Q. Please provide the article by Beaton and Desroches (2011) referenced in footnote 31.

A. Attachment A is the article by Beaton and Desroches (2011) referenced in footnote 31.

Bank of Canada: Financial Spillovers Across Countries:
The Case of Canada and the United States

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Financial Spillovers Across Countries: The Case of Canada and the United States

by

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Abstract

The authors investigate financial spillovers across countries with an emphasis on the effect of shocks to financial conditions in the United States on financial conditions and economic activity in Canada. These questions are addressed within a global vector autoregression model. The framework links individual country vector autoregression models in which the domestic variables are related to the country-specific foreign variables. The authors' results highlight the importance of financial variables in the transmission of shocks to real activity and fmancial conditions in the United States to Canada. First, they show that shocks to U.S. output are transmitted quickly to Canada, with important implications for financial conditions. Second, they show that the most important source of financial transmission between the United States and Canada is through shocks to U.S. equity prices. Financial transmission through movements in the quantity of U.S. credit is also important for Canada.

JEL classification: E27, E32, F36, F40
Bank classification: Businessfluctuations and cycles; Economic models; Financial stability; International topics

Resume

Les auteures etudient la propagation des chocs financiers entre pays, et plus particulierement !'incidence des chocs qui se produisent aux Etats-Unis sur les conditions financieres et l'activite economique au Canada. Leur cadre d'analyse est un modele vectoriel autoregressif mondial. Celui-ci relie des modeles vectoriels autoregressifs distincts pour chaque pays qui mettent en rapport les variables nationales et les variables etrangeres propres au pays. Les resultats obtenus font ressortir !'importance des variables fmancieres dans la transmission des chocs touchant l'activite reelle et les conditions fmancieres des Etats-Unis vers le Canada. En premier lieu, ils montrent que les chocs de production qui surviennent aux Etats-Unis se transmettent rapidement au Canada, ce qui comporte des effets importants sur les conditions financieres. En deuxieme lieu, ils demontrent que les chocs qui frappent les cours boursiers aux Etats-Unis sont la principale source de transmission des chocs financiers entre les deux pays. Le Canada est egalement tres sensible aux variations du volume du credit aux Etats-Unis.

Classification JEL: E27, E32, F36, F40
Classification de la Banque : Cycles etfluctuations economiques; Modeles economiques; Stabilitefinanciere; Questions internationales

1 Introduction

One of the most striking features of the international business cycle is the co-movement of output, inflation and interest rates across countries. This co-movement has become more pronounced over the past three decades, owing to increased trade and financial liberalization. Over the past two years in particular, the turmoil in global financial markets, which originated in the U.S. subprime mortgage market, has underscored the importance of financial linkages between countries. Moreover, the financial crisis has highlighted the important impact that financial conditions can have on real economic activity. These increasing interdependencies that exist across countries must be taken into account by policy-makers when formulating domestic policy. Although the real linkages between countries, particularly through trade, are well understood, we have yet to develop a complete understanding ofthe financial linkages across countries.

For Canada in particular, developments in U.S. economic activity and financial conditions are likely to exert a significant effect on the Canadian business cycle. Historically, the effect of the U.S. business cycle on the Canadian business cycle has generally been studied through trade linkages, since the United States represents about three-quarters of Canadian trade. However, there are also strong financial linkages between Canada and the United States. For example, Canadian non-financial corporations rely on U.S. financing, since about 20 per cent of shares of Canadian firms are held by U.S. residents. Moreover, foreign loans typically account for about 40 per cent of total bank loans to the Canadian non-bank sector, highlighting the importance of foreign credit for Canada.[1] Therefore, developments in U.S. financial conditions may exert a significant effect on the Canadian business cycle. In this paper, we assess the importance of external financial developments for the Canadian business cycle. In particular, we study how U.S. financial shocks are transmitted to Canada.

The transmission of U.S. financial shocks to Canada has also been examined by Klyuev (2008) using structural vector autoregressions. His results suggest that a tightening of U.S. financial conditions has significant negative implications for Canadian real activity through three distinct channels: 1) the direct financial channel, where the slowdown is attributed to a rising cost of funds for Canadian companies raising capital in the United States, 2) the indirect financial channel, where Canadian growth is hampered as financial conditions tighten in response to a tightening in the United States, and 3) the trade channel, which occurs through a slowing in the U.S. economy and correspondingly lower demand for Canadian exports. We build on Klyuev's (2008) work by assessing the spillover of U.S. financial conditions to Canada within a global vector autoregression (GVAR) model.

