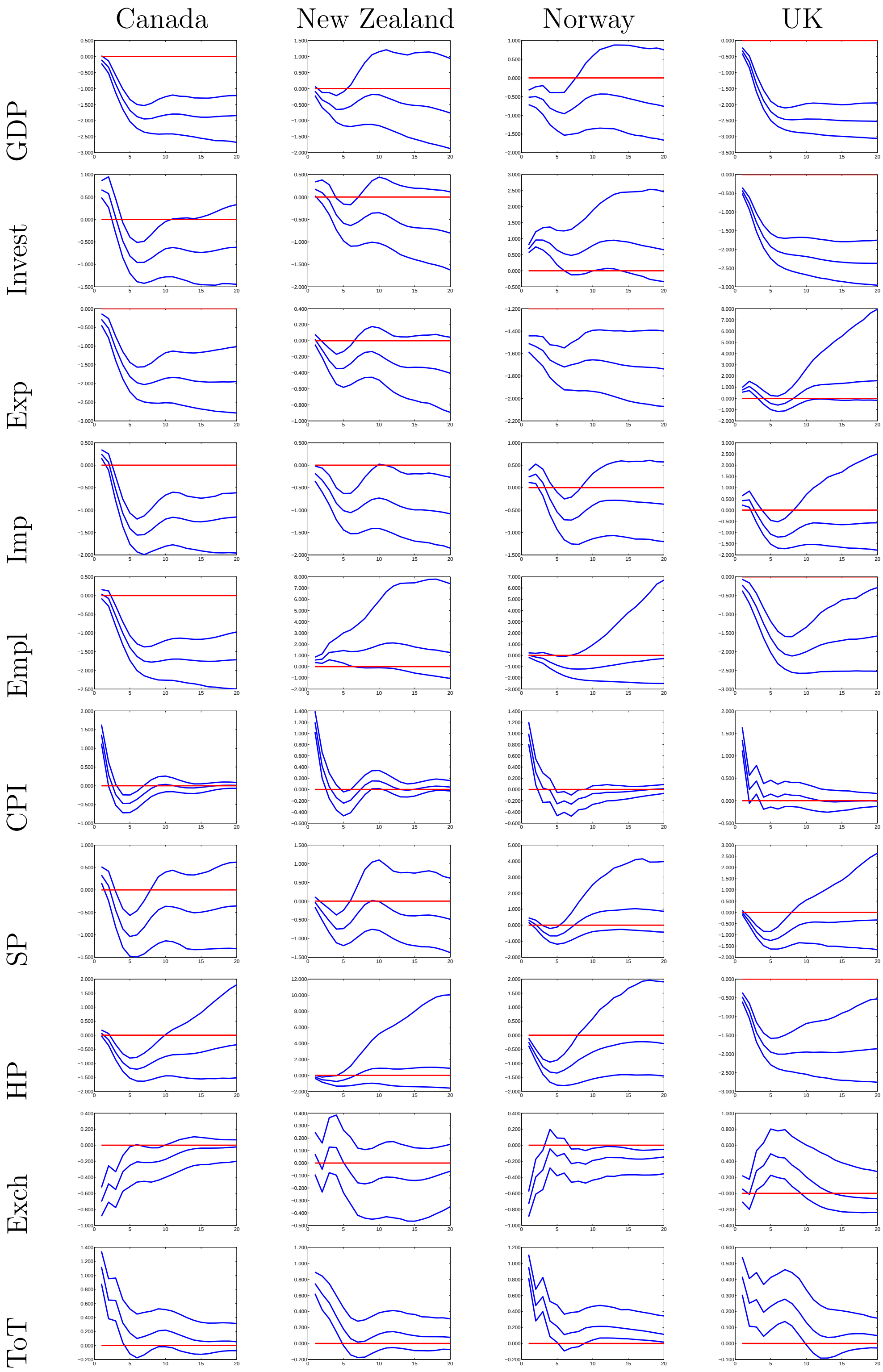
[20] As the only country in the sample, unit labour costs increase in Norway following a world activity shock, implying a fall in cost competitiveness.

Figure 2: **Impulse responses - world activity shock**



Note: Impulse responses of a one unit increase in world activity. The following abbreviations are used: GDP = Gross domestic product, Invest = Investment, Exp = Export, Imp = Import, Empl = Employment, CPI = Consumer price index, SP = Share prices, HP = House prices, Exch = Exchange rate, ToT = Terms of trade. See Table 6 in the appendix for details. All responses are in log levels except, CPI inflation. 90 percent error bands.

Figure 3: **Impulse responses - world price shock**



Note: Impulse responses of a one unit increase in world prices. See also notes in Figure 2 and Table 6 in the appendix for details.

Regional activity shock. The regional activity shock is by far the most important of the regional shocks. It has many of the same characteristics as a world activity shock, increasing the components of output and inflation. The effect is most pronounced in Canada and New Zealand, while in Norway and the UK, the effect is small or not significantly different from zero.

An important channel for which the regional activity shocks affect Canada and New Zealand is through trade. The impulse responses and the variance decompositions emphasize substantial and positive effects on exports from a regional activity shock in these two countries.[21] Imports also increases, but by much less. Hence, there are clear positive gains from increased trade. This stimulates investment activities and increases the value of stock price, so that the overall contribution to GDP is large. This is not the case in Norway and the UK, where the regional activity shock has only a marginal positive effect on export. The effects on investment are also smaller (explaining 10-15 percent of the variance in Norway and the UK, versus 20-30 percent in Canada and New Zealand) and stock prices actually fall following a shock to European activity.

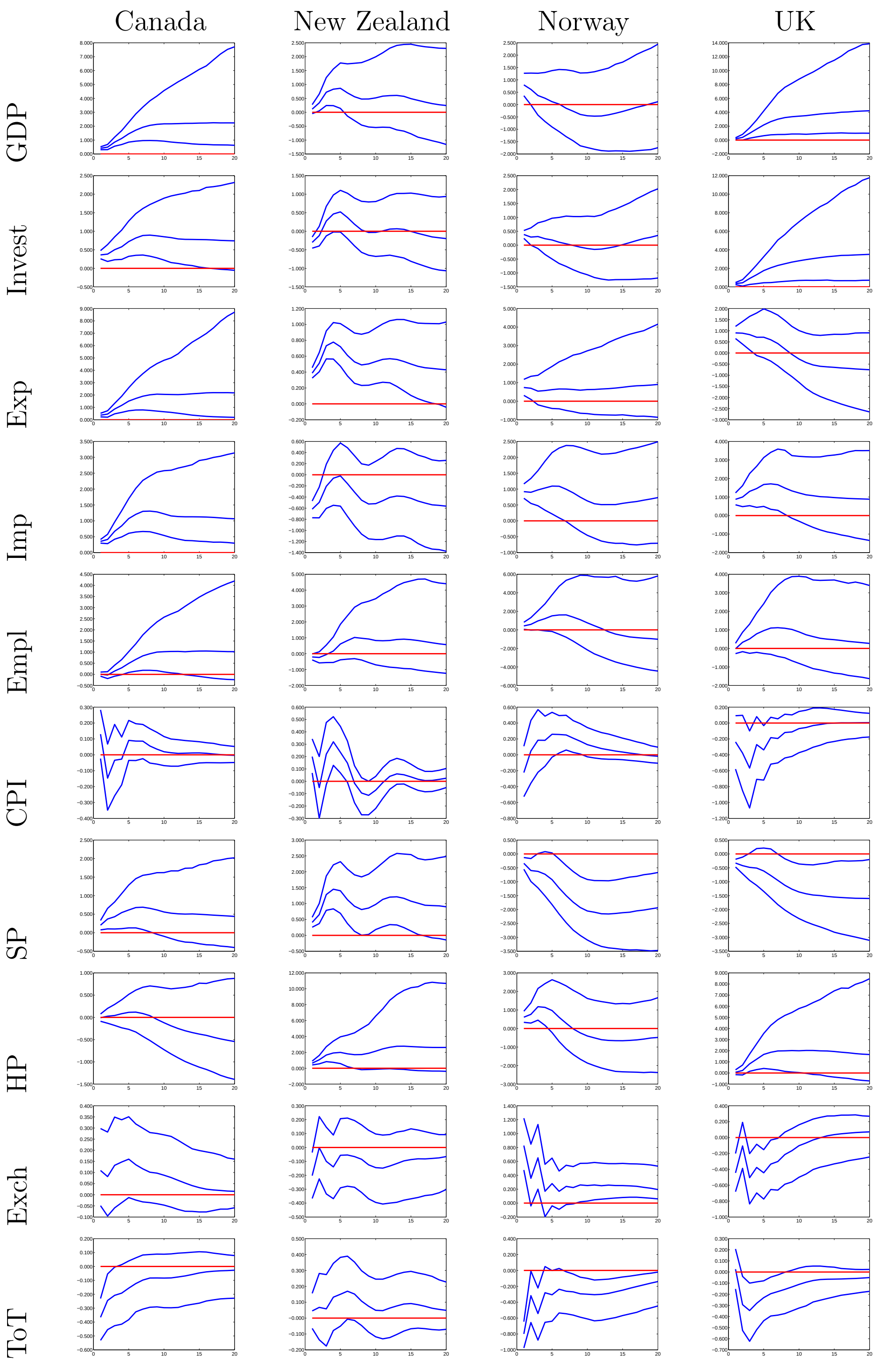
Independent of the effects on trade, all countries seem to be positively affected by consumer sentiment following a regional activity shock, as consumption, import and house prices pick up. This is in particular evident in Norway, where regional activity shocks explain a large share of the development in house prices, despite the fact that the effects on export are not significant. Hence, consumer's expectations matter and is a potential source for transmitting the regional shocks to the domestic business cycles.

