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Abstract

Building on the growing evidence on the importance of large data sets for empirical macroeconomic modeling, we use a factor-augmented VAR (FAVAR) model with more than 260 series for 20 OECD countries to analyze how global developments affect the Canadian economy. We focus on several sources of shocks, including commodity prices, foreign economic activity, and foreign interest rates. We evaluate the impact of each shock on key Canadian macroeconomic variables to provide a comprehensive picture of the effect of international shocks on the Canadian economy. Our findings indicate that Canada is primarily exposed to shocks to foreign activity and to commodity prices. In contrast, the impact of shocks to global interest rates or global inflation is substantially lower. Our findings also expose the different channels through which higher commodity prices impact the Canadian economy: Canada benefits from higher commodity prices through a positive terms of trade shock, but at the same time, higher commodity prices tend to lower global economic activity, hurting demand for Canadian exports.

JEL classification: C32, F41
Bank classification: International topics; Econometric and statistical methods; Business fluctuations and cycles

Résumé

Sur la base des indications croissantes de l'importance des vastes ensembles de données en modélisation macroéconomique empirique, nous utilisons un modèle VAR enrichi de facteurs (modèle FAVAR) et plus de 260 séries relatives à 20 pays de l'OCDE pour analyser l'incidence de l'évolution mondiale sur l'économie canadienne. Nous nous intéressons tout particulièrement à certaines sources de chocs, notamment les prix des produits de base, l'activité économique à l'étranger et les taux d'intérêt étrangers. Nous évaluons les répercussions de chaque choc sur des variables macroéconomiques canadiennes clés afin de dresser un tableau complet de l'effet des chocs internationaux sur l'économie du pays. Nos résultats indiquent que le Canada est principalement exposé aux chocs touchant l'activité étrangère et les prix des produits de base. Par contre, il est beaucoup moins exposé aux chocs qui frappent les taux d'intérêt ou d'inflation mondiaux. Nos résultats mettent également au jour les divers canaux par lesquels les hausses de prix des produits de base se répercutent sur l'économie canadienne : ces hausses avantagent le pays par l'amélioration des termes de l'échange qu'elles entraînent, mais, parallèlement, elles ont tendance à ralentir l'activité économique mondiale, nuisant ainsi à la demande des exportations canadiennes.

Classification JEL : C32, F41
Classification de la Banque : Questions internationales; Méthodes économétriques et statistiques; Cycles et fluctuations économiques

1 Introduction

As the global economy becomes more integrated, foreign developments and their impact on the domestic economy are becoming increasingly important for policymakers. The macroeconomic outlook for small open economies, in particular, can be strongly influenced by international developments. Canada – a textbook example of a small-open economy – is a case in point: The Canadian economy has become much more integrated with the rest of the world during the last decades, as international trade has expanded and financial integration with the rest of the world has deepened. There is evidence that existing links, for example, through commodity prices, may have become more important in the last few years (Maier and DePratto, 2008).

As a highly open economy, Canada is exposed to the global business cycle, and understanding how these developments impact the domestic economy is important for identifying the best policy response to these developments. This study provides a detailed assessment of the dynamic effects of developments originating outside Canada on a wide variety of Canadian macroeconomic variables. Relatively little work has been done on how global developments affect the Canadian economy. Previous studies have evaluated the transmission of foreign shocks using small scale econometric models, primarily vector autoregression models (VARs) or structural vector autoregression models (SVARs).[1] For instance, Klyuev (2008) focuses on the impact of U.S. financial conditions on Canada, but the analysis is restricted to a relatively limited set of variables (primarily GDP, inflation, and short-term interest rates).[2] The findings from these small scale VAR models suggest that a small open economy, such as Canada, is heavily exposed to foreign shocks.

Although small scale models provide plausible assessments of the dynamic responses of key macroeconomic variables to shocks, these models are essentially low-dimensional. This results in two shortcomings. First, while these models provide important insights into the behavior of some key macroeconomic variables, the analysis is typically restricted to a few series, lacking a detailed assessment of the transmission of a foreign shock. Second, the parsimonious setup can complicate the identification of a

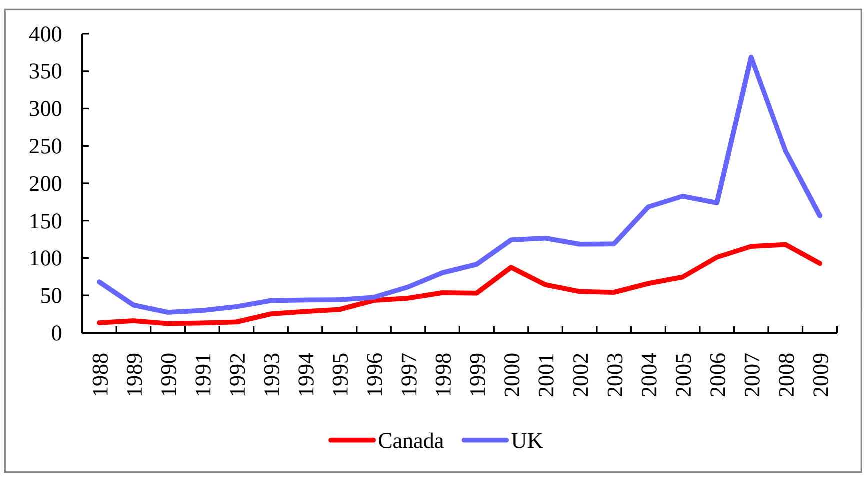
[1] See, for instance, Eichenbaum and Evans (1995) and Grilli and Roubini (1995) for pioneering work using VARs; and Souki (2008) and Klyuev (2008) for SVARs focusing on Canada. Another alternative is the use of structural models, such as in Schmitt-Grohe (1998).

[2] The use of small scale econometric models, primarily vector autoregression models (VARs) or structural vector autoregression models (SVARs), is common in evaluating linkages across countries. See, for instance, Eichenbaum and Evans (1995) and Grilli and Roubini (1995) for pioneering work using VARs. Another alternative is the use of structural models, such as in Schmitt-Grohe (1998).

foreign shock. These shortcomings can be addressed by using factor-augmented VARs (FAVARs), as developed by Bernanke et al. (2005), and implemented by Boivin and Giannoni (2008) and Mumtaz and Surico (2009), among others. These models have the ability to process a vast amount of information, while reducing the dimensionality of the data, such that traditional VAR estimation techniques can still be applied.

Mumtaz and Surico (2009) extend the Bernanke et al. (2005) FAVAR model to an open-economy framework in order to examine how foreign developments impact the U.K. economy. They find that shocks to foreign economic activity have relatively little impact on the U.K. economy, whereas shocks to foreign short-term interest rates can have substantial effects. This result is not surprising, given the country's importance as a global financial center. Given the substantial differences in terms of economic structure between the Canadian and the UK economy, we expect global developments to have very different effects on Canada. First, the U.K. is a net importer of commodities, while Canada is a net exporter of commodities. If commodity prices increase in response to an increase in global economic activity, it is likely to be beneficial for the Canadian economy, but is likely to act as a drag on the U.K. economy. Second, among the G7, Canada is the most open to trade, and thus more likely to be affected by global economic developments through changes in imports and exports. Lastly, the importance of the financial sector is considerably higher in the U.K. than it is in Canada (figure 1).

Figure 1: Stocks traded, total value (percentage of GDP)



Source: World Bank.