Originally developed by Pesaran, Schuermann and Weiner (2004), and further developed by Dees et al. (2007), the GVAR model provides a global framework to study the transmission of U.S. financial shocks to Canada. The GVAR model is constructed by combining separate vector autoregression (VAR) models for each economy that link developments in each country's core macroeconomic and financial variables to corresponding country-specific foreign variables. The model estimated in our paper includes 33 countries; it can be used to study the impact of a shock to any country on any other country in the model. In our study, we limit our analysis to assessing the impact of shocks to U.S. financial conditions on Canada. The appeal of the GVAR framework when addressing this question is that it allows a shock to U.S. financial conditions to affect Canada both directly and

[1] Excluding mortgages.

indirectly, through its effect on the other regions included in the model and their spillover effects on Canada. In light of the highly synchronous deterioration in financial conditions globally throughout the financial crisis of 2007-09, these spillover effects may be quite sizable and would not be captured within a traditional VAR framework. Therefore, our framework augments Klyuev's (2008) framework by allowing Canada to be endogenously affected by the response of the other regions of the world to shocks to U.S. financial conditions. Galesi and Sgherri {2009) also use a GVAR framework to assess financial spillovers. However, unlike our study, their focus is on regional financial spillovers across Europe following a slowdown in U.S. equity prices. Their results reveal considerable co-movement of equity prices across mature equity markets in Europe.

Overall, the results of our study suggest that financial conditions in the United States have important spillover effects on the Canadian economy. We find that the most important source of financial contagion is through shocks to U.S. equity prices. Financial contagion through movements in the quantity of U.S. credit is also important for Canada. Finally, we study the importance of second-round effects in the transmission of U.S. shocks to Canada, since U.S. shocks affect other economies and therefore Canada through trade and financial linkages. We find evidence of sizable second-round effects following shocks to U.S. output and equity prices.

The remainder of this paper is organized as follows. In section 2 we describe our empirical strategy. In section 3 we describe the results. In section 4 we conduct sensitivity analysis around the results. In section 5 we offer some conclusions.

2 The Empirical Strategy

In this study, we make use of the GVAR model originally developed by Pesaran, Schuermann and Weiner (2004) and further developed by Dees et al. (2007) to assess financial spillovers between the United States and Canada. The GVAR model provides a multi-country framework to model interlinkages between countries. It is composed of a system of VARX* models, one for each country included in the model, that are linked together by including country-specific foreign variables in the VARX* models. Therefore, each country is affected by developments in other countries in the model. The GVAR model thus provides a suitable global framework for our study of the transmission of U.S. financial shocks to Canada.

The GVAR model estimation approach can be briefly described in two steps. In the first step, the country-specific VARX* models, in which the core domestic variables are related to country-specific foreign variables, are estimated. In the second step, the estimated coefficients from the country-specific VARX* models are stacked and solved in a global system, generating the GVAR model. Appendix A provides more details on the GVAR model and Appendix B describes the model diagnostics.

2.1 The data

As in Dees et al. (2007), our GVAR model covers 33 countries representing more than 85 per cent of world output. Table 1 provides a complete list of the countries included in the model. Note that we also follow Dees et al. (2007) and model the eight original euro area economies as a single region, while the remainder of the countries included in the dataset are modelled independently.[2] Our model, given the large share of world output accounted for by the countries included in it, allows us to capture not just the direct effect of U.S. shocks on Canada, but also the indirect effect through the effect of U.S. shocks to conditions in other economies. We estimate the GVAR model using quarterly data over 1979Ql-2008Q4, thus extending the dataset in Dees et al. (2007) by five years. At its core, the model includes real output, inflation, the real exchange rate, a short-term interest rate, a long-term interest rate, oil prices and real equity prices. Appendix C provides definitions of specific variables.

Although the variables mentioned above represent the core variables included in the GVAR model, the variables in the country-specific VARX* models differ somewhat across countries. In each country-specific model, domestic real GDP, inflation, the short-term interest rate, the long-term interest rate, real equity prices and the real bilateral exchange rate with the U.S. dollar are included as endogenous variables. However, given that not all countries have well-developed capital markets, we were not able to obtain data on some of the financial variables for a subset of the countries. Therefore, not all VARX* models contain the same number of domestic variables.[3] All country-specific models also include weakly exogenous country-specific foreign variables for real GDP, inflation, the short-term interest rate, the long-term interest rate, oil prices and equity prices.

Given the importance of the United States in the global economy, we follow Dees et al. (2007) and treat the U.S. economy as a special case. In the U.S. VARX* model, we include the same endogenous variables as in the other individual VARX* models, with two exceptions. First, we exclude the U.S. real exchange rate, since all of the other country-specific VAR models include their respective bilateral exchange rates with the U.S. dollar. Second, we include oil prices as an endogenous variable in the U.S. model, which allows developments in the global economy to affect oil prices.[4] As weakly exogenous variables in the U.S. model, we include the foreign real exchange rate, foreign real output and foreign inflation, as in Dees et al. (2007). We exclude the U.S. specific foreign financial variables from the U.S. VARX* model, since they are also unlikely to be weakly exogenous with respect to developments in the U.S. economy, given the importance of the United States in global financial markets.[5]

For all countries, the country-specific foreign variables are constructed using time-varying trade weights. For these weights we use rolling 3-year moving averages of the annual trade weights. See Appendix C for additional details on the construction of the trade weights. By using 3-year moving averages versus annual weights in our time-varying trade weights, we are able to abstract from volatile movements in trade and still capture important changes in trading relationships over time. In addition, because trade weights are used to construct the country-

[2] See Appendix C for a description of the aggregation procedure for the euro area economies.