We therefore conclude that developments in the region matters for the neighboring countries, over an above the direct effects on trade. The recent slowdown of debt driven Europe and the US may therefore have negative effects on Norway, the UK and Canada, while New Zealand, located close to fast growing Asia, may be less affected.

This illustrates again the importance of allowing foreign shocks to affect the domestic variables directly, and not just through the traditional trade channels as is often imposed in the more theoretical DSGE models.

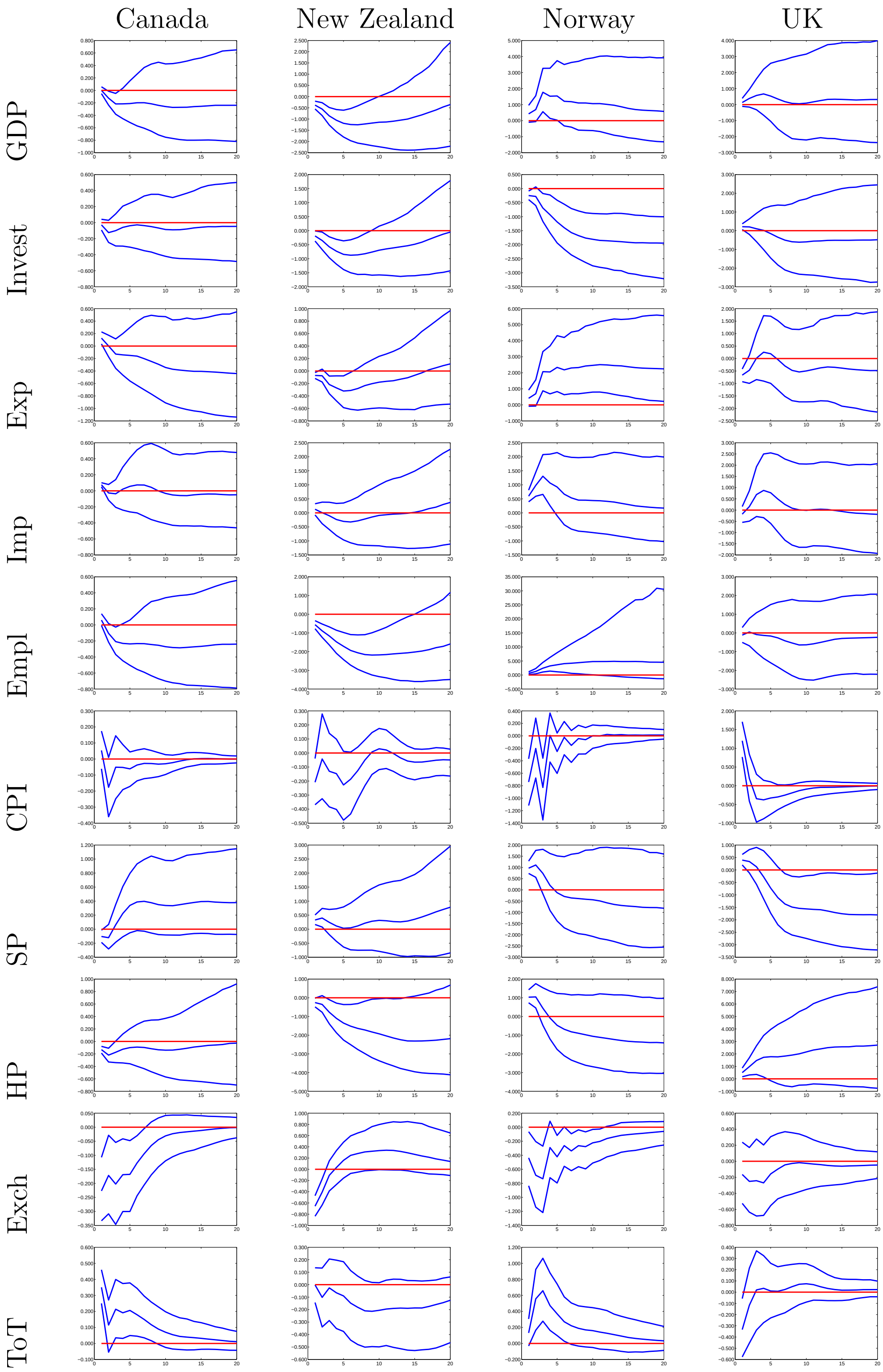
[21] 40-60 percent of the variance in export is explained by shocks to the region in Canada and New Zealand.

Figure 4: **Impulse responses - regional activity shock**



Note: Impulse responses of a one unit increase in regional activity. See also notes in Figure 2 and Table 6 in the appendix for details.

Figure 5: **Impulse responses - regional price shock**



Note: Impulse responses of a one unit increase in regional prices. See also notes in Figure 2 and Table 6 in the appendix for details.

On a final note. The fact that exports respond very little to the European activity shocks in Norway and the UK, seems at odds with the fact that the European Union as a whole is the most important trading partner for both Norway and the UK (see Table 4). Two points should be noted then. First, the UK and in particular Norway's exports of goods to the EU are concentrated on primary products, of which a large share is supply of energy, which is not very price and income elastic. Second, the share of export of traditional goods (excluding energy) in both Norway and the UK, is much smaller than in Canada and New Zealand, making the economy as a whole less influenced by trade.

Regional price shock. The regional price shock that increases inflation in the region is more difficult to interpret, as the effects on the different variables are small or not significant. There is a tendency, however that the components of output and employment fall, although little clear evidence that inflation picks up significantly in these four countries, except in the UK (recall the high correlation between inflation in the UK and the price factor in Europe). The exchange rate appreciates in all the countries, although not significantly in the UK. The currency appreciation leads to lower import prices (in particular in Canada and Norway), which pushes up terms of trade temporarily in these two countries. Lower import prices quickly reduce overall inflation. Hence, the regional price shock may be interpreted as a regional cost push shock that increases inflation in the region its originates. The effect on the trading partners is however small, as the exchange rate work to absorb the shock, sheltering the domestic economies effectively.

To sum up, we have found that the world activity shock has characteristics of a positive aggregate demand shock, stimulating trade, activity, employment, wealth and prices in all countries. The direct effects are in particular strong in Canada and the UK. A world price shock, on the other hand, reduces the components of output substantially while inflation picks up briefly in all countries. As a consequence, export, import, employment and asset prices gradually fall in all countries. Hence, the world price shock can be interpreted as an adverse aggregate supply shock.

The regional factors impact the four countries differently, though. In Canada and New Zealand, the regional activity shocks affect the domestic economy positively primarily through trade and employment. The effects of a regional activity shock in Norway and UK are also substantial, but the positive impact on trade is somewhat weaker. Instead, variables such as consumption, import and house prices are affected directly, possibly through consumer sentiment.

The results reported here suggest that policymakers in small open economies need to understand how international developments transmit into the domestic economy and respond accordingly. In many policy institutions, DSGE models play an important role for policy decisions. Our results of a strong transmission of both global and regional shocks to small open economies are in sharp contrast to evidence from recent developed small open economy DSGE models that incorporate foreign factors, such as Galí and Monacelli (2005), Justiniano and Preston (2010) and Christiano et al. (2010). One concern in some of these models is that they assume uncorrelated shocks across countries. For instance, model-implied cross-correlation between Canada and US are essentially zero in Justiniano and Preston (2010). This is at odds with the data and what we find here. A specification that assumes correlated cross-country shocks partially resolves this discrepancy, but still falls well short of matching our findings.