To investigate the importance of global business cycle movements for Canada, we build a global FAVAR model in the spirit of Mumtaz and Surico (2009). We extract international and Canada-specific common components from a large panel of data covering 20 OECD countries and more than 260 series. We use the FAVAR approach to model the interaction between the Canadian economy and the rest of the world, which we treat as the "foreign" block. Given the importance of commodity price movements for the Canadian economy, we extend the open-economy FAVAR model in Mumtaz and Surico (2009) to include commodity prices as additional observable variables. Then, we analyze the impact of several types of foreign developments, including changes in foreign interest rates, changes in foreign economic activity, and changes in commodity prices, and rank these developments in terms of their impact on the Canadian economy.

To preview the conclusions, our results show that unlike the findings of Mumtaz and Surico (2009) for the U.K., changes in foreign interest rates have relatively small effects on the Canadian economy. Canada is primarily exposed to shocks to global economic activity and, in particular, to commodity prices. As a commodity exporter, Canada benefits from higher commodity prices through a positive terms of trade shock, but at the same time, higher commodity prices tend to lower global economic activity, hurting Canadian non-commodity exports. Put simply, Canada benefits from higher commodity prices, but only to the extent that they do not choke off global economic activity.

The remainder of the paper proceeds as follows. Section 2 places our study in the literature. Section 3 explains the methodology applied. Section 4 reports our estimation results. Section 5 summarizes our main findings and discusses their policy implications.

2 The international transmission of shocks

The transmission of domestic and foreign developments through an economy has been analyzed extensively in the literature. Most studies have focused either on domestic or foreign monetary policy shocks, or on the transmission of business cycles. Since Bernanke and Blinder (1992) and Sims (1992), a substantial literature has developed that uses VARs to study the effects of domestic or foreign monetary policy innovations on macroeconomic variables (see Christiano et al., 2000, for a survey).[3] The international transmission of business cycles has been studied by Schmitt-Grohe (1998) and Eickmeier (2007), among others. The common feature of all these studies is that they focus on a relatively parsimonious set of shocks and thus, economic variables. This has important implications in terms of econometric methodology as it enables using either VARs when the set of variables is small, or SVARs when relatively straightforward identifying restrictions can be applied. The main advantage of using VAR models is that they can provide plausible assessments of the dynamic responses of key macroeconomic variables to shocks without requiring a complete structural model of the economy.[4]

There are, however, limitations with using VARs to analyze the transmission of international shocks. Specifically, VARs tend to become very large very quickly.[5] In order to preserve degrees of freedom, analysis using standard VARs is typically restricted to only a few selected variables. This raises two issues. First, the identification of a foreign shock can become somewhat arbitrary, potentially leading to biases due to omitted variables.[6] Second, economic developments have become more interconnected *globally*, not only between two countries. Thus, the limitations of traditional VAR models become more severe in examining the international transmission mechanism as the number of countries (and relevant variables) increases rapidly when moving from close to open economy considerations.[7] Due to these limitations, VARs cannot provide a very detailed analysis of how different foreign developments are transmitted through a domestic economy.

A relatively recent approach to circumvent these limitations are factor-augmented

[3] The transmission of domestic monetary policy shocks in terms of output and prices in the G7 countries has, for example, been examined by Gerlach and Smets (1995). Kim (2001) examines the transmission of foreign monetary policy shocks.

[4] Leeper, Sims and Zha (1996), using Bayesian methods, manage to estimate larger VARs, but still with fewer than 20 variables.

[5] As an example, a VAR with 6 variables and 4 time lags already as $4 \times 6^2 = 144$ coefficients.

[6] The bias from omitting relevant variables can be substantial. Sims (1992) argues that the 'price puzzle' – the counterintuitive result of many VAR studies that inflation seems to be rising after a tightening of monetary policy – is the result of imperfectly controlling for information that the central bank may have about future inflation. If the central bank tightens policy in anticipation of future inflation, then what appears to be a policy shock in the VAR may just be the response of the central bank to new information. Bernanke et al. (2005) argue that if Sims is correct, the estimated responses of all macroeconomic variables to the monetary policy shock may be incorrect, not just the price response.

[7] An alternative approach to circumvent this limitation is the global VAR (GVAR) model introduced by Dees et al. (2007). GVARs allow dealing with multiple countries, while preserving degrees of freedom, and are particularly suitable for examining the impact of shocks originating in *specific* foreign countries (rather than the rest of the world, as is the focus of our study). Beaton and Desroches (2010) use a GVAR model to analyze the effect of shocks to financial conditions in the U.S. on financial conditions and economic activity in Canada.

VARs or FAVARs. These models allow one to incorporate a large amount of information by replacing economic series by factors extracted from *multiple* series. Thus, one can trace the impact of foreign developments on each domestic indicator (in our case, it enables examining the implications of global business cycle shocks to different components of Canadian GDP, Canadian wage and price developments, and Canadian interest rates, among others). This makes FAVARs very promising tools to analyze international linkages, but so far, they have not been applied widely. In what follows, we explain the FAVAR methodology in more detail.

3 Methodology

3.1 Open-Economy FAVARs

The econometric framework used in this paper is based on the Bernanke et al. (2005) FAVAR model, extended to include international factors. Following Boivin and Giannoni (2008) and Mumtaz and Surico (2009), the model consists of two blocks: one for Canada ('domestic') and one for the rest of the world, named 'foreign'.[8] By and large, the state of the economy cannot be observed directly, but is summarized by K unobserved factors, $F_t = [F_t^* \ F_t^c]'$, where the asterisks denote the foreign economies and c refers to Canada. In contrast, the Canadian central bank policy rate, R_t, is assumed to be directly observable. The joint dynamics of F_t and R_t evolve according to the following transition equation:

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

where $B(L)$ is a conformable lag polynomial of finite order p, and u_t is an error term with mean zero and a covariance matrix Ω.

Equation (1) is a standard VAR, except that the vector of factors F_t is unobserved. These unobserved factors are extracted from a panel of N indicators containing information about the economy. Let X_t be a $N \times 1$ vector of informational variables, where

[8]Throughout the paper, we will use the terms "rest of the world", "international", and "foreign" interchangeably. Canada will be referred to as the domestic economy.

N is large, such that $N > K+1$. X_t is related to both the *unobserved* factors F_t and the *observed* variable R_t by an observation equation of the form

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

where Λ^F and Λ^R are $N \times K$ and $N \times 1$ matrices of factor loadings, respectively, and v_t is a $N \times 1$ vector of zero mean disturbances.

The equations (1)-(2) represent the FAVAR model by Bernanke et al. (2005), but extended by a foreign block (as in Boivin and Giannoni, 2008, and Mumtaz and Surico, 2009). F_t and R_t drive the joint dynamics of X_t. The main advantage of the static representation of the dynamic factor model given by equation (2) is that the factors can be estimated by principal components (see Stock and Watson, 1998, 2002).

3.2 Identification of the Factors

To estimate the FAVAR given by equation (1), we first need the unobserved factors F_t. We compute four factors for the 'foreign' block, F_t^*: $F_t^* = \{Y_t^*, \pi_t^*, M_t^*, R_t^*\}$, where Y_t^* represents international co-movements in real activity, π_t^* denotes an international inflation factor, M_t^* is an international money factor, and R_t^* denotes co-movements in international interest rates. These international factors are identified through the upper $Nx4$ block of the matrix Λ^F, which is assumed to be block diagonal. In other words, we extract the international real activity factor from our series capturing international real activity. Similarly, the international inflation factor is derived from our international inflation series. The other international factors are also identified accordingly.