[3] In Brazil, China, Chile, Indonesia, Mexico, Peru, Singapore and Turkey, we exclude the domestic long-term interest rate and real equity prices from the respective country-specific VARX* models. In India, Malaysia and the Philippines, we exclude the domestic long-term interest rate. Equity prices are excluded in Switzerland and Thailand, and equity prices and short- and long-term interest rates are excluded from the individual VARX* models for Argentina and Saudi Arabia.

[4] Although oil is included as an endogenous variable only in the U.S. VARX* model, other countries can still affect world oil prices through their impact on the United States. For example, a one standard deviation shock to Chinese GDP (1 per cent) results in a 5 per cent decline in world oil prices.

[5] This assumption is tested and the results are consistent with our priors.

specific foreign variables, the effect of shocks to one country on another country in our GVAR model will depend on the size and pattern of their bilateral trade.

Since the Canadian response to foreign shocks, particularly those originating in the United States, is the focus of this study, it is useful to consider which countries have the largest weights in Canadian trade. Shocks originating in the countries accounting for the largest share of Canada's country-specific foreign variables will have the largest effect on the Canadian economy. Table 2 shows the 2008 trade weights for Canada and its six largest trading partners. Combined, these countries account for over 90 per cent of Canadian trade. Canada's largest trading partner is clearly the United States, representing 73 per cent of Canadian trade. The euro area and China each represent about 6 per cent of Canada's trade, while Japan, the United Kingdom and Mexico each represent about 3 per cent of Canada's trade. Given these trade weights, movements in the Canadian-specific foreign variables will be dominated by movements in the U.S. economy. Note also that the United States accounts for a significant share of the country-specific foreign variables of Canada's other major trading partners. Therefore, shocks to the U.S. economy may also be transmitted to Canada through second-round effects as they affect Canada's other trading partners.

Given that we use time-varying trade weights, we can also consider the evolution of the Canadian trade weights with its major trading partners. In Figure 1, a few dynamics of the Canadian trade weights are noteworthy. First, it appears that Canadian trade with other North American economies increased after the North American Free Trade Agreement was signed in 1994. Second, China's accession into the World Trade Organization in 2001 appears to have increased Canadian trade with China. Third, the recent U.S. recession has negatively affected the share of Canadian trade associated with the United States. These changing dynamics of Canadian trade captured by our time-varying trade weights may have important effects on the impact of foreign shocks on the Canadian economy that would not be captured by fixed trade weights.

Although the GVAR model can be estimated using either stationary or integrated variables, we include variables integrated of order one (1(1)) in our GVAR model to distinguish between short- and long-run dynamics. The order of integration of the variables is assessed using augmented Dickey-Fuller (ADF) statistics for the log-levels and first and second differences of all series. Results of the ADF tests on the domestic and country-specific foreign variables in the GVAR model are available from the authors upon request. In general, both domestic and country-specific foreign real output, inflation, real interest rates (both short and long term), real exchanges rates and real equity prices are found to be 1(1) for all countries. Oil prices are also found to be 1(1). Thus, we find that all variables included in our GVAR model are 1(1).

3 Results

In this section, we turn to the core of our analysis: studying the transmission of U.S. shocks to Canada. First, we examine the contemporaneous effect of the country-specific foreign variables on their domestic counterparts, and then the dynamic responses of the Canadian economy to U.S. shocks using generalized impulse-response functions. Finally, we further examine the linkages between the Canadian and U.S. economies by considering the forecast error variance decomposition of each Canadian variable included in the GVAR model.

3.1 Estimation results

Table 3 shows the contemporaneous effects of the country-specific foreign variables on their domestic counterparts, which can also be interpreted as the impact elasticity between domestic and foreign variables. We show only results for Canada and its six largest trading partners, since these countries play the largest role in our analysis of the transmission of U.S. shocks to Canada. Full results can be obtained from the authors. The results indicate that real linkages between countries are generally important. In particular, in most countries the contemporaneous effect of foreign real GDP on domestic real GDP is positive and significant. Canada, China and Japan are key exceptions; contemporaneous effects in these countries are not statistically significant. In China's case, this could reflect the relatively closed nature of the Chinese economy until recently; however, it is surprising that foreign GDP is not found to have a contemporaneous effect on Japanese GDP given the open nature of its economy and its strong global trade ties. Most interesting for this study is that the contemporaneous response of real GDP in Canada to developments in its foreign counterpart is not significant. This result is particularly surprising given the relatively strong weight of trade in Canadian GDP. Nevertheless, the contemporaneous effect of foreign GDP on Canadian GDP is positive, with an impact elasticity of 0.24.[6]