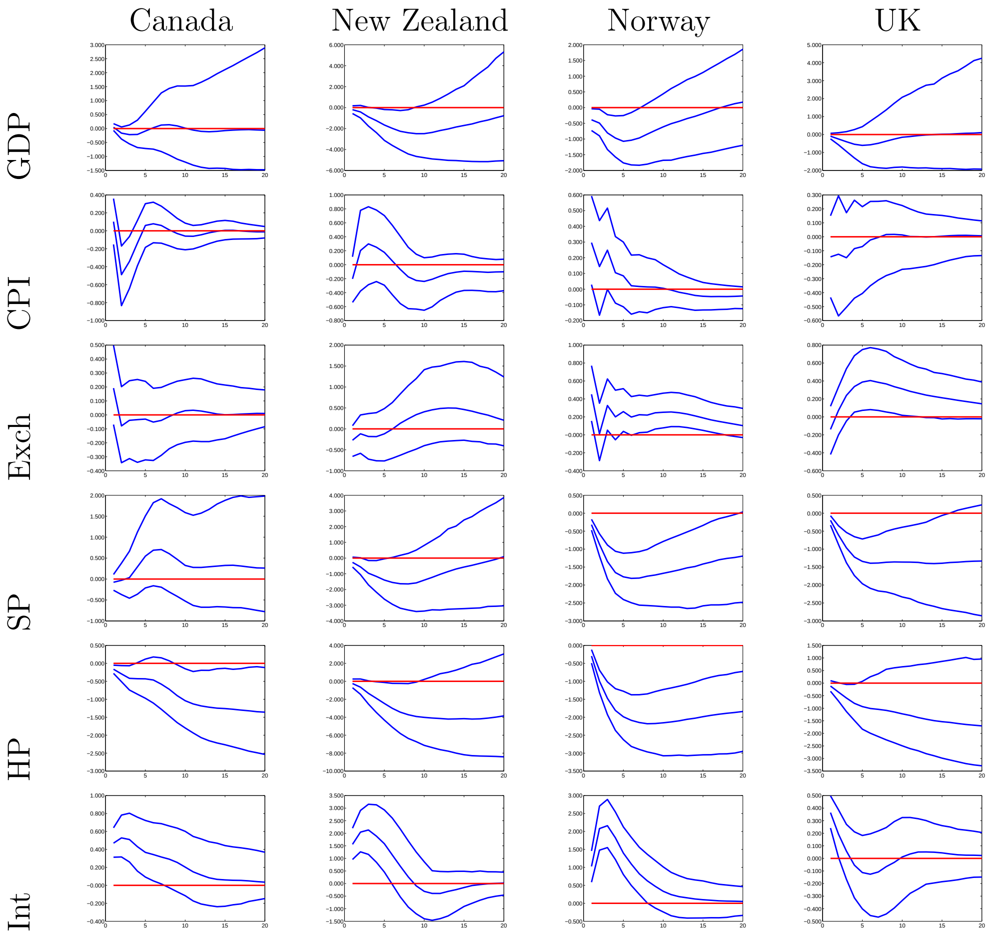
3.4 Regional monetary policy shocks

Finally, we turn to examine the effects of a *Regional monetary policy shock.* That is, Figure 6 investigates the effects of an unsystematic shock in regional monetary policy on GDP, inflation, the exchange rate, asset prices and domestic interest rates in Canada, New Zealand, Norway and the UK. Recall that we select the Euro Area interest rate as regional interest rate for Norway and UK, the US interest rate as regional interest rate for Canada and the Australian interest rate as regional interest rate for New Zealand.

The figure shows that a one percentage point unexpected increase in the short term interest rate in the region has a significant (brief) negative effect on real activity in all countries. Inflation gradually falls, although in Norway, with a long delay. The exchange rate mostly depreciates (temporarily) while stock prices and house prices fall. These effects are in particular strong in New Zealand and Norway. The currency depreciation and the fall in asset prices must be seen in relation to the domestic interest rate response, which increases in all countries, but most notably in New Zealand and Norway.

Hence, regional dependence in monetary policy seems in particular strong in the two smallest countries; New Zealand and Norway.

Figure 6: **Impulse responses - regional monetary policy shock**



Note: Impulse responses of a one unit increase in regional interest rates. Int = Domestic interest rate. See also notes in Figure 2 and Table 6 in the appendix for details.

3.5 The world and oil price shocks

According to the seminal work of Hamilton (1983), all US recessions but one since World War II were preceded by a spike in oil prices. Higher oil prices typically lead to an increase in production costs and inflation, thereby reduced overall demand, output and trade in the economy. Subsequent to Hamilton's work, a large body of research has suggested that oil price variations have strong and negative consequences for a series of countries, see for instance Bjørnland (2000), Jiménez-Rodriguez and Sanchez (2005), and again more recently, Hamilton (2009).

Thus, understanding the effect of oil price shocks are important and interesting in its own right, and we therefore investigate the model predictions when explicitly including oil price to the model. However, in this analysis the inclusion of the oil price serves additional purposes. First, Canada and Norway (and previously the UK) are net oil exporters, where higher oil prices historically have tended to coincide with increased terms of trade (due to higher export prices), increased investment demand, higher valued stock prices (through the cash flow of oil related firms) and an appreciated exchange rate. We saw above that a world price shock affected Canada and Norway in such a way (although the effect on stock prices were not significant). Hence we want to separate out the effect of oil prices from world price shocks, to examine to what extent oil price shocks play an independent role for macroeconomic fluctuations in these energy producing countries. Second, the small open economies we are analyzing are all very oil dependant, not only as oil exporters, but also in their oil use relative to the size of GDP (especially Canada and New Zealand).[22] Insofar as oil prices are globally determined, our choice of countries can potentially bias the results against finding a role for regional factors. Explicitly including oil price to the model controls for this.

In the FAVAR model, oil prices are placed first in the ordering, reflecting a plausible small country assumption (see for instance Bjørnland (2000)), while allowing monetary policy to respond to oil price shocks. Note, that this implies that oil prices will not be able to react contemporaneously to changes in global economic activity, as in Kilian (2009). Hence, we will not be able to distinguish between oil supply and oil demand shocks in our model.[23] This separation would obviously be important if oil price shocks were of main interest in this paper. Since the purpose here is to examine the importance of adding oil prices as a common shock, we believe it suffices to place oil prices at the top of the ordering. We can, however, show that our results are robust to this alternative way of identification, and results can be obtained at request.[24]

[22] All parts of the economy is affected by oil price changes; Transport, manufacturing, agricultural production through machinery etc.

[23] See Aastveit (2011) for a study of the macroeconomic effects of oil supply and oil demand shocks using a FAVAR model.

[24] Allowing oil price shocks to be affected contemporaneously by world activity shocks, i.e. ordering oil prices after the world activity factor, implies very similar responses. The main difference is that a world activity shock now explains approximately 25 percent of

Table 3: **The contribution of oil price shocks**

	Horizon	Oil	World	Region	Domestic
Canada	1	0.12	0.21	0.19	0.48
	8	0.16	0.33	0.22	0.30
New Zealand	1	0.12	0.23	0.18	0.47
	8	0.13	0.28	0.19	0.39
Norway	1	0.13	0.21	0.20	0.46
	8	0.15	0.26	0.23	0.36
UK	1	0.12	0.27	0.18	0.43
	8	0.22	0.39	0.18	0.22

Note: Variance decomposition for all domestic variables (average) divided into oil, world, regional and domestic contributions.

Table 3 displays the variance decomposition when oil price is included into the FAVAR. We see that oil price shocks account for approximately 10 percent of the variation in all the variables on impact, increasing to 15-20 percent after two years. Hence oil price shocks matter! Comparing the variance decomposition from the FAVAR model with oil price (Table 3) with the FAVAR model without oil price (baseline model in Table 2), we find that by including oil price shocks into the model, the contribution from the world price factor decreases almost proportionably with the increased contribution from the oil price shock, while the regional and domestic factors remain very similar. Hence, the world price factor was also capturing the common responses to the oil price shocks.

The effect of an oil price shock on a selection of variables of interest can be seen in Figure 9, while variance decomposition to the same variables can be seen in Figure 10, both displayed in Appendix E. The results can be summarized as follows. First, the figures emphasize the importance of oil price shocks in explaining the surge in inflation in all countries, but most notably in New Zealand. Compared to the results in the baseline model, the contribution of world (price) shocks declines almost proportionally with the increased role for oil price shocks in explaining inflation. Second, with regard to the effects on the net oil exporting countries Canada and Norway, oil price shocks are clearly stimulating the economy, as terms of trade, stock prices and investment increase temporarily following the oil price shocks. The positive effect on GDP, however, is small. The exchange rate also appreciates

the variation in oil prices after two years, compared to 15 percent when oil prices were ordered first. That reduces the impact of the oil price shock on the domestic variables slightly.

on impact in both Canada and Norway, explaining why some of the beneficial effects on the real economy may short lived.[25]

Hence, adding oil prices to the FAVAR model implies important dynamics in many of these countries, dynamics that was previously captured by the common world price shocks. Yet, despite adding oil prices to the FAVAR, the overall variance explained by the foreign shocks remains much the same, which implies that world price shocks were capturing well the effects of a common commodity price shock. Further, the contribution from the regional shocks remains very much the same, and we believe this to be a strength of our analysis; even for highly oil dependent small open economies, the world is not enough.

4 Robustness

We have run a number of different model specifications to check that our main findings are robust. The results are encouraging, as they do not alter our conclusions. The details are presented in Appendix F. Here we summarize the main results.

First, employing sign restrictions to identify the shocks to the world and regional factors does not alter the main results. As Table 9 in Appendix F reports, the regional shocks still explain a considerable share of the total variance in domestic variables both on impact and after 8 quarters. Furthermore, the impulse responses to the world shocks also remain very similar, as the restrictions imposed on the responses when we use signs are very similar to the responses we actually found using the recursive restrictions.[26] For the regional shocks, the changes are more notable, as the sign restriction methodology imposes slightly different restrictions for some variables than what we found using recursive restrictions. However, the overall variance decomposition from the regional shocks, remains the same.

As seen in Figure 1, the recent financial crisis affects the world and the

[25] Hence, although the petroleum income in Norway has since 2001 been regulated to be phased into the economy on par with the development in expected return on the Government Petroleum Fund, we find the oil price to still be an important asset price affecting the economy in a cyclical way.