The dynamics of the Canadian variables are captured by k domestic factors, which are extracted from the full panel of Canadian series. Thus, the bottom Nxk block of Λ^F is a full matrix. The rationale for this choice is that the dynamics of the variables in X_t is driven by the structure imposed on the factor loadings. If all the domestic real activity indicators shared a single domestic activity factor, then the domestic real activity series would also share the dynamics of that common component, up to a scale factor pinned down by the loading. Since our goal is to investigate possible heterogeneity in the responses of domestic economic activity indicators, we do not impose a tight constraint on the dynamics of the individual series. The same reasoning applies to the series for domestic prices, money and interest rates. Thus, in the spirit of Mumtaz and Surico

(2009), our identification imposes most of the structure on the foreign block leaving the domestic block relatively unconstrained. As in Bernanke et al. (2005), we treat R_t as the monetary policy instrument for the domestic economy. The dynamics of each Canadian series is a linear combination of all Canadian factors, which are linked to the foreign factors through the transition equation (1).

Following Bernanke et al. (2005), we divide the panel of Canadian variables into slow- and fast-moving series. The slow-moving variables are predetermined as of the current period, such as the real variables, and by assumption are not affected contemporaneously by R_t. The fast-moving variables, on the other hand, are those that are highly sensitive to contemporaneous economic news or policy shocks, such as prices. Common factors $\hat{C}(F_t^c, R_t)$ are estimated using principal components on all domestic variables in X_t (i.e. the first k principal components of X_t). The slow-moving factors $\tilde{C}(F_t^c)$ are estimated by using only the slow-moving variables. Then, the common components $\hat{C}(F_t^c, R_t)$ are regressed on the estimated slow-moving factors and the observed policy factor, as shown by the following regression:

$$\hat{C}(F_t^c, R_t) = b_1 \tilde{C}(F_t^c) + b_2 R_t + \eta_t \tag{3}$$

Following Bernanke et al. (2005), we calculate the estimated factors $\hat{F}_t$ as the differences between the common components and the product of the observed factor and its estimated beta coefficient. In other words, $\hat{F}_t$ is derived as the part of the space covered by $\hat{C}(F_t^c, R_t)$ that is not covered by R_t. Then, the identification of the domestic policy shock is achieved by recursively ordering F_t^*,$[\hat{C}(F_t^c, R_t) - b_2 R_t]$ and R_t, with R_t last. Also, note that if N is large and the number of principal components used is at least as large as the true number of factors, then the principal components consistently recover the space spanned by both F_t and R_t.

The model is subject to the rotational indeterminacy problem, and is econometrically unidentified without a normalization. We use the standard normalization implicit in the principal components and take $C'C/T = I$, where $C(.)$ represents the common space spanned by the factors of X_t in each block (see Bernanke et al., 2005, for details).

3.3 Estimation and Identification of the FAVAR

Bernanke et al. (2005) and Mumtaz and Surico (2009) propose a two-step procedure to estimate the model. In the first step, the space spanned by the factors, $\hat{C}(F_t^c, R_t)$, is estimated using principal components.[9] As described above, $\hat{F}_t$ is derived as the part of $\hat{C}(F_t^c, R_t)$ that is not spanned by R_t. In the second step, the FAVAR model in equation (1) is estimated as a standard VAR with the true factors, F_t , replaced with the estimated ones, $\hat{F}_t$. This two-step approach is chosen for computational simplicity.[10] As in the case of standard VARs, this model also requires an identification assumption for the policy shock. We assume a Cholesky identification scheme, in which the policy variable (Canada's central bank rate), is ordered last, based on the assumption that the unobserved factors do not react contemporaneously to monetary policy shocks.

The ordering of the variables in our FAVAR specification is as follows:$[Y_t^*, \pi_t^*, M_t^*, R_t^*, F_{j,t}^c, R_t]$ with $j = 1, ...4$. We include four Canadian factors in our benchmark model and estimate the model with 4 lags.[11] The foreign shocks in our model are identified using the recursive ordering scheme. In this scheme, the impact matrix, A_o is lower triangular implying that the rest of the world does not react to Canadian variables contemporaneously.[12]

As regards the number of factors required to effectively summarize the information content in the dataset, Bai and Ng (2002) provide information criterion to determine the number of factors when the time period and the number of variables in the dataset approach infinity. Our analysis shows that up to four factors capture most of the variation. Lastly, the FAVAR model is estimated with 4 lags.

[9] Stock and Watson (2002) show that if N is large, and if the number of principal components is at least as large as the number of factors, then the principal components recover the space spanned by both F_t and R_t.

[10] An alternative estimation approach is a single-step Bayesian likelihood approach. Bernanke et al. (2005) show that both yield very similar results.

[11] Our results do not change significantly if additional Canadian factors are included.

[12] Although it is a standard practice in the literature to use the Cholesky decomposition, its appropriateness has not gone unquestioned (see Christiano et al., 2000 for an excellent survey of the literature). While there are other alternative identification schemes available in the literature, the focus of our study is to highlight the contributions of factor models to the analysis of the international transmission mechanism and not to analyze alternative identification schemes. Thus we follow Bernanke et al. (2005) and other related studies in using a Cholesky decomposition scheme.

3.4 Data

We use monthly data from 1985:01 to 2008:05 for 20 countries. The data set contains 261 series. We refer to Canada as the ‘domestic’ economy. The ‘foreign’ block comprises Australia, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, and United States. Thus, we include most major economies and Canada’s main trading partners, with the exception of China which could not be included due to data limitations. For each country, we include data on real activity, inflation, money, and interest rates (see appendix A for a detailed description).

- For real economic activity, we use data on output growth, industrial production, exports, and employment.
- For inflation, we consider data on the CPI, producer price index, core inflation, wage growth, and import prices.
- Money is measured by a range of monetary aggregates.
- We also use data on short-term, long-term and overnight interest rates for each country.

The data for Canada is very similar to the ‘foreign’ block. Some series in our dataset are only available at quarterly frequency or have missing observations. To address this issue, we use the Expectations Maximization (EM) algorithm described in Stock and Watson (2002). Lastly, all data series are transformed to ensure stationarity and standardized prior to estimation to allow comparisons across shocks.

4 Results

We consider the following types of shocks in our open-economy FAVAR model: shocks to foreign economic activity, foreign interest rates, foreign inflation, and commodity prices.

4.1 Comovements between Canadian variables and international factors

We begin by exploring the extent to which Canadian variables are correlated with Canadian and foreign factors to verify the identification of factors. Figure 2 shows the fraction of the volatility of selected Canadian variables explained by 5 Canadian factors (i.e. 4 factors and the policy rate, which is treated as an observed factor) and 12 world factors.[13] The figure reports the R^2 statistics obtained by the regression of these variables on the appropriate set of factors for the entire sample.