There are also positive linkages between financial variables across countries. Concerning short-term interest rates, linkages are the most important for Canada and the euro area. If one considers that developments in the short-term interest rate reflect, to a degree, movements in monetary policy, then it is not surprising that the Japanese and Chinese short-term interest rates are less tied to their foreign counterparts. In recent years, the policy rate in Japan has remained at the effective lower bound as authorities continue to combat the liquidity trap that has plagued the Japanese economy since the early 1990s. Likewise, the short-term interest rate in China may move less closely with those of its foreign counterparts, since the central bank must take into account the fact that changes in the interest rate will have implications for its managed exchange rate regime. In addition, studies have shown that the nominal interest rate is one of several tools employed by the People's Bank of China when conducting monetary policy (e.g., Goodfriend and Prasad 2006; Burdekin and Siklos 2008). Thus, it may move less with developments in the real economy than the short-term interest rates in other economies. Canadian equity prices are also found to respond by more than one-for-one to a shock to foreign equity prices, likely because of the large proportion of their market capitalization accounted for by oil and gas firms. Overall, these results suggest that external financial developments matter for domestic financial conditions. More specifically, contemporaneous financial linkages between Canada and its major trading partners appear to be strong.

[6] **The contemporaneous effect of developments in foreign inflation on domestic inflation appears to be somewhat more important in smaller economies relative to larger economies. In Canada, the United Kingdom and Mexico the contemporaneous effect of foreign inflation on domestic inflation is positive and significant, while it is insignificant in the United States, the euro area and China. While this finding may be related to the relative sizes of these economies, it may also reflect that developments in foreign inflation are transmitted more slowly to the latter economies relative to the former. Notably, developments in foreign inflation are transmitted quite rapidly to Canada, with an impact elasticity of 0.77.**

3.2 Generalized impulse-response functions

To study the effect of U.S. shocks on Canada we use generalized impulse-response functions (GIRFs) as developed by Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998).[7] GIRFs are an alternative to orthogonalized impulse-response functions (OIRFs), typically used when evaluating the dynamic properties of structural models. In contrast with OIRFs, GIRFs do not require identification of the structural shocks to the GVAR model. Accordingly, GIRFs cannot explain how, for example, inflation reacts to a monetary policy shock. The shocks obtained with this approach are a combination of different structural shocks, making their interpretation difficult. However, the GVAR approach provides a general tool for describing the dynamics in a time-series model by mapping out the reaction in, for example, inflation to a one standard deviation shock to the residual in the interest rate equation. While the OIRF approach requires the impulse responses to be computed with respect to orthogonalized shocks, the GIRF approach considers shocks to individual errors and integrates out the effects of the other shocks using the observed distribution of all the shocks without any orthogonalization. Put simply, GIRFs identify the shocks as intercept shifts in the various equations using the historical variance-covariance matrix of the errors.

In the context of our GVAR model, GIRFs offer several interesting features. First, identification of all the structural shocks (the total number of endogenous variables is 133) in the GVAR model would be quite difficult. Second, GIRFs are invariant to the ordering of the countries and variables in the GVAR model. While economic theory is often used to determine the ordering of variables within a system for a particular country, it is not clear how one would decide on the ordering of countries within a GVAR model. Third, in the absence of a priori beliefs on ordering of the variables or the countries, the GIRF approach can provide useful information about the impact of changes in macroeconomic variables on other variables. Although the GIRF approach is silent as to the reasons behind these variable changes, it can be quite informative about the dynamics of the transmission of shocks. In section 4.1 we complete the sensitivity analysis around our use of GIRFs.

We examine the response of the Canadian economy to three U.S. shocks in our baseline model:

1. A one standard error negative shock to U.S. real GDP.
2. A one standard error positive shock to the U.S. short-term interest rate.
3. A one standard error negative shock to U.S. equity prices.

Thus, we consider how one shock to the U.S. real economy and two shocks to U.S. financial conditions affect the Canadian economy in our baseline model. Figures 2 to 7 present the GIRFs showing the responses of U.S. and Canadian variables to the shocks.

[7] See Garratt et al. (2006, Chapters 6 and 10) for a description of GIRFs applied to VARX* and cointegrating VAR models.

3.2.1 A one standard error negative shock to U.S. real GDP

A one standard error negative shock to U.S. real GDP is equivalent to a decrease in real GDP of about 0.6 per cent in one quarter.[8] Figure 2 also shows the 90 per cent confidence intervals for GIRFs.[9] In the U.S. economy, the decrease in output is accompanied by a decrease in inflation. Moreover, a negative shock to U.S. output is typically associated with statistically significant declines in short- and long-term interest rates, which fall by about 80 and 50 basis points, respectively.[10] Finally, U.S. equity prices fall with U.S. output; however, the decrease is relatively small and statistically insignificant.