[26] Recall that using recursive restrictions we found that a world activity shock could be interpreted as a world demand shocks, increasing both activity and prices, whereas a world price shock could be interpreted as a world supply shock, reducing activity while increasing prices. This is exactly what we impose using sign restrictions.

regional factors significantly. It would be natural to expect that this also has some influence on our model estimates. To control for this we have also run the model with a shorter estimation sample, letting 2007Q4 be the end of the estimation sample. Table 10 summarizes the variance decomposition results. Clearly, the main message does not change, if anything, the importance of regional shocks have become even stronger.

We have also experimented with the world factor definition. That is, we first used all 33 countries in the world block when estimating the world factors and then scaling the number down using a subset of countries. This can be thought upon as controlling for country weights.[27] The impulse responses are slightly affected by this, but the variance decompositions are very much the same.

5 Conclusions

We estimate a three block factor augmented VAR (FAVAR) model with separate world, regional and domestic blocks for four small open economies; Canada, New Zealand, Norway and the UK. Doing so we bridge the new open economy FAVAR studies with the later findings in the business cycle synchronization literature by explicitly including both regional and world factors into the FAVAR model.

Our analysis finds that foreign shocks explain a major share of business cycle fluctuations in small open economies, accounting for 50-70 percent of the variation in the domestic variables in the four countries examined here. Of these, shocks that are common to the world explain the largest proportion of the variance in the domestic variables, thus extending the results commonly found in earlier business cycle studies to more recent time, new countries and additional variables. However, regional factors are also non-trivial, explaining approximately 20 percent of the variance in domestic variables. Hence for all countries, the world is not enough!

Further, as several papers have highlighted, we find that trade is an important transmission channel for foreign shocks. However, our results also suggest that other channels are important. Independent of the effects of trade, variables such as consumption, investment and house prices are affected directly by foreign shocks, possibly through consumer sentiment. This is in

[27] By including more countries from one or more regions, and less countries from other regions, the factor estimates will potentially change.

particular the case for how the regional activity shocks affect Norway and UK. Finally, we also find that the domestic interest rate setting is highly influenced by regional monetary policy shocks, in particular in the two smallest countries; New Zealand and Norway.

Our paper contributes to the literature in several ways. First, compared to the business cycle synchronization literature (i.e. Kose et al. (2003)), the FAVAR model allows us to identify both price and activity shocks in addition to the domestic shocks. By utilizing a large domestic data set, we also allow for a much richer description of the domestic responses to different world, regional and domestic shocks.

Second, by explicitly including both regional and world factors into the FAVAR model, we extend the global FAVAR model proposed by Mumtaz and Surico (2009) to also include regional factors. Our identification strategy differs, though, as we allow the dynamics of each domestic series to be a linear combination of both the domestic factors as well as the global and regional factors.

Our results suggest that policymakers in small open economies need to understand how international developments transmit into the domestic economy and respond accordingly. In many policy institutions, DSGE models play an important role for policy decisions. Our findings of a strong transmission of both global and regional shocks to small open economies are in sharp contrast to evidence from recent developed small open economy DSGE models that incorporate foreign factors, such as Galí and Monacelli (2005), Justiniano and Preston (2010) and Christiano et al. (2010).

On a final note, the three block open economy FAVAR framework suggested here opens up many interesting questions suited for future research. For example, given the increased influence of Asia in the world economy the last decade, one could ask to what extent region specific shocks originating from Asia can affect countries across the world? Also, given the large role for foreign shocks documented in this paper, and the small role these shocks typically play in DSGE policy models, it would be interesting to investigate to what extent domestic monetary policy responds timely to foreign shocks. We do not elaborate more on this here, but leave it for future research.

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Appendices

Appendix A Estimation and sign restrictions

In this section we give a more detailed explanation of the estimation of the FAVAR model and the identification of sign restrictions.

A.1 Estimation of the FAVAR model

We estimate the system in equation (1) and (2) using a two step procedure:[28]

Step 1: Estimating the factors The unobserved factors are first estimated by principal components.[29] The world activity factor is extracted based on the world activity numbers, the world price factor is extracted based on the world price data, etc. The factors are identified according to the following procedure:

(i) World activity and price factors are estimated as the first principal component from the G20 activity and price series. To identify a world activity and world price factor, we restrict the world activity factor to have a positive loading on US activity and the world price factor to have a positive loading on US prices.

(ii) To obtain the regional activity (price) factor, we first regress all regional activity (price) series on the global activity (price) factor. We then obtain a set of activity (price) residuals. We estimate the regional activity (price) factor as the first principal component of the activity (price) residuals. This will guarantee the regional activity (price) factors to be orthogonal to the world activity (price) factor. For the European regional factors we restrict the activity and the price factor to load positively on respectively German activity and prices. The Asian activity and price factors are restricted to have a positive loading on Japanese activity and prices and finally for North America the regional activity and price factor load positively on US activity and prices.

(iii) To obtain the domestic factors, we regress all the domestic series on the world and regional factors and obtain a set of residuals. The three domestic factors are estimated as the first three principal components of these residuals. This will guarantee the domestic factors to be orthogonal to the global and regional factors. Finally, the identified factors are used to estimate the restricted factor loading matrix in equation (2) and to estimate the transition in equation (1).

Step 2: Estimating the VAR Given our relatively short estimation sample we

[28] The estimation procedure resembles the two step procedure of Bernanke et al. (2005). Computationally it would have been feasible to estimate the whole system simultaneously using likelihood-based Gibbs sampling techniques. However, the identification of the factors and shocks would then have been much more difficult.

[29] To avoid the rotational indeterminacy problem associated with principal component analysis, we use the standard normalization implicit in the literature and restrict $C'C/T = I$, where $C(\cdot)$ represents the common space by the factors of X in each block of data.

estimate the VAR in equation (1) using Bayesian techniques. In our baseline model we restrict the number of lags to 2. Restrictions on the world and regional block of the VAR follow naturally from our identification strategy. We do however not have any priors regarding the dynamics of the domestic block of the VAR, which therefore contains 2 lags of all variables.

We apply an independent normal-Wishart prior for the VAR and use the Gibbs sampler to derive the posterior distributions of the parameters. To further avoid the problem of overfitting we adopt a Minnesota-type prior on the coefficients. That is, we set the prior of the first own lag of the dependant variable in each equation equal to its AR(1) coefficient, while the prior mean for all other variables are set to zero. For the prior variances we adjust for differences in scale between the variables and the lag length of the system according to the following scheme:

$$V_{i,jj} = \begin{cases} \frac{a_1}{p^2} & \text{for coefficients on own lags} \\ \frac{a_2 \sigma_{ii}}{p^2 \sigma_{jj}} & \text{for coefficients on lags of variable } j \neq i \\ \frac{a_3}{\sigma_{ii}} & \text{for coefficients on exogenous variables} \end{cases}$$

where the standard errors are derived from AR(p) estimations, where p is equal to the number of lags in the full system. We set the values of the hyperparameters a_1, a_2 and a_3 to 0.6, 0.3 and 0.1, respectively. The degrees of freedom prior is set to 50, and the prior covariance matrix equals $I(n)*0.01$, where n is equal to the number of equations in the system. Thus, our prior is relatively tight, and imposes a fair amount of shrinkage. Finally, we make 10000 iterations of the Gibbs sampler, with 2000 iterations used as burn-in.

A.2 Identification through Sign Restrictions

Sign restrictions have become a popular method used to identify shocks of interest in structural VAR models. Influential papers that have employed sign restrictions are e.g. Faust and Rogers (2003), Uhlig (2005) and Scholl and Uhlig (2008). The implementation of the sign restrictions in this paper assumes the same ordering of the variables as in the recursive identification scheme, but with additional restrictions on the structural disturbances. Especially we restrict Ω, defined in section 2, to have the structure:

$$
\begin{bmatrix} u^{act*} \\ u^{pri*} \\ u^{act**} \\ u^{pri**} \\ u^{r**} \\ u^{D} \\ u^{R} \end{bmatrix} = \begin{bmatrix} + & + & 0 & 0 & 0 & 0 & 0 \\ + & - & 0 & 0 & 0 & 0 & 0 \\ x & x & + & + & - & 0 & 0 \\ x & x & + & - & - & 0 & 0 \\ x & x & + & - & + & 0 & 0 \\ x & x & x & x & x & x & 0 \\ x & x & x & x & x & x & + \end{bmatrix} \begin{bmatrix} \varepsilon^{demand*} \\ \varepsilon^{supply*} \\ \varepsilon^{demand**} \\ \varepsilon^{supply**} \\ \varepsilon^{r**} \\ \varepsilon^{D} \\ \varepsilon^{R} \end{bmatrix} \tag{3}
$$

where a + indicates that the parameter must be positive, a − restricts the parameter to be negative, x leaves the parameter unrestricted, and finally zero imposes exclusion restrictions.