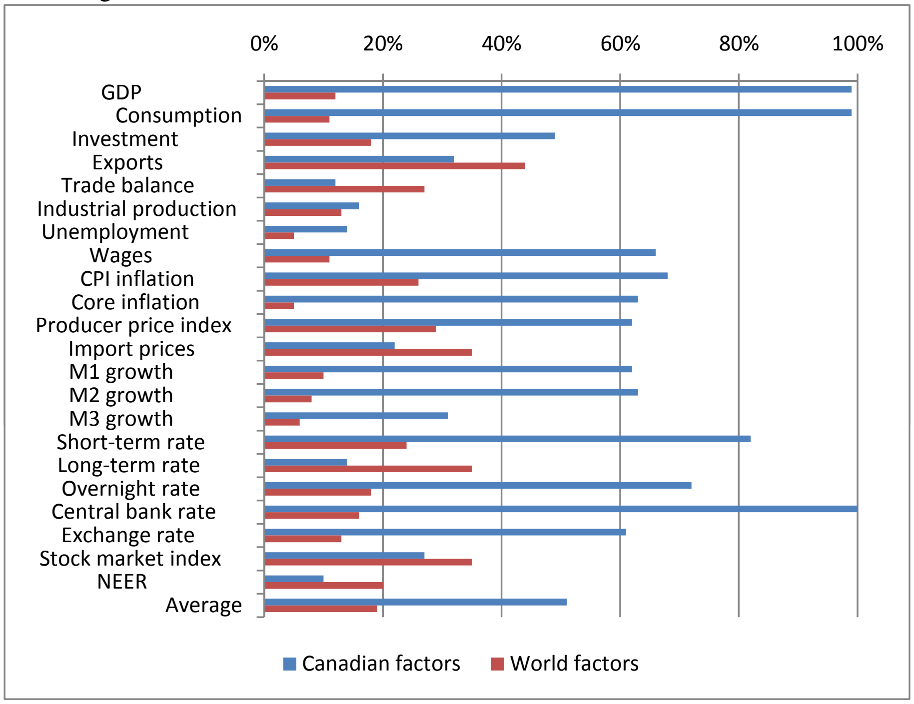
Figure 2 yields several interesting observations. First, all Canadian series are strongly correlated with the Canadian common factors. On average, Canadian factors explain about 51% of the variance of Canadian series. However, world factors do also appear to be correlated with Canadian variables, with an average R^2 of 0.19. Likely this reflects that the Canadian macroeconomic variables are affected by global economic shocks which could impact simultaneously the Canadian and world factors. At this point, we do not attempt to determine the origin of the fluctuations in the factors and the direction of causality, but we note that world factors can explain fluctuations in Canadian macroeconomic series with information that is not contained in Canadian factors.

Second, looking at selected Canadian indicators, the correlations differ quite substantially. The most aggregated measure of real economic activity, GDP, shows a very high correlation with the Canadian factors (and low correlation with the world factors). This shows that most of the fluctuations in Canadian GDP are determined by domestic factors. Similarly, consumption is not very highly correlated with world factors. However, investment and, most notably exports, are increasingly correlated with the world factors, with relatively lower correlations with Canadian factors. Third, Canadian inflation rates are quite strongly correlated with the domestic factors. The importance of the international factors, however, for the inflation rates varies considerably depending on the price index used. Core inflation, for instance, is well described by the Canadian factors and displays very little correlation with the world factors. In contrast, the correlation of the growth rates of the producer price index and import prices with world factors is much higher than that of core inflation. Overall, these results suggest that the more open sectors of the Canadian economy are indeed influenced by global de-

[13] We include 3 factors for each one of the 4 "foreign" categories, i.e. foreign economic activity, foreign interest rates, foreign inflation and foreign money growth.

velopments, whereas consumption (and, consequently, GDP, as consumption has the highest share of all GDP components) is primarily determined by domestic economic developments.

Figure 2: Comovements between Canadian variables and various factors



The figure reports the R^2 statistics for regressions of selected Canadian series on different sets of factors.
Note that the R^2 statistic for the central bank rate is 1 by construction.

4.2 An increase in foreign economic activity

Figure 3 shows the impulse responses for a shock to foreign economic activity, defined as a one standard deviation increase in the world economic activity factor. The first row shows the response of the global variables while the rows below show the impact on Canadian variables. The increase in world economic activity leads to an increase in global inflation and global money growth, triggering a rise in global interest rates.[14]

[14]Note that for all world variables we show the response of the first factor, with the exception of money growth for which we show the responses of the third factor. The responses of the first and the second factor in global money growth were counterintuitive, possibly reflecting distortions arising from substantial shifts in the velocity of money. Thus, all FAVAR graphs display the responses of the third factor.

Of particular interest is the transmission of this shock to the Canadian economy. Higher global activity boosts Canadian exports directly, because world demand for Canadian goods increases. This contributes to an improvement in the Canadian trade balance. GDP growth is clearly positive, as consumption is growing, leading to higher Canadian wages. CPI inflation also rises, triggering an increase in the Canadian monetary policy rate.

4.3 An increase in foreign interest rates

This section describes the dynamic effects of an unanticipated increase in foreign interest rates. Figure 4 shows the results of a foreign interest rate shock in our FAVAR model, defined as a one standard deviation increase in the world interest rate factor. As can be seen in the top panel, an increase in world interest rates tends to lower world economic activity and world inflation. Canadian GDP growth falls in response to higher world interest rates, as all major components of economic activity experience a contraction. The response of investment, however, is muted. Further, on impact, the Canadian exchange rate depreciates, but exports fall and the trade balance deteriorates, as the negative demand effect through lower world growth seems to dominate the positive effect on exports through a weaker Canadian exchange rate.[15] The fall in consumption and investment growth triggers a fall in wages. The central bank responds to slowing economic activity by cutting interest rates.

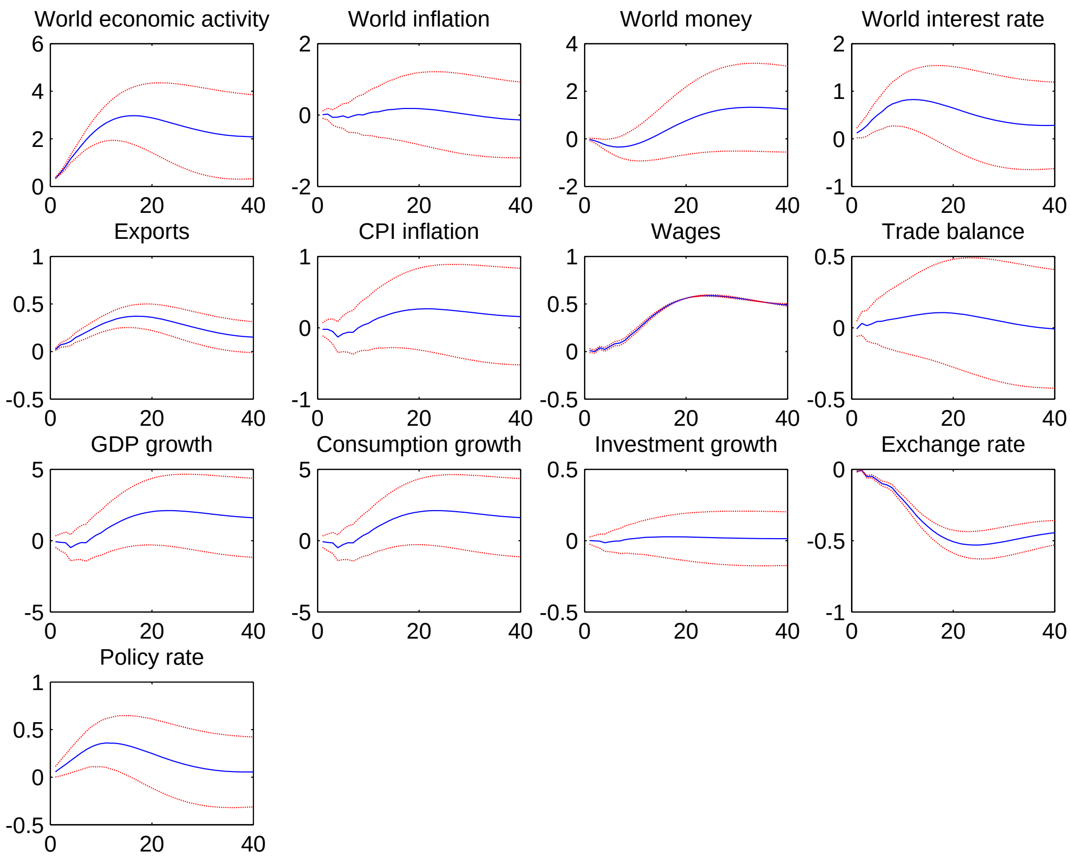
Taken together, a positive shock to world interest rates is directly transmitted to Canada through the exchange rate and the export sector, and given Canada's openness to trade, the fall in foreign demand implies a substantial fall in Canadian GDP growth as well.