As expected, the shock to U.S. real GDP is transmitted quickly to Canada. Canadian output decreases immediately following the negative shock to U.S. output. In fact, the decrease in Canadian output is only slightly smaller than the response of U.S. output to the shock. This strong response is likely partly associated with the strong trade relationship between the two economies. Despite the fall in output, the decline in Canadian inflation is relatively small, perhaps due to the fact that Canadian interest rates fall following the decrease in U.S. output. The limited decline in Canadian inflation could also be associated with well-anchored inflation expectations in Canada. The Canadian short- and long-term interest rates fall significantly, with the declines similar to those observed in the United States. Canadian equity prices also decline following the decrease in U.S. output, decreasing by about 2 per cent. This decline is larger than that observed in the United States. The larger decline iri Canadian equity prices may be associated with the fact that world oil prices fall by about 9 per cent. For Canada, this decline in oil prices would likely have an important effect on Canadian equity prices, given the large proportion of their market capitalization accounted for by oil and gas firms. Overall, these results suggest that shocks to the U.S. real economy are quickly transmitted to the Canadian economy and can have important implications for both real and financial variables in Canada.

We can also assess the importance of second-round effects in the transmission of the shock to U.S. GDP to Canada. To do so, we adjust the Canadian-specific foreign variables in the GVAR model such that the U.S. economy has a weight of one. In this set-up, U.S. shocks can affect Canada only directly. We then re-estimate the GVAR model and resimulate the shock to U.S. GDP.[11] Under this framework, we attribute the impact on the Canadian economy from the U.S. GDP shock to the direct effect of the U.S. shock on Canada. The importance of second-round effects on Canada as the shock affects other countries and is then transmitted to Canada via trade and financial linkages with those countries can be gauged by the difference between the initial results and the results with the Canadian-specific foreign variables equal to the U.S. variables. Our results, shown in Figure 3, suggest that second-round effects are important for the Canadian economy following a shock to U.S. GDP; for instance, about 25 per cent of the response of Canadian GDP can be attributed to second-round effects. These

[8] The standard errors of all the U.S. and Canadian shocks in the GVAR model are reported in Table 4.

[9] We show the bootstrap means and confidence bands computed using the sieve bootstrap procedure for simulation of the GVAR model as a whole developed by Dees et al. (2007).

[10] On an annualized basis, the short- and long-term interest rates fall by about 20 and 13 basis points, respectively. All figures are on an annualized basis.

11 Note that the U.S. responses to the shock are very similar to those in the initial estimation. This is expected, since the only change in the U.S. response would be due to the different Canadian responses to the shock, which would affect the United States through the U.S. country-specific foreign variables.

effects are less important for Canadian financial variables following shocks to U.S. output: they play only a small role in the response of Canadian equity markets and long-term interest rates. However, about one-third of the response of the Canadian short-term interest rate is associated with second-round effects.

3.2.2 A one standard error positive shock to the U.S. short-term interest rate

Consider next the effect of a one standard error positive shock to the U.S. short-term interest rate (Figure 4). This shock is equivalent to an increase of 80 basis points in the short-term interest rate in one quarter.[12,13] Since this shock is non-structural, it cannot be considered a monetary policy shock. U.S. inflation rises in response to the increase in interest rates. In section 4.1, we examine a structural interest rate shock - which can be considered a monetary policy response - and assess whether this counterintuitive response is due to the fact that the non-structural shock examined is not a pure monetary policy shock. Unexpectedly, U.S. output also increases slightly following the increase in interest rates; however, this increase is quite temporary. The increase in the short-term interest rate is reflected in other financial variables, with the long-term interest rate rising by about 36 basis points. Moreover, U.S. equity prices decline slightly, although the decline is not statistically significant.

This tightening of U.S. financial conditions also tends to lead to a tightening of financial conditions in Canada. There are statistically significant increases in short- and long-term Canadian interest rates, with both interest rates rising in line with their U.S. counterparts. Like U.S. equity prices, Canadian equity prices are fairly stable following the increase in the U.S. short-term interest rate. However, in contrast to our expectations, this tightening of financial conditions leads to a small, temporary initial increase in Canadian output. This response is likely related to the fact that the non-structural interest rate shock may be contaminated by other shocks. In section 4.1, we will investigate whether this response is also observed when we identify the structural shocks to the U.S. economy. Finally, second-round effects on Canada are less important when considering the transmission of a shock to the U.S. short-term interest rate to Canada than when considering a shock to U.S. GDP (Figure 5). Nevertheless, second-round effects play an important role in the response of Canadian GDP to the U.S. interest rate shock, in that they offset part of the counterintuitive increase in Canadian GDP following the increase in short-term interest rates. This confirms that the increase in Canadian GDP is mainly due to developments in the U.S. economy. Second-round effects also explain some of the movement in Canadian interest rates, accounting for about one-third of the response in the short-term interest rate.