Following this identification scheme we can identify global and regional demand and supply shocks, and a regional monetary policy shock. A positive world demand shock increases world activity and prices, while a positive world supply shock increases world activity and has a negative impact on world prices. The regional shocks are identified as demand and supply shocks following the same restrictions as for the world demand and supply shocks. The restrictions only affect the regional block itself though. In addition, regional interest rates shocks are restricted to reduce regional activity and prices, but rise interest rates. The domestic shocks are mostly left unrestricted, and for both the world demand, supply and interest rate shocks we have left the responses of the domestic variables unrestricted. The zero restrictions follow the block exogenous assumption outlined above. Domestic shocks do not affect the region nor the world.[30]

With minor modifications, the sign restrictions are implemented following the procedure outlined in Rubio-Ramirez et al. (2010) and Mumtaz and Surico (2009). Specifically we implement the following algorithm for each draw of the reduced form covariance matrix Ω:

1. Let $Omega = PP'$ be the Cholesky decomposition of the VAR covariance matrix Ω, and $\tilde{A}_0 = P$.
2. Draw an independent standard normal n x k matrix J, where n is the size of the block (e.g. world and regional block) and k is the number of shocks affecting that block according to the block exogenous structure outlined in section 2.2 and equation (3). Let $J = QR$ be the "economy size" QR decomposition of J with the diagonal of R normalized to be positive.

[30]Note that the sign restriction identification scheme is thus a combination of the recursive ordering and sign restrictions.

3. Compute a candidate structural impact matrix $A_0 = \tilde{A}_0 \cdot \tilde{Q}$, where $\tilde{Q}$ is a N x N identity matrix with Q' in the n x k block associated with either the world or regional block in equation (3).
4. Redo step 1-3 for the next block of data.

The candidate matrix A_0 will have a lower triangular structure for the domestic block, as in the standard Cholesky decomposition, while also satisfying the zero restrictions outlined in equation (3). If the candidate matrix satisfies the sign restrictions, we keep it. Otherwise the procedure above is repeated.

Appendix B Data set

Below we present details on the trading partners for the four countries analyzed here and on the data we are using in the model.

B.1 Trading partners

Table 4: **Main trading Partners: Export and import shares**

	Country	**Exports**	**Country**	**Imports**
Canada	United States	75.0	United States	51.2
	European Union	8.3	European Union	12.4
	China	3.1	China	10.9
	Japan	2.3	Mexico	4.5
	Mexico	1.3	Japan	3.4
New Zealand	Australia	23.0	Australia	18.4
	European Union	13.0	European Union	17.3
	United States	10.0	China	15.1
	China	9.1	United States	10.8
	Japan	9.1	Japan	7.4
Norway	European Union	80.4	European Union	66.3
	United States	4.8	China	7.8
	Canada	2.1	United States	6.2
	China	2.0	Japan	2.5
	Korea	1.9	Canada	2.2
UK	European Union	54.9	European Union	53.0
	United States	14.9	United States	9.6
	China	2.3	China	9.0
	Switzerland	1.7	Norway	4.8
	Canada	1.9	Japan	2.2

Note: 5 most important trading partners. Based on export and import values in 2009. Source: WTO.

B.2 Data set

In the interest of brevity we do not report the details of every time series used in this analysis, since we entertain well over 400 variables in total. However, Table 5 lists the international variables we have used, and Table 6 lists the domestic series reported in the main graphs of the paper. For some countries and series we have not been able to find time series covering the sample period used for estimation. For this reason the number of international series do not exactly match across countries and measure (activity and prices).[31]

We report the mnemonic, source, transformation and description for each series. Details about series not listed can be obtained from the authors on request. As described in the main text we construct the world factors based on countries belonging to the G20 group, excluding Russia, Indonesia, Turkey and Saudi Arabia.

[31] According to the results obtained from the alternative model specifications discussed in section 4, we do not think this is a big issue. However, we do acknowledge that there is a trade-off between excluding series and adjusting the sample. Leaving out too many series, or shortening the sample, would potentially bias the results. For this reason, our data set do contain missing values for some variables and countries. That is, when the number of data points missing for a particular time series are not too large, we have chosen to include the series in our sample. When estimating the factors we have then used the EM algorithm, as described in Stock and Watson (2002), to fill in the missing observations.

Table 5: **Data summary: International variables**

Country	Source	Transf.	Description
Oil price			
	HAVER	5	Oil Brent UK. US Dollars per Barrel
Asia: Activity			
Malaysia	ECOWIN	5	Malaysia, Production, Manufacturing, Constant Prices, Index, MYR, 2005=100
Taiwan	ECOWIN	5	Taiwan, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, SA, TWD, 2006 prices
Taiwan	ECOWIN	5	Taiwan, Production, Manufacturing, Constant Prices, Index, TWD, 2006=100
Singapore	ECOWIN	5	Singapore, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, SGD, 2005 prices
Singapore	ECOWIN	5	Singapore: IP: Manufacturing (excl Rubber Processing) (SA, 2007=100)
Hong Kong	ECOWIN	5	Hong Kong, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, HKD, 2008 chnd prices
Hong Kong	ECOWIN	5	Hong Kong, Production, All manufacturing industries, Index, HKD, 2008=100
Thailand	ECOWIN	5	Thailand, Production, Manufacturing, total, Index, THB, 2000=100
Japan	ECOWIN	5	Japan, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, AR, SA, JPY, 2000 prices
Japan	ECOWIN	5	Japan, Production, By Industry, Manufacturing, SA, Index, JPY, 2005=100
India	ECOWIN	5	India, Production, Manufacturing, Index, INR, 1993-1994=100
South Korea	ECOWIN	5	South Korea, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, SA, KRW, 2005 prices
South Korea	ECOWIN	5	South Korea, Production, Manufacturing, SA, Index, KRW, 2005=100
China	NB	5	China GDP index. Constructed by Norges Bank. 1992Q1=100
China	ECOWIN	0	China, Production, Overall, Value added, industry total, growth rate, Constant Prices, Chg Y/Y
Australia	ECOWIN	5	Australia, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, SA, AUD, 2007-2008 prices
Australia	ECOWIN	5	Australia, Production, Manufacturing, SA, Index, AUD, 2000=100

See end of table for notes

Table 5 – continued from previous page

Country	Source	Transf.	Description
Asia: Prices			
Malaysia	ECOWIN	5	Malaysia, Consumer Prices, Total, Index, MYR, 2005=100
Taiwan	ECOWIN	5	Taiwan, Consumer Prices, Total, SA, Index, TWD, 2006=100
Taiwan	ECOWIN	5	Taiwan, Wholesale Prices, Total, Index, TWD, 2006=100
Singapore	ECOWIN	5	Singapore, Consumer Prices, All items, Index, SGD, 2009=100
Singapore	ECOWIN	5	Singapore, Producer Prices, Overall items, Index, SGD, 2006=100
Hong Kong	ECOWIN	5	Hong Kong, Producer Prices, All manufacturing industries, Index, HKD, 2008=100
Thailand	ECOWIN	5	Thailand, Consumer Prices, Total, Index, THB, 2007=100
Japan	ECOWIN	5	Japan, Consumer Prices, Nationwide, All Items, General, SA, Index, JPY, 2005=100
Japan	ECOWIN	5	Japan, Corporate Goods Prices, Domestic, total, Index, JPY, 2005=100
South Korea	ECOWIN	5	South Korea, Consumer Prices, Total, Index, KRW, 2005=100
South Korea	ECOWIN	5	South Korea, Producer Prices, All items, Index, KRW, 2005=100
China	ECOWIN	5	China, Consumer Prices, Overall, Total, average, Index, CNY, CPPY=100
Australia	ECOWIN	5	Australia, Consumer Prices, All Items, Total, Index, AUD, 1989-1990=100
Australia	ECOWIN	5	Australia: Producer Price Index: Manufacturing (NSA, 1989-90=100)
Asia: Interest Rate			
Australia	ECOWIN	0	Australia: 3-Month Bank Accepted Bills (AVG, %)
Europe: Activity			
Switzerland	ECOWIN	5	Switzerland, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, SA, CHF, 2000 prices
Switzerland	ECOWIN	5	Switzerland, Production, Manufacturing industry, Index, CHF, 1995=100
Netherlands	ECOWIN	5	Netherlands, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, Cal Adj, SA, EUR, 2000 prices
Finland	ECOWIN	5	Finland, Expenditure Approach, Gross Domestic Product, Total at market prices, Constant Prices, SA, EUR, 2000 prices

See end of table for notes

Table 5 – continued from previous page

Country	Source	Transf.	Description
Finland	ECOWIN	5	Finland, Production, Manufacturing, SA, Index, EUR, 2005=100
Denmark	ECOWIN	5	Denmark, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, SA, DKK, 2000 prices
Sweden	ECOWIN	5	Sweden, Expenditure Approach, Gross Domestic Product, Total at market prices, Constant Prices, SA, SEK, 2009 prices
Sweden	ECOWIN	5	Sweden, Production, By Industry, Manufacturing, Overall, NACE Rev.2 C, Total, Cal Adj, SA, Index, SEK, 2005=100
Belgium	ECOWIN	5	Belgium, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, Cal Adj, SA, EUR, 2007 chnd prices
Belgium	ECOWIN	5	Belgium, Production, Manufacturing, Constant Prices, Index, EUR, 2000=100
Spain	ECOWIN	5	Spain, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, Cal Adj, SA, Index, EUR, 2000=100 adjusted
Italy	ECOWIN	5	Italy, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, Cal Adj, SA, EUR, 2000 prices
Italy	ECOWIN	5	Italy, Production, By Industry, Overall, NACE Rev.2 TOTAL, Total industry excluding construction, SA, Index, EUR, 2005=100
France	ECOWIN	5	France, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, Cal Adj, SA, EUR, 2000 prices
France	ECOWIN	5	France, Production, Manufacturing, Cal Adj, SA, Index, EUR, 2005=100
Germany	ECOWIN	5	Germany, Expenditure Approach, Gross Domestic Product, Total, Constant Prices, Cal Adj, SA, EUR, 2000 prices
Germany	ECOWIN	5	Germany, Production, Manufacturing industry, Cal Adj, SA, Index, EUR, 2005=100
Europe: Prices			
Switzerland	ECOWIN	5	Switzerland, Consumer Prices, Total, Index, CHF, 2005M12=100
Switzerland	ECOWIN	5	Switzerland, Producer Prices, Total, Index, CHF, 2003M5=100
Netherlands	ECOWIN	5	Netherlands: PPI: Manufacturing (SA, 2005=100)
Finland	ECOWIN	5	Finland, Consumer Prices, All items, Index, EUR, 2005=100
Denmark	ECOWIN	5	Denmark, Consumer Prices, By Commodity, All Items, Total, Index, DKK, 2000=100