4.4 An increase in foreign inflation

Next, we look at the transmission of a shock to foreign inflation. Figure 5 shows the results of a foreign inflation shock, defined as a one standard deviation increase in the world inflation factor. Higher global inflation leads to an increase in world interest

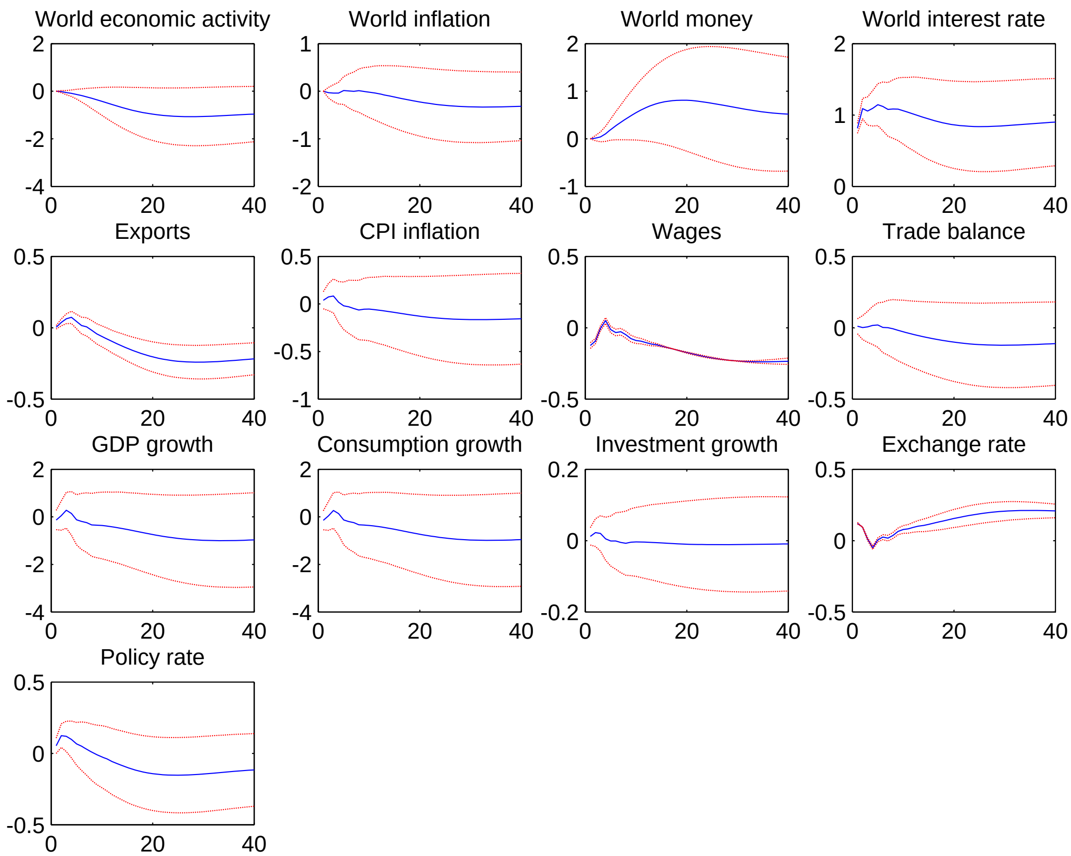
[15]The exchange rate is defined such that an increase corresponds to a depreciation. The relatively small effect of foreign interest rates on the Canadian dollar is in line with previous studies, including Cayen et al. (2010).

Figure 3: A one standard deviation increase in world economic activity



Notes: The X-axis denotes the number of months. The red dotted lines depict the 95 percent confidence intervals.

Figure 4: A one standard deviation increase in foreign interest rates



Notes: The X-axis denotes the number of months. The red dotted lines depict the 95 percent confidence intervals.

rates, which also acts as a drag on global economic activity. Thus, overall, higher global inflation is followed by a contraction in global economic activity.

The transmission of this shock to the Canadian economy is illustrated by the response of the Canadian dollar: In the short term, the Canadian dollar appreciates and then begins to depreciate. Not surprisingly, the appreciation of the Canadian exchange rate leads to an immediate fall in Canadian exports. The fall in foreign demand leads to a decline in Canadian consumption and investment growth. In response to the negative shock, however, the Canadian central bank lowers interest rates. While the fall in Canadian exports continues, as lower global economic activity implies lower demand for Canadian goods (also reflected in a drop in the Canadian trade balance), the drop in domestic consumption and investment is cushioned by the expansionary monetary stance.