3.2.3 A one standard error negative shock to U.S. equity prices

Strong co-movement between U.S. and Canadian financial conditions is also evident when considering a negative shock to U.S. equity prices (Figure 6). Consider first the domestic economy. The one standard error negative shock to U.S. equity prices represents a 5.8 per cent decrease in U.S. equity prices in a given quarter. As a result, there is a statistically significant decrease in real output, which falls by about 0.6 per cent, a'nd in inflation, which decreases by just under 0.2 per cent. Moreover, there are statistically significant decreases in

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[12] On an annual basis, this is an increase in the short-term interest rate of 20 basis points. All figures are in annualized terms.

[13] We also consider the dynamics of the Canadian economy following a shock to the U.S. long-term interest rate, which are comparable to the responses following a shock to the U.S. short-term interest rate. Results are available from the authors.

both short- and long-term interest rates. The short-term interest rate decreases by about 120 basis points, while the long-term interest rate falls by about half the decline in the short-term interest rate.

The decrease in U.S. equity prices is also reflected in Canadian equity markets, highlighting the strong co-movement between Canadian and U.S. equity markets. As observed following some of the previous shocks, the decrease in Canadian equity prices is stronger than the decrease in U.S. equity prices. As with the shock to U.S. GDP, this larger response may be attributed to the important relationship between Canadian equity markets and oil prices. Oil prices are about 10 per cent lower a year after the shock to U.S. equity prices. Given the importance of the natural resources sector for Canada, this fall in oil prices likely explains some of the additional volatility in Canadian equity markets. Moreover, as with U.S. output, Canadian output falls. Overall, the decrease in Canadian output is of about the same magnitude as that observed in the United States, although it is more persistent. Not surprisingly, we also observe a decrease in Canadian inflation following the negative shock to equity prices. Short- and long-term interest rates decrease. The short-term interest rate falls by about 80 basis points and the long-term interest rate falls by about 40 basis points. Finally, the Canadian dollar depreciates by about 3 per cent in response to the decrease in U.S. equity prices. As in Canada, the other regions of the world are highly negatively affected by the negative shock to U.S. equity prices. In fact, the fall in output in the other regions is actually stronger than it is in the United States. Therefore, the second-round effects on Canada in the case of the negative shock to U.S. equity prices are quite strong (Figure 7).

3.3 Generalized forecast error variance decomposition

We further investigate the linkages between the Canadian and U.S. economies by examining the forecast error variance decomposition of Canadian GDP, the Canadian short-term interest rate, and Canadian real equity prices (Tables 5-7).[14] The variance decomposition provides the percentage of the s-step forecast error variance of the Canadian variables due to shocks to all other variables in the model. We focus our analysis specifically on the proportion of the forecast error variance of Canadian variables that can be attributed to domestic variables and U.S. variables. These results provide additional intuition on the transmission channels through which U.S. shocks affect economic activity in Canada.

In Table 5 we can see that Canadian variables explain most of the historical shock to Canadian GDP. Canadian GDP itself explains most of the forecast error variance; however, the share decreases over time. Canadian equity prices are also an important determinant of the forecast error variance of Canadian GDP, suggesting that there are strong real-financial linkages within the Canadian economy. Moreover, a large share of the forecast error variance of Canadian GDP is explained by U.S. variables. After one year, U.S. variables explain about 30 per cent of the forecast error variance of Canadian GDP, compared to the 53 per cent explained by Canadian variables. The relative contributions of the U.S. variables after one year are, in decreasing order, 15 per cent for real equity prices, 9 per cent for real GDP, 3 per cent for the long-term interest rate, and 2 per cent for the short-term interest rate. Interestingly, U.S. financial variables explain a larger share of the forecast error variance of Canadian GDP than movements in U.S. GDP, suggesting that developments in U.S. financial variables have important effects on real activity in Canada.

[14] Note that, in practice, the contributions do not sum to one, due to non-zero covariance between the shocks to the variables in the model. However, we rescale the contributions in Tables 5-7 such that they sum to one. This facilitates the interpretation of the results.

The forecast error variance decomposition of the Canadian short-term interest rate suggests that financial linkages between the Canadian and U.S. economies are quite strong (Table 6). U.S. variables, particularly U.S. financial variables, explain a large share of the forecast error variance. On impact, the Canadian short-term interest rate explains most of the forecast error variance of its historical shock (59 per cent); however, its contribution falls over time. The U.S. short-term interest rate also explains a large share of the forecast error variance of the Canadian short-term interest rate. The contribution of U.S. equity prices is also quite strong, explaining about 8 per cent of the forecast error variance after one year, with its contribution increasing over the long-term. Similar patterns are evident when considering the forecast error variance decomposition of the Canadian long-term interest rate (results are available from the authors).