See end of table for notes

Table 5 – continued from previous page

Country	Source	Transf.	Description
Sweden	ECOWIN	5	Sweden, Consumer Prices, By Commodity, All Items, Total, Index, SEK, 1980=100
Sweden	ECOWIN	5	Sweden, Producer Prices, By Industry, Overall, NACE Rev.2 B_TO_E, Total, Index, SEK, 2005=100
Luxembourg	ECOWIN	5	Luxembourg: Consumer Price Index (SA, 2005=100)
Belgium	ECOWIN	5	Belgium, Consumer Prices, All items, Index, EUR, 2004=100
Spain	ECOWIN	5	Spain, Consumer Prices, By Commodity, All Items, Total, Index, EUR, 2006=100
Spain	ECOWIN	5	Spain, Producer Prices, By Commodity, Total industry, Index, EUR, 2005=100
Portugal	ECOWIN	5	Portugal, Harmonized Consumer Prices, CP00, Total, Index, EUR, 2005=100
Italy	ECOWIN	5	Italy, Harmonized Consumer Prices, Total, Linked and Rebased, Index, EUR, 2005=100
Italy	ECOWIN	5	Italy, Producer Prices, NACE Rev.2 TOTAL, Total industry, Linked and Rebased, Index, EUR, 2005=100
France	ECOWIN	5	France, Harmonized Consumer Prices, (HICP), Total, Index, EUR, 2005=100
Germany	ECOWIN	5	Germany, Consumer Prices, All Items, Total, Index, EUR, 2005=100
Germany	ECOWIN	5	Germany, Producer Prices, Total industry, SA, Index, EUR, 2005=100
Europe: Interest Rate			
Euro	ECOWIN	0	Euro Area11-16: 3-Month Average Money Market Rate (AVG, %)
North America: Activity			
USA	ECOWIN	5	United States, National Product Account, Gross Domestic Product, Overall, Total, Constant Prices, AR, SA, USD, 2005 prices
USA	ECOWIN	5	United States, Production, Manufacturing, Overall, Total (SIC), Constant Prices, SA, Index, USD, 2007=100
North America: Prices			
USA	ECOWIN	5	United States, Consumer Prices, All items, SA, Index, USD, 1982-1984=100
USA	ECOWIN	5	United States, Producer Prices, Finished goods total, SA, Index, USD, 1982=100

See end of table for notes

Table 5 – continued from previous page

Country	Source	Transf.	Description
North American: Interest Rate			
USA	ECOWIN	0	U.S.: 3-Month London Interbank Offered Rate: Based on US$ (AVG, %)
Other: Activity			
Brazil	ECOWIN	5	Brazil, Expenditure Approach, Gross Domestic Product, Total, at market prices, Constant Prices, SA, Index, BRL, 1995=100
Brazil	ECOWIN	5	Brazil, Production, By Industry, Manufacturing, Overall, Manufacturing industry, SA, Index, BRL, 2002=100
South Africa	ECOWIN	5	South Africa, Expenditure Approach, Gross Domestic Product, Total, at market prices, Constant Prices, AR, SA, ZAR, 2005 prices
South Africa	ECOWIN	5	South Africa, Production, By Industry, Manufacturing, Total, SA, Index, ZAR, 2005=100
Mexico	ECOWIN	5	Mexico, Production Approach, Gross Domestic Product, Total, Constant Prices, AR, SA, MXN, 2003 prices
Argentina	ECOWIN	5	Argentina, Expenditure Approach, Gross Domestic Product, At market prices, Constant Prices, AR, SA, ARS, 1993
Other: Prices			
Brazil	ECOWIN	3	Brazil, Consumer Prices, Wider index (IPCA), Index, BRL, 1993M12=100
Brazil	ECOWIN	3	Brazil, Wholesale Prices, IPA-DI total, Index, BRL, 1994M8=100
Argentina	ECOWIN	5	Argentina, Consumer Prices, Total, Index, ARS, 2008M4=100
Argentina	ECOWIN	5	Argentina, Producer Prices, General, Index, ARS, 1993=100
South Africa	ECOWIN	5	South Africa, Producer Prices, Overall, All commodities, total, Index, ZAR, 2000=100
Mexico	ECOWIN	5	Mexico, Consumer Prices, Overall, Total, Index, MXN, 2002M6=100

Note: The following transformation codes have been applied: 0 = no transformation, 1 = log, 3 = percentage growth and 5 = log difference. The source abbreviations are: DS = Datastream, EW = Ecowin, NB = Norges Bank, OECD = Organization of Economic Co-operation and Development and RBNZ = Reserve Bank of New Zealand.

Table 6: **Data summary: Selection of domestic variables**

Mnemonic	Source	Transf.	Description
Panel 1: Canada			
GDP	OECD	5	Gross domestic product - expenditure approach. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Cons	OECD	5	Final consumption expenditure. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Inv	OECD	5	Gross capital formation. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Exp	OECD	5	Exports of goods. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Imp	OECD	5	Imports of goods. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Empl	OECD	5	Employment. All persons. Level, rate or quantity series, s.a.
SP	OECD	5	Financial Indicators (MEI). Share Prices, Index 2005=100
ULC	OECD	5	Quarterly Indicator. Unit labour costs measure the average cost of labour per unit of output. They are calculated as the ratio of total labour costs to real output.
CPI	CANSIM	5	CPI, 2005 basket. All-items. NSA (2002=100)
HP	CANSIM	5	Royal Lepage Resale Housing Price
Exch	CANSIM	1	Exchange rate, monthly average of noon rate. USCAD per foreign current
ToT	DS	0	Terms of trade (export prices/import prices), s.a.
Panel 2: New Zealand			
GDP	OECD	5	Gross domestic product - expenditure approach. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Cons	OECD	5	Final consumption expenditure. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Inv	OECD	5	Gross capital formation. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Exp	OECD	5	Exports of goods. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Imp	OECD	5	Imports of goods. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Empl	OECD	5	Employment. All persons. Level, rate or quantity series, s.a.
SP	OECD	5	Financial Indicators (MEI). Share Prices, Index 2005=100
ULC	OECD	5	Quarterly Indicator. Unit labour costs measure the average

See end of Table 5 for notes

Table 6 – continued from previous page

Mnemonic	Source	Transf.	Description
			cost of labour per unit of output. They are calculated as the ratio of total labour costs to real output.
CPI	RBNZ	5	Headline inflation
HP	RBNZ	5	Quarterly house price index, s.a.
Exch	RBNZ	1	CPI based real exchange rate: Relative trade weighted
ToT	RBNZ	0	Terms of trade index
Panel 3: Norway			
GDP	OECD	5	Gross domestic product - expenditure approach. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Cons	OECD	5	Final consumption expenditure. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Inv	OECD	5	Gross capital formation. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Exp	OECD	5	Exports of goods. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Imp	OECD	5	Imports of goods. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Empl	OECD	5	Employment. All persons. Level, rate or quantity series, s.a.
SP	OECD	5	Financial Indicators (MEI). Share Prices, Index 2005=100
ULC	OECD	5	Quarterly Indicator. Unit labour costs measure the average cost of labour per unit of output. They are calculated as the ratio of total labour costs to real output.
CPI	NB	5	Consumer Price Index (KPI). Seasonally adjusted
HP		5	House prices. 1000 kroner per square meter. Sources: NEF, NFF, Finn.no, Econ Pöyry. Seasonally adjusted
Exch	NB	1	Real exchange rate (I-44)
ToT	NB	0	Export price deflator/Import price deflator. Base year 2007. Including oil. NSA
Panel 4: UK			
GDP	OECD	5	Gross domestic product - expenditure approach. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Cons	OECD	5	Final consumption expenditure. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Inv	OECD	5	Gross capital formation. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Exp	OECD	5	Exports of goods. Millions of national currency, chained volume estimates, national reference year,

See end of Table 5 for notes

Table 6 – continued from previous page

Mnemonic	Source	Transf.	Description
			quarterly levels, seasonally adjusted
Imp	OECD	5	Imports of goods. Millions of national currency, chained volume estimates, national reference year, quarterly levels, seasonally adjusted
Empl	OECD	5	Employment. All persons. Level, rate or quantity series, s.a.
SP	OECD	5	Financial Indicators (MEI). Share Prices, Index 2005=100
ULC	OECD	5	Quarterly Indicator. Unit labour costs measure the average cost of labour per unit of output. They are calculated as the ratio of total labour costs to real output.
CPI	EW	5	Consumer Prices, by commodity, all items, Index, GBP (2005=100)
HP	EW	5	House Prices, Nationwide, all properties, s.a. Index, GBP, (1993Q1=100)
Exch	US	1	Broad effective exchange rate index, Sterling (Jan 2005=100)
ToT	DS	0	Terms of trade (export prices/import prices), s.a.