4.5 The role of commodity prices

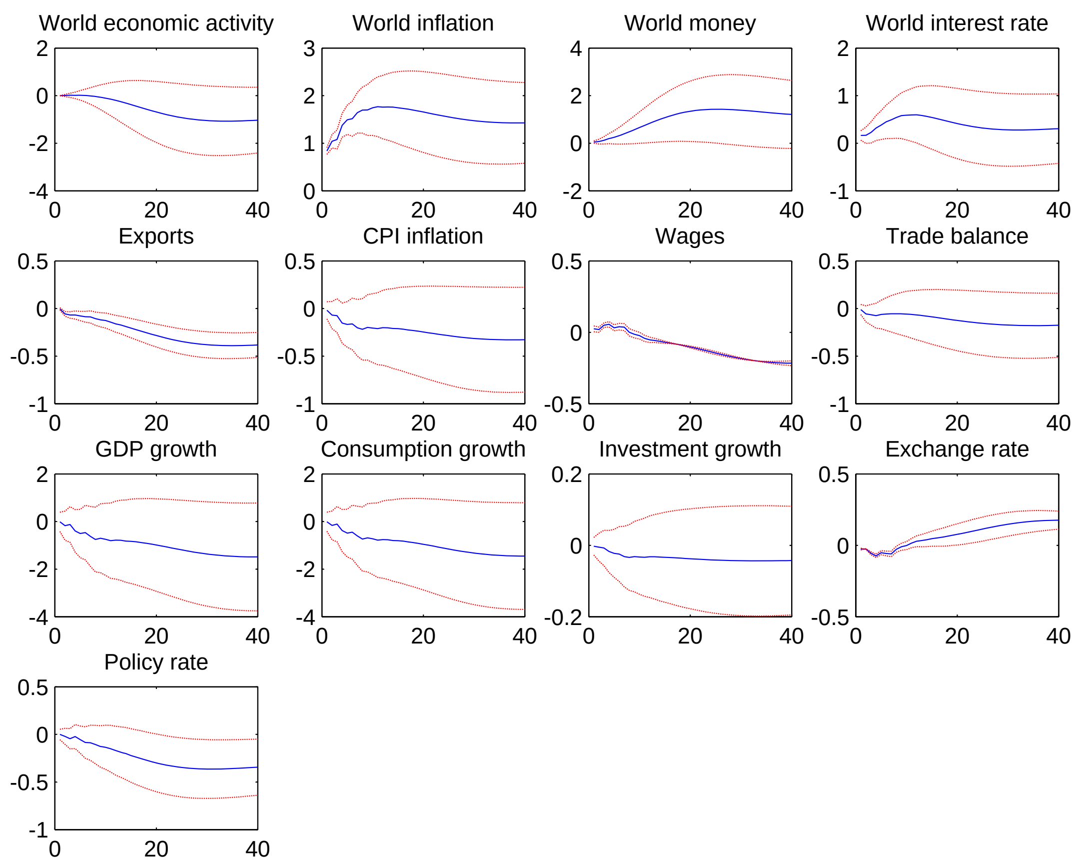
As an important exporter of a broad range of commodities, the Canadian economy is exposed to changes in global commodity prices. Changes in commodity prices affect Canada through its terms of trade, as well through demand for other Canadian export goods. Another motivation for including commodity prices comes from the literature. For example, Sims (1992) suggested that including oil prices in VARs can improve the identification of monetary policy shocks, although it is not the focus of our analysis here.

To examine the role of commodity price shocks, we consider two cases: first, a positive shock to oil prices[16]; second, a positive shock to the Bank of Canada's *index* of commodities. The latter covers a broad range of industrial and agricultural commodities, and is therefore relatively more indicative of global economic growth than oil prices alone, which can exhibit high volatility due to supply shocks. Commodity prices are placed in the foreign block of the FAVAR, first in the ordering, and are assumed to be able to affect simultaneously all world variables as well as Canadian variables, and not be affected by Canadian variables.[17] Figure 6 shows the effects of a one standard deviation shock to oil prices. As can be seen, higher oil prices lead to a rise in global inflation, but the drop in global economic activity is relatively contained.

[16] We use the annual growth rate of the West Texas Intermediate (WTI) price.

[17] We also considered an alternative way of ordering the variables in the FAVAR by placing the commodity prices last since they are fast moving variables. However, the impulse responses do not change substantially.

Figure 5: A one standard deviation increase in foreign inflation



Notes: The X-axis denotes the number of months. The red dotted lines depict the 95 percent confidence intervals.

For Canada, rising oil prices are beneficial: exports and the trade balance improve, the Canadian dollar appreciates (limiting upward pressure on inflation, although the central bank still increases monetary policy rates), and GDP and consumption growth rise. These results are similar to Klyuev (2008) who, using a SVAR model, finds that higher oil prices lead to higher inflation and interest rates in Canada. Note also that investment growth falls, which is consistent with the notion of a negative supply shock.

While an increase in oil prices is beneficial for Canada, a broad-based increase in commodity prices has a very different effect, as illustrated in figure 7. First, note that global economic activity falls in response to a one standard deviation increase in the commodity price index. Also, global inflation rises as in the case of an oil price shock, despite the fall in global output. Consequently, global interest rates rise in order to combat global inflation. Canadian exports contract, after increasing initially, reflecting the weaker external environment. Given that an increase in the broader commodity price index is a more substantial negative supply shock than an oil price shock alone, the Canadian economy experiences stronger 'headwind' (reflecting the sharper fall in global economic activity). This is also reflected in the fall in Canadian consumption and investment growth.[18]

4.6 Forecast error variance decomposition

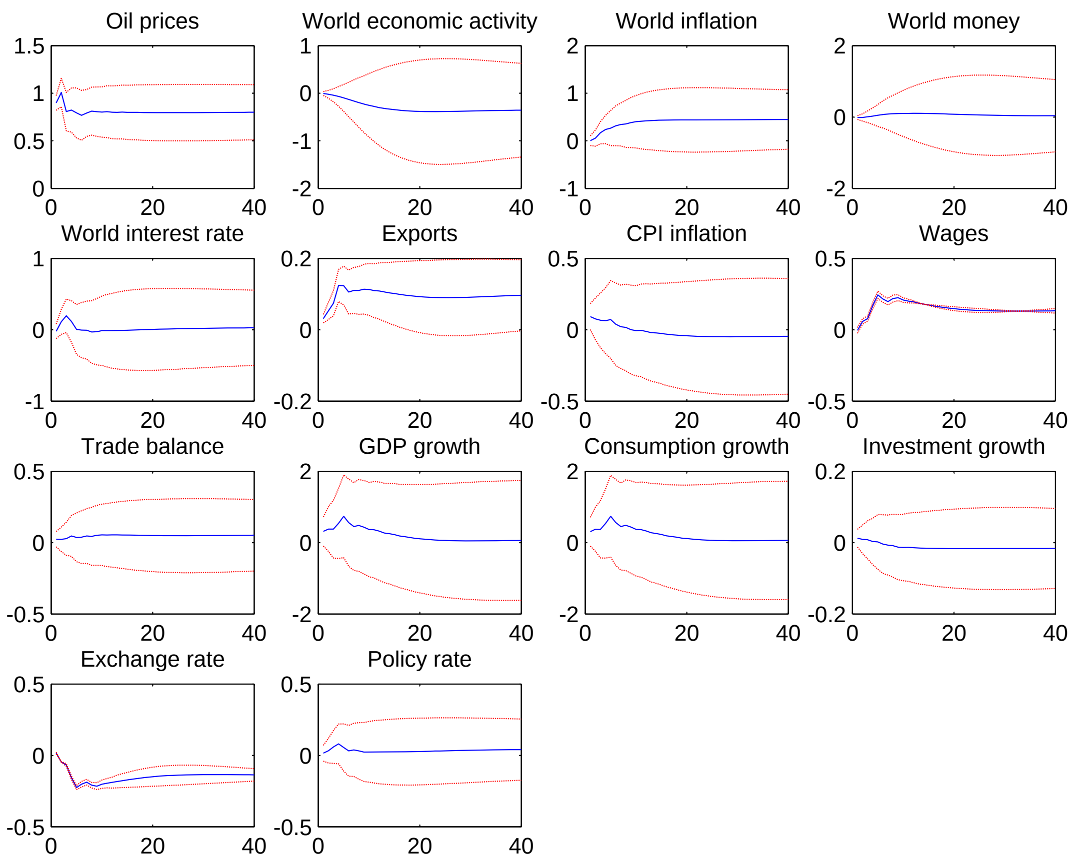
Forecast error variance decomposition determines the fraction of the forecasting error of a variable, at a given horizon, that is attributed to a particular shock. Variance decomposition results follow from the coefficients of the moving average (MA) representation of the VAR system and the variance of the particular shock. Formally, the fraction of the variance of $X_{t+k} - \hat{X}_{t+k}$ due to a particular shock, say ε_t, can be expressed as:

$$\frac{var(X_{t+k} - \hat{X}_{t+k|t} \mid \varepsilon_t)}{var(X_{t+k} - \hat{X}_{t+k|t})} \tag{4}$$