Financial linkages between the Canadian and U.S. economies are also evident when examining the forecast error variance decomposition of Canadian equity prices (Table 7). It is U.S. variables, particularly U.S. financial variables, that explain the majority of the forecast error variance of Canadian equity prices (64 per cent versus 11 per cent after one year). The contribution of U.S. equity prices is the largest, explaining 60 per cent of the forecast error variance after one year. These results suggest that developments in Canadian equity prices are closely linked to developments in U.S. equity prices. Finally, the importance of the oil sector for Canadian equity prices is evident when considering the forecast error variance of Canadian equity prices. Oil prices are the third most important variable in explaining the forecast error variance of Canadian equity prices (following U.S. and Canadian equity prices); they explain about 8 per cent of the forecast error variance in the long term.

4 Sensitivity Analysis

In this section, we complete several sensitivity analyses around our findings described in section 3. First, we examine whether our results would differ if we had examined the structural shocks to the U.S. economy and the associated structural impulse-response functions (SIRFS). Second, we estimate a version of the GVAR model that includes credit and examine the transmission of shocks to U.S. credit to Canada. Third, we evaluate the importance of our choice of trade weights for the weighting scheme used to construct the country-specific foreign variables. While trade weights provide a convenient way to measure the degree of interlinkages between countries, they may not be the ideal measure when assessing financial linkages between countries.

4.1 Structural identification of U.S. shocks

In this section, we identify the structural shocks to the U.S. variables and assess whether these shocks and their transmission to Canada are different than observed under the GIRFs. Given that we are interested only in assessing the transmission of U.S. shocks to Canada, we identify only the U.S. shocks.

In order to identify the structural shocks to the U.S. economy, we order the United States first and Canada second in the country ordering.[15] Moreover, we must identify an order for the variables included in the GVAR. We order the variables based on their relative exogeneity at time t; that is, according to the perceived degree to which they respond to movements in other variables. For the United States, our ordering is: output, inflation, oil

[15] Since we order the United States first, these structural shocks could also reflect a common global element, rather than simply a U.S. shock.

prices, the short-term interest rate, the long-term interest rate and equity prices. Therefore, as is typical in the literature (e.g., Dees et al. 2007; Beaton, Lalonde and Luu 2009), financial variables are ordered after the other variables in the model, which assumes that financial variables do not affect output or inflation at time t. In our view, this is a reasonable assumption given that financial variables should affect output with lags. Sensitivity analysis conducted around the ordering of the financial variables suggests that our results are robust to the ordering of the variables included in the model. Using our chosen ordering, we are then able to consider the structural shocks to the GVAR model using the methodology outlined in Dees et al. (2007).

We then re-estimate our GVAR model and re-examine the transmission of the same four U.S. shocks to Canada when the shocks are structurally identified. Results from the negative shocks to U.S. GDP and equity prices are qualitatively and quantitatively very similar to the GIRFs examined in section 3. In contrast, the structural identification of the U.S. interest rate shocks leads to a larger difference in the dynamics of both the U.S. and Canadian economies. In particular, the counterintuitive responses of inflation and output following the U.S. interest rate shocks shown in Figure 4 are partially resolved when the shocks are structurally identified.

Figure 8 shows the results of the impulse-response functions describing the behaviour of the U.S. and Canadian economies following the structurally identified one standard deviation shock to the U.S. short-term interest rate. With the shock to the U.S. short-term interest rate now structurally identified (given that we impose the correct restrictions), it can be interpreted as a shock to U.S. monetary policy. The monetary policy shock is a bit smaller than the shock to the U.S. short-term interest rate described in section 3. Moreover, the counterintuitive increase in U.S. GDP following the positive monetary policy shock observed in the GIRFs, while still present, persists for only two quarters before GDP begins to fall, versus the six quarters observed in the GIRFs. In addition, although inflation responds positively to the interest rate shock, the increase is not statistically significant and is smaller and less persistent than observed under the GIRFs. The responses of the other U.S. variables are similar to those observed previously in the GIRFs.

Overall, the response of the Canadian economy to a tightening of U.S. monetary policy is more muted when the U.S. monetary policy shock is structurally identified. Only Canadian interest rates respond significantly to the rise in the U.S. short-term interest rate. Absent a structural model, it is difficult to interpret this result; however, it may suggest that U.S. interest rate shocks are transmitted mainly to Canada via financial channels. The dynamics of the other variables in both countries are very similar to those in the GIRFs in section 3.

4.2 The role of credit

While we include several measures reflective of the price of credit in our baseline model, we do not include a variable measuring the quantity of credit. Over the recent financial crisis, however, we observed large declines in the quantity of credit in many countries. It is possible that declines in U.S. credit, in particular, were partially responsible for the Canadian recession that coincided with the global financial crisis. To examine the importance of shocks to the quantity of credit in the United States for Canada, we replace long-term interest rates in our baseline model with the stock of credit and re-estimate our model.[16] Overall, the U.S. and Canadian responses to

[16] **Although it would be ideal to include credit and long-term interest rates in the model, we decided to omit long-term interest rates in order to conserve degrees of freedom.**

other types of U.S. shocks are relatively unchanged by the addition of credit to the model. In this sensitivity analysis, we limit our discussion to the transmission of a shock to U.S. credit across the two economies of interest. A one standard error negative shock to credit (Figure 9), or a decrease of about 1 per cent in U.S. credit, has an important effect on the U.S. economy. Output declines significantly following the decline in credit and the short-term interest rate falls. There is little movement in any of the other U.S. variables included in the model. This suggests that while developments in credit can have important implications for the real economy, they are not necessarily translated into movements in other financial variables, such as equity prices.