See end of Table 5 for notes

Appendix C Correlations

Table 7: Correlations: Activity

	World	**Europe**	**Asia**	**US**
Panel a: Europe				
Norway GDP	0.26	0.14		
Denmark GDP	0.50	0.34		
Spain GDP	0.57	0.64		
Switzerland GDP	0.62	0.26		
Netherlands GDP	0.66	0.49		
Germany GDP	0.72	0.31		
Finland GDP	0.75	0.27		
Sweden GDP	0.75	0.26		
France GDP	0.79	0.38		
Belgium GDP	0.78	0.26		
UK GDP	0.77	0.35		
Italy GDP	0.83	0.31		
Panel b: Asia				
China GDP	0.24		0.36	
India IP	0.28		0.09	
Australia GDP	0.33		-0.09	
New Zealand GDP	0.33		0.20	
Singapore GDP	0.56		0.64	
Taiwan GDP	0.58		0.44	
Hong Kong GDP	0.57		0.55	
Korea GDP	0.64		0.23	
Malaysia IP	0.61		0.47	
Japan GDP	0.64		0.32	
Panel c: North America				
USA GDP	0.67			0.69
Canada GDP	0.66			0.32
Panel d: Other				
Peru GDP	0.22			
Argentina GDP	0.28			
Chile GDP	0.32			
Brazil GDP	0.57			
South Africa GDP	0.53			
Mexico GDP	0.62			
Panel e: Oil				
Oil Price	0.59	-0.24	0.24	-0.15

Note: Pairwise correlation coefficients between the estimated factors and the individual country activity measures. Only correlations with GDP are displayed, with the exceptions of India and Malaysia, where the correlation is measured against industrial production. Panel e reports the correlation between the factors and the oil price.

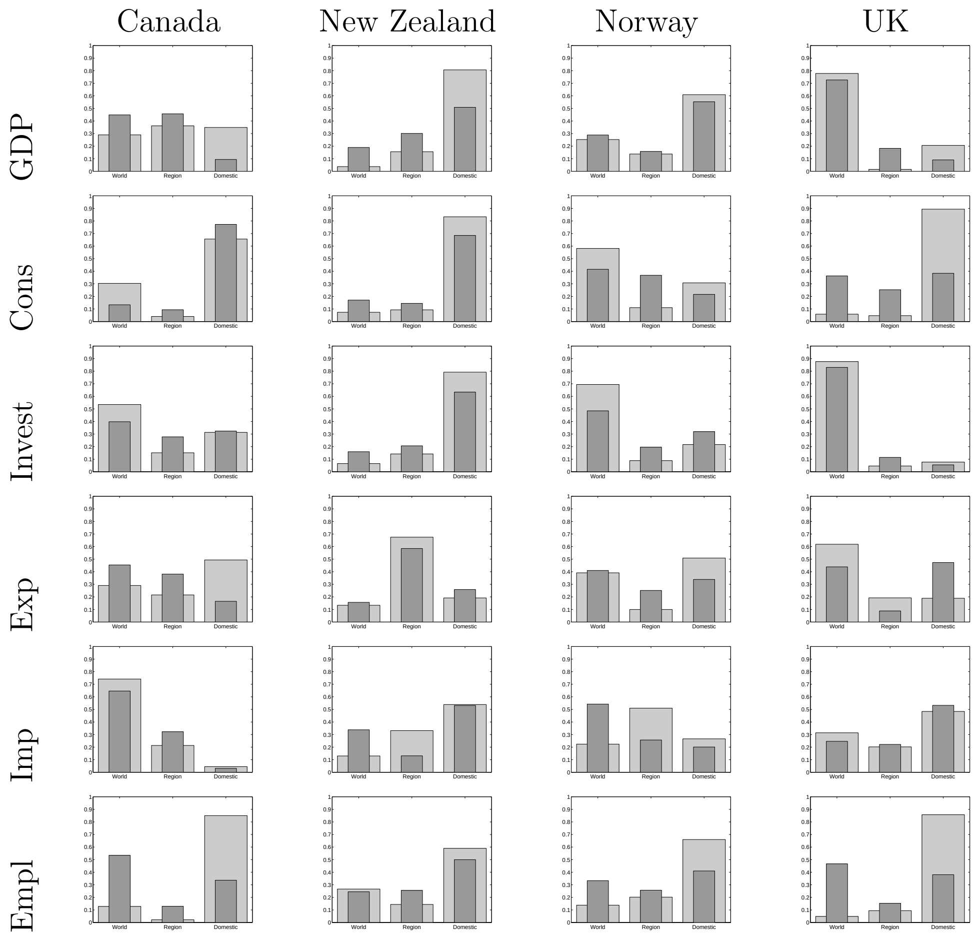
Table 8: Correlations: Prices

	World	**Europe**	**Asia**	**US**
Panel a: Europe				
Norway CPI	0.37	0.04		
UK CPI	0.52	0.49		
Denmark CPI	0.55	0.14		
Germany CPI	0.57	0.62		
Italy CPI	0.58	0.49		
Finland CPI	0.59	0.21		
Sweden CPI	0.59	0.47		
Switzerland CPI	0.72	0.47		
Belgium CPI	0.73	0.32		
Spain CPI	0.71	0.35		
France CPI	0.78	0.34		
Luxembourg CPI	0.73	0.32		
Netherlands PPI	0.78	-0.19		
Panel b: Asia				
Korea CPI	0.26		0.73	
China CPI	0.27		-0.02	
Japan CPI	0.42		0.41	
Australia CPI	0.50		-0.32	
Malaysia CPI	0.53		0.54	
Taiwan CPI	0.48		0.45	
Thailand CPI	0.51		0.53	
New Zealand CPI	0.58		-0.10	
Singapore CPI	0.59		0.10	
Hong Kong PPI	0.58		0.14	
Panel c: North America				
USA CPI	0.72			0.63
Canada CPI	0.60			0.13
Panel d: Other				
Mexico CPI	-0.01			
Brazil CPI	0.12			
Argentina CPI	0.20			
Peru CPI	0.17			
Chile CPI	0.42			
Panel e: Oil				
Oil Price	0.52	-0.02	-0.22	0.11

Note: Pairwise correlation coefficients between the estimated factors and the individual country price measures. Only correlations with CPI are displayed, with the exceptions of the Netherlands and Hong Kong, where the correlation is measured against producer prices. Panel e reports the correlation between the factors and the oil price.

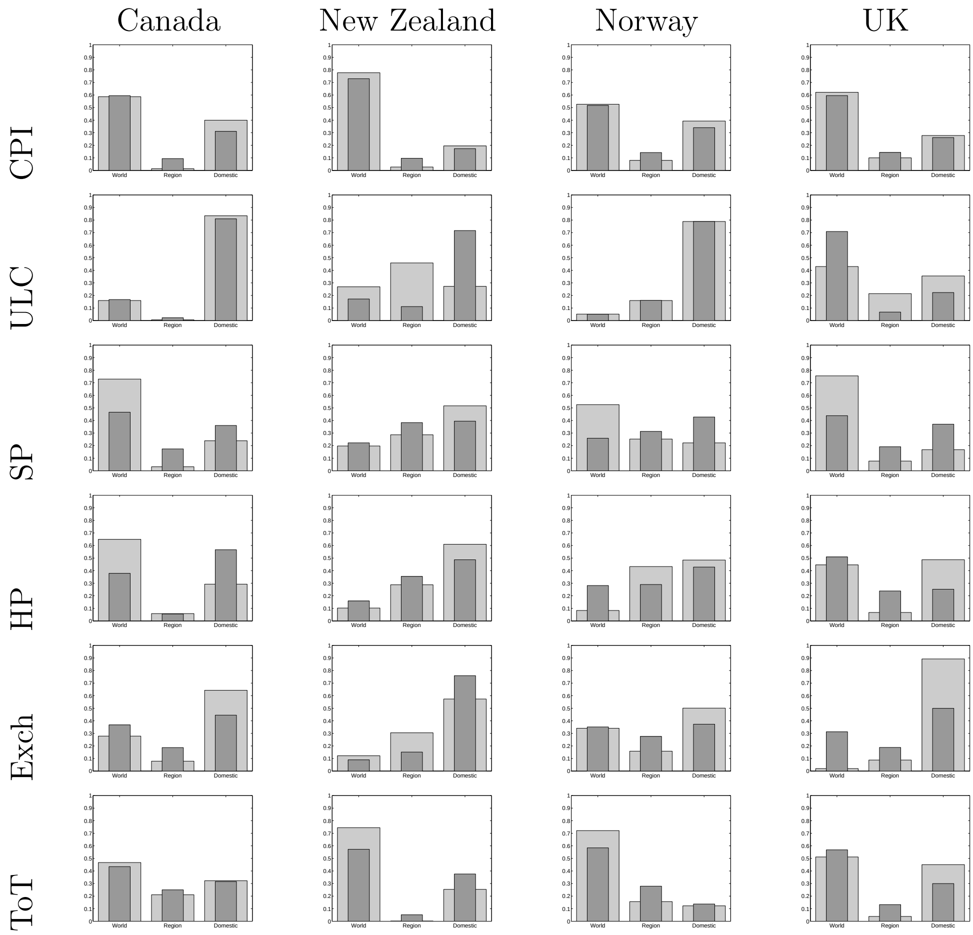
Appendix D Variance decomposition for a selection of variables

Figure 7: **Variance decomposition**



Note: The bars display the variance decomposition for each variable and shock for horizons 1 and 8 quarters. The widest bars correspond to the shorter horizon. The following abbreviations are used: GDP = Gross domestic product, Cons = Consumption, Invest = Investment, Exp = Export, Imp = Import, Empl = Employment. See Table 6 in the appendix for details.