However, as shown in equation 2, part of the variance of the macroeconomic variables comes from their idiosyncratic component which might reflect, in part, measurement error. Business cycle determinants should have no influence on this part of the

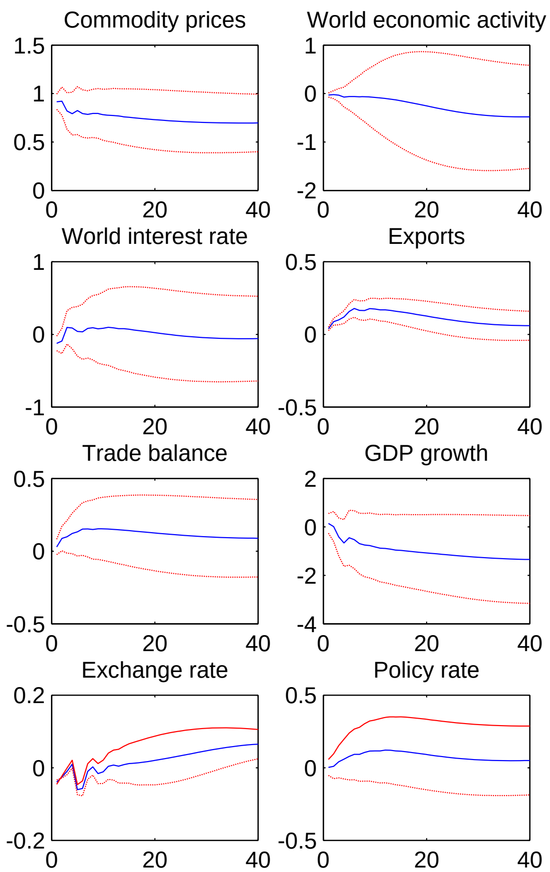
[18] We also considered an alternative specification of the commodity price shock based on the Bank of Canada's new Fisher commodity price index. While the responses of most Canadian variables to this shock are qualitatively similar to those presented above, the impact on exports and trade balance is similar to the case of an oil price shock. This probably reflects the greater share of energy in the new Fisher based index compared to the old index.

Figure 6: A one standard deviation increase in oil prices



Notes: The X-axis denotes the number of months. The red dotted lines depict the 95 percent confidence intervals.

Figure 7: A one standard deviation increase in the Bank of Canada commodity price index



Notes: The X-axis denotes the number of months. The red dotted lines depict the 95 percent confidence intervals.

Table 1: **Forecast error variance decomposition**

	World activity	World inflation	World rates	Commodity prices	Oil prices
Exports	1.35	0.37	0.94	0.48	0.39
Trade balance	0.34	0.20	0.30	0.25	0.17
GDP growth	54.00	14.53	19.56	23.85	8.94
Consumption	53.22	14.31	19.67	23.51	8.80
Investment	0.14	0.04	0.10	0.04	0.03
Inflation	2.99	0.93	1.45	1.35	0.64
Wages	2.73	1.00	1.83	1.28	0.85
Mon. policy	4.64	1.35	4.77	0.97	1.27
Exchange rate	2.45	0.95	1.74	1.20	0.83

The table reports the percentage of the variance of the forecast error, at the 40-month horizon, explained by the various shocks.

variance. Thus, it is not clear that the standard VAR variance decomposition gives an accurate measure of the relative importance of a structural shock (Bernanke et al., 2005). In this context, the FAVAR approach suggests a potentially more appropriate decomposition, where the relative importance of a structural shock is assessed only to the portion of the variable explained by the common factors. More formally, this variance decomposition for X_{it} can be expressed as:

$$\frac{\Lambda_i var(C_{t+k} - \hat{C}_{t+k} \mid \varepsilon_t)\Lambda_i'}{\Lambda_i var(C_{t+k} - \hat{C}_{t+k})\Lambda_i'} \tag{5}$$

where Λ_i is the i^{th} line of Λ and $\frac{var(C_{t+k} - \hat{C}_{t+k} | \varepsilon_t)}{var(C_{t+k} - \hat{C}_{t+k})}$ is the standard VAR variance decomposition based on equation 1. Table 1 reports the results for the variance decomposition exercise.

The columns report the fraction of the forecast error at the 40-month horizon explained by the various shocks for each variable whose impulse is plotted in Figures 3-7. The foreign shocks explain less than 5 per cent of the forecast variance of most variables, with the exception of GDP growth and consumption growth. This suggests a relatively small effect of the shocks.

4.7 Ranking foreign shocks according to impact

In this section, we provide a ranking of foreign shocks according to their impact on Canadian variables, as derived from the impulse responses presented in Figures 3-7. While Mumtaz and Surico (2009) do not explicitly rank different foreign developments according to their impact on the U.K. economy, their results show that an unanticipated fall in foreign short-term interest rates has a substantial effect on the U.K. economy via investment, GDP, consumption growth, and CPI and GDP deflator inflation. On the other hand, the impact of an unanticipated increase in foreign real activity is relatively muted. In contrast to these results, we find that shocks to foreign activity have substantial implications for the Canadian economy, likely reflecting the importance of the resource sector for the economy. In particular, an unanticipated increase in foreign economic activity is beneficial for Canada as it is not only associated with an increase in exports, but also higher commodity prices.

These two effects are clearly seen when comparing the patterns of response to shocks to foreign activity and 'isolated' shocks to commodity prices. In terms of the peak response of Canadian GDP and Canadian consumption, the effect of a one standard deviation shock to foreign activity is roughly 50 per cent higher than that for a one standard deviation shock to commodity prices. The same is true for the impact on Canadian exports. An economic interpretation for this result is that a drop in global economic activity hurts Canada through two channels. The first, and direct, channel is through a fall in demand for Canadian exports. The second channel operates through lower commodity prices, as a weakening global economy typically implies lower demand for raw materials. Consequently, a foreign activity shock has also the largest impact on the Canadian exchange rate and the monetary policy rate.

The foreign shock triggering the quickest Canadian monetary policy response is a shock to oil prices. Canadian exports react faster, and – somewhat surprisingly – shocks to oil prices are also transmitted fairly rapidly through wages. Two other results are worth highlighting. First, shocks to global interest rates and global inflation have substantially smaller effects on the Canadian economy. Second, as mentioned before, the Canadian economy tends to benefit from higher oil prices, but suffers from higher prices for a broad basket of commodities, given that in the latter case the effect through lower global demand dominates the positive terms of trade shock.

Lastly, in terms of domestic transmission channels, note the importance of Canadian exports and domestic consumption. In contrast, it seems that investment is not a major channel through which foreign shocks are transmitted, as the response of investment to all shocks is relatively muted.

5 Conclusion

The Canadian economy has become much more integrated with the rest of the world during the last few decades. While international economic integration allows countries to gain from specialization and provides better opportunities for international risk sharing, it also increases the vulnerability to external shocks. The financial turmoil that started in summer 2008 provides an example of an economic event that was transmitted to the Canadian economy through falling external demand and deteriorating external conditions.

To better understand how the global business cycle is transmitted to Canada, we estimate an open economy FAVAR model for Canada. In contrast to the existing literature on the transmission of international shocks, we use a rich data set comprising 20 countries and over 260 variables, covering economic activity, pries and monetary indicators. The FAVAR methodology allows us to trace the effects of global developments on a broad range of Canadian macroeconomic variables.