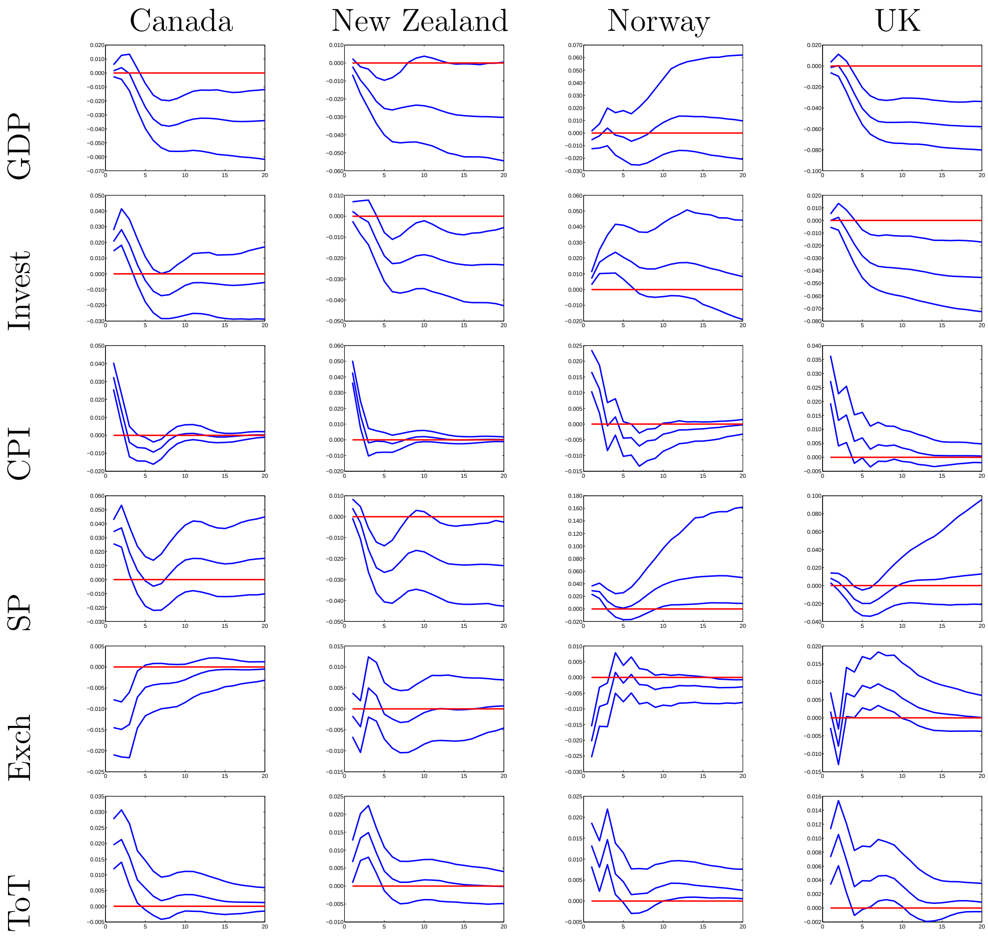
Figure 8: **Variance decomposition**



Note: The bars display the variance decomposition for each variable and shock for horizons 1 and 8 quarters. The widest bars correspond to the shorter horizon. The following abbreviations are used: CPI = Consumer price index, ULC = Unit labor cost, SP = Share prices, HP = House prices, Exch = Exchange rate, ToT = Terms of trade. See Table 6 in the appendix for details.

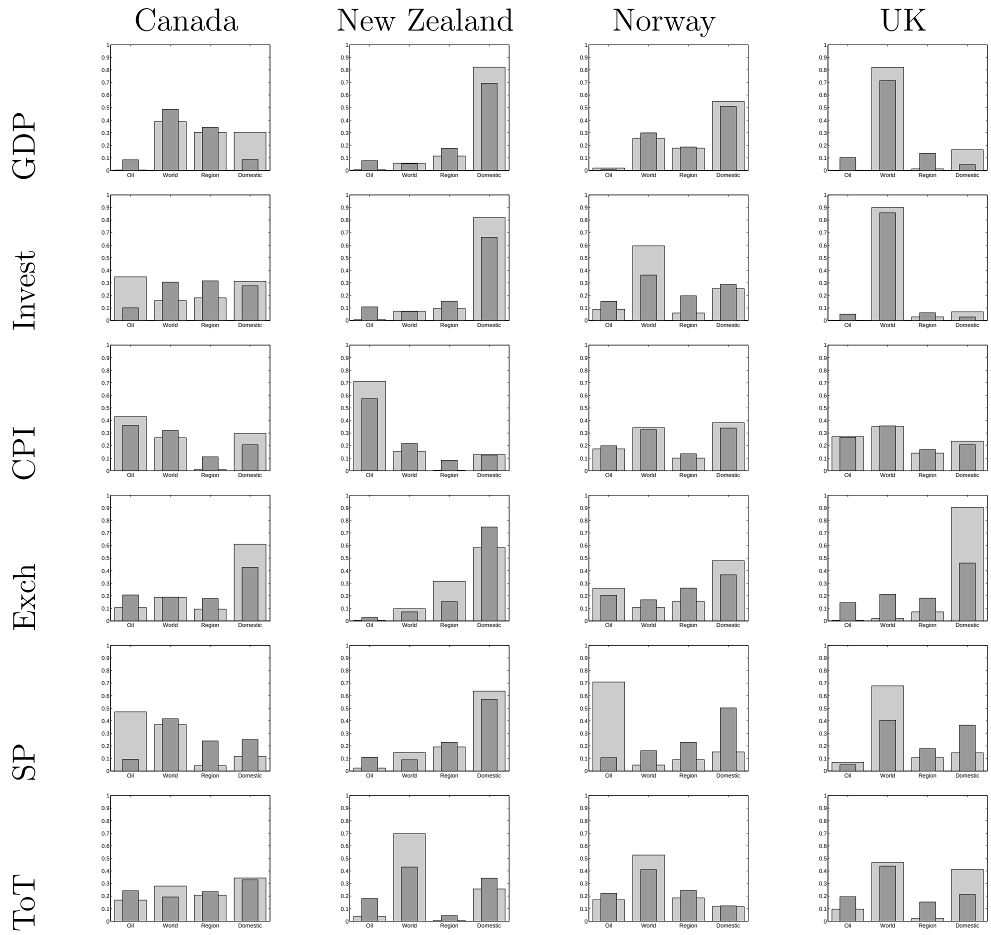
Appendix E The world and oil price shocks

Figure 9: **Impulse responses - oil price shock**



Note: Impulse responses of a one unit increase in oil prices. The following abbreviations are used: GDP = Gross domestic product, Invest = Investment, CPI = Consumer price index, SP = Share prices, Exch = Exchange rate, ToT = Terms of trade. See Table 6 in the appendix for details. All responses are in log levels except, CPI inflation. 90 percent error bands.

Figure 10: **Variance decomposition - oil price shock**



Note: The bars display the variance decomposition for each variable and shock for horizons 1 and 8 quarters. The widest bars correspond to the shorter horizon. See Figure 9 and Table 6 in the appendix for details.

Appendix F Robustness

Table 9: **Variance decomposition sign restrictions: International and domestic contributions**

	Horizon	World	Region	Domestic
Canada	1	0.30	0.17	0.53
	8	0.47	0.20	0.34
New Zealand	1	0.31	0.17	0.52
	8	0.37	0.19	0.44
Norway	1	0.28	0.20	0.51
	8	0.37	0.23	0.40
UK	1	0.35	0.17	0.48
	8	0.57	0.17	0.27

Note: Variance decomposition for all domestic variables (average) divided into world, regional and domestic contributions. The shocks are identified employing sign restrictions.

Table 10: **Variance decomposition short sample: International and domestic contributions**

	Horizon	World	Region	Domestic
Canada	1	0.28	0.19	0.53
	8	0.37	0.25	0.38
New Zealand	1	0.26	0.21	0.53
	8	0.30	0.26	0.44
Norway	1	0.27	0.22	0.51
	8	0.36	0.23	0.41
UK	1	0.30	0.17	0.53
	8	0.41	0.21	0.38

Note: Variance decomposition for all domestic variables (average) divided into world, regional and domestic contributions. The estimation period is 1992:Q2-2007:Q4.