We focus on four main types of foreign developments: foreign economic activity, foreign inflation, foreign interest rates, and commodity prices. Our findings indicate that Canada – the most open of all G7 economies – is primarily exposed to shocks to foreign activity and to commodity prices. In contrast to the findings of Mumtaz and Surico (2009) for the UK, changes to foreign interest rates are relatively less important for Canada, possibly reflecting the relatively lower importance of the financial sector for Canada's economy as compared to the U.K. Also, our findings reveal that higher commodity prices are a 'mixed blessing' for Canada: on the one hand, Canada benefits through a positive terms of trade shock, but on the other hand, higher commodity prices tend to lower global economic activity, hurting demand for Canadian exports. Overall, our results provide a rationale for Canadian policymakers to watch the global business cycle carefully.

There are several avenues to extend this analysis further. First, given that Canada's trade openness has increased over time, it is plausible that global business cycle developments have become *increasingly* important for Canada. It would, thus, be interesting to conduct a sub-sample analysis to investigate whether the Canadian economy has become more sensitive to foreign developments over time. Another potential avenue is to examine the relative importance of unanticipated developments in different regions, say emerging Asia and Europe, in terms of their impact on the Canadian economy. We leave these extensions for future research.

A Appendix: Description of the data

Our dataset contains data on real activity, inflation, money growth, and interest rates for Australia, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, and United States. We use monthly data from 1985:01 to 2008:05 for 261 series. All data series are first transformed to induce stationarity and are then standardised.

Industrial production

- All Countries: Production of total industry (Excluding Construction), Volume Index, Seasonally adjusted, 2000=100. Source: Main Economic Indicators, OECD.
- South Korea: Industrial Production. Volume Index, Seasonally adjusted, 2005=100. Source: National Statistics Office

Exports
All Countries: Exports (FOB), Billions US Dollar, Seasonally adjusted. Source: Main Economic Indicators OECD

Unemployment

- Main: Standardized unemployment rates, percentage, seasonally adjusted. Source: Main Economic Indicators OECD
- Mexico: Unemployment rate (percent of total workforce), Seasonally adjusted. Source: Main Economic Indicators OECD
- Data for Germany is from the BIS. Data for South Korea is from the Global Insight.

Gross domestic product

- Australia: Million Australian Dollars, 1996-1997, Seasonally adjusted. Source:IFS
- Austria: Volume Index, 2000=100. Not seasonally adjusted. Source:IFS
- Belgium: Volume Index, 2000=100. Not seasonally adjusted. Source:IFS
- Denmark: Volume Index, 2000=100. Not seasonally adjusted. Source:IFS
- Finland: Volume Index, 2000=100. Not seasonally adjusted. Source:IFS
- France: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- Germany: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- Italy: Volume Index, 2000=100. Seasonally adjusted. Source:OECD Main Economic Indicator
- Japan: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- South Korea: Volume Index, 2000=100. Seasonally adjusted. Source:OECD Main Economic Indicator
- Mexico: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- Netherlands: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- New Zealand: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- Norway: Volume Index, 2000=100. Seasonally adjusted. Source:OECD Main Economic Indicators
- Spain: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- Sweden: Volume Index, 2000=100. Seasonally adjusted. Source:OECD Main Economic Indicator
- Switzerland: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- United Kingdom: Volume Index, 2000=100. Seasonally adjusted. Source:IFS
- United States: Volume Index, 2000=100. Seasonally adjusted. Source:IFS

CPI

- Germany: Consumer Price Index, Not seasonally adjusted, 2000=100. Source: Main Economic Indicators, OECD
- All other countries: Consumer Price Index, Not seasonally adjusted, 2000=100. Source:IFS

Core inflation

- South Korea: CPI - Excluding agricultural products and oil, price index, Not seasonally adjusted, 2005 =100. Source: National Statistics Office
- All other countries: CPI - Excluding food and energy, price index, Not seasonally adjusted, 2000=100. Source: Main Economic Indicators OECD

Producer price inflation

- France: PPI Manufactured goods, Price Index, Not seasonally adjusted, 2000=100. Source: Main Economic Indicators, OECD
- All other countries: PPI, Price Index, Not seasonally adjusted, 2000=100, IFS

Import prices

- Finland: Import Price Index, not seasonally adjusted, 1995=100. Source: Statistics Finland
- Mexico: Import price index, not seasonally adjusted, 2000=100. Source: Monthly Statistics of International trade, OECD
- New Zealand: Import price index. Source: Statistics New Zealand
- Norway: Import Price Index, not seasonally adjusted, 1995=100. Source:IFS
- France, Italy, South Korea: Unit value import prices. Source: IFS and Datastream
- All other countries: Import price indexes from IFS and Datastream

Wages

- Australia and New Zealand: Total unit labour cost from the OECD
- South Korea, Mexico, and Netherlands: Manufacturing wages from the OECD
- All other countries: Unit labor cost from the IFS

Money growth We use the M1 series for all countries except U.K and Norway, for which we use the M2. The main source for the data is the OECD with the following exceptions:

- Austria: Datastream and Global Insight
- Belgium: OECD and the National Bank of Belgium
- Finland, France, Denmark, Netherlands and Spain: Global Insight
- Norway and Sweden: DataStream
- Italy: Central bank of Italy

Short-term interest rate Data source: Main Economic Indicators OECD, unless otherwise noted.

- Australia: Yield 90-day Bank accepted bills
- Austria: 3-month VIBOR
- Belgium: 3-month Treasury certificates
- Canada: 3-month corporate paper rate
- Denmark: 3-month uncollateralized interbank rate
- Finland: 3-month HELIBOR
- France: 3-month PIBOR
- Germany: 3-month FIBOR
- Italy: 3-month interbank rate on deposits
- Japan: Rate New 90 to less than 120 CDS
- South Korea: Commercial paper rate, IFS
- Mexico: 91-Treasury certificate rate
- Netherlands: 3-month AIBOR
- New Zealand: 90-day Bank bills yield
- Norway: 3-month NIBOR
- Spain: Interbank loans - 3month
- Sweden: Yield 90-day Treasury certificate
- Switzerland: 3-month CHF LIBOR
- UK: 3-month mean LIBOR/LIBID
- US: Rate 3-month CDS, Main Economic Indicators OECD

Long-term interest rate

- Australia: Commonwealth government bond Yield (10 years). Source: Reserve Bank of Australia
- Austria, Belgium, Denmark, Finland, France, Germany, Italy, Spain, and the United Kingdom: Long term government bond yield (10 years) - Maastricht Definition (Avg.). Source: Eurostat
- Canada: Government bond yield: 10 year benchmark (End of month). Source: CANSIM - Statistics Canada
- Japan: Interest bearing government bonds - 10 years (Source: Main Economic Indicators, OECD
- Mexico: Yield 10-year benchmark federal bonds (Proxy 1-Year Government Bonds)
- South Korea: Government bond yield (Long term) Source: IFS
- Netherlands: Yield latest 10 year central government bonds. Source: Main Economic Indicators, OECD

- New Zealand: Yield 10 year government bonds. Source: Main Economic Indicators, OECD
- Norway: Yield 10 year government bonds. Source: Main Economic Indicators, OECD
- Sweden: Government bond yield - 10 year. Source: Sveriges Riksbank
- United States: Government bond yield (10 years)

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