There are statistically significant declines in Canadian credit and output following the decrease in U.S. credit. Moreover, unlike in the United States, financial variables in Canada respond to the fall in U.S. credit. In particular, Canadian equity prices decline following the decrease in U.S. credit. This may be associated with the fall in oil prices, which decline by about 8 per cent. Overall, the responses of both the U.S. and Canadian economies to the decrease in U.S. credit are very similar to those observed in response to a loan supply shock in the Bank of Canada's Global Economy Model (the BoC-GEM-FIN, de Resende et al. forthcoming). These results suggest that a fall in U.S. bank credit may have important implications for the Canadian economy. This is perhaps not surprising given that Canada obtains approximately 44 per cent of its bank-based credit from foreign sources, with about 47 per cent originating in the United States.[17] Taken as a whole, these results suggest that the transmission of financial shocks from the United States to Canada also occurs through movements in the quantity of credit, in addition to through movements in the price of credit and asset prices.

4.3 Financial weights

While the time-varying trade weights in the preceding analysis capture trade linkages between countries, our focus is on the transmission of financial shocks across countries; therefore, financial weights, which may better reflect the degree of financial interaction between countries, may be more suitable for our analysis. Thus, in this section we consider an alternative weighting scheme in which we use financial weights to derive the country-specific foreign variables. Financial weights are also used by Galesi and Sgherri (2009) in their study of financial spillovers across Europe.

The financial weights are constructed using data on consolidated foreign claims of banks on individual countries by nationality of reporting banks from the Bank for International Settlements' (BIS) international banking statistics. These data provide information on the size of linkages between the banking sectors of different countries. Moreover, they provide information on the distribution of each country's financial exposures. Further information on the construction of the weights is provided in Appendix C. Because of data limitations, the weights are fixed, calculated using average claims over 2006Ql-2007Q4.[18]

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[17] Source: Bank for International Settlements' international banking statistics.

[18] Currently, central banks in 30 countries report their aggregate consolidated data to the BIS. Therefore, some countries in our dataset are not covered by the BIS database. Nevertheless, the missing data represent a small share of total loans flows, since they are for smaller countries. For these countries, we impose a weight of zero in the construction of the country-specific foreign variables. We expect that this assumption has only a small effect on our results, since our focus is on the transmission of U.S. financial shocks to Canada. One exception may be China, which is excluded from the BIS dataset. However, while China is an important trading partner, it is much less important when considering financial flows given the relatively closed nature of its financial markets.

Table 8 shows the financial weights for Canada and the main countries on which Canada relies for foreign financing. These countries are also the same countries with which Canada has the most important trading relationships. Combined, they account for just fewer than 90 per cent of financial claims on Canada. Compared to the trade relationships discussed earlier, Canada is much less reliant on the United States financially. While the weight of Canadian trade completed with the United States in Table 2 is close to 73 per cent, only 47 per cent of foreign loans to Canadians are accounted for by the United States. This lower share reduces the importance of the United States in Canada's country-specific foreign variables. This reduction is entirely offset by a rise in the importance of the United Kingdom and the euro area, each of which represents close to 20 per cent of foreign loans to Canada. This finding is not surprising given the large financial centres in the United Kingdom and the euro area. Thus, not only should shocks to these economies have a larger direct effect on Canada under this alternative weighting scheme, but also the indirect effect of U.S. shocks, through their effect on these economies, may play a larger role.

Using these financial weights we re-estimate our GVAR model and re-examine the response of the Canadian economy to the three U.S. shocks examined in section 3. Results are shown in Figures 10 and 11.

Overall, we find that the domestic U.S. responses to the shocks are fairly similar relative to what is observed in the baseline model. This is perhaps not surprising given that it is only the change in the U.S. country-specific foreign variables that would alter the dynamics of the U.S. response. Since the United States is a relatively closed economy, we would not expect small changes in these country-specific foreign variables to have a large effect on the dynamics of the U.S. economy following a shock. We also observe that the Canadian responses to U.S. shocks under this new weighting scheme are relatively unchanged.

A few factors are at play. First, given the smaller weights on the U.S. variables under this weighting scheme and the fairly similar dynamics in the U.S. economy following the U.S. shocks, the overall direct effect of the U.S. shocks on Canada is smaller than observed under the time-varying trade weights. Second, this smaller direct effect is roughly completely offset by a larger indirect effect of the U.S. shocks on Canada. This could, for example, be associated with the much stronger importance of the United Kingdom under financial weights rather than trade weights. Under trade weights, the U.S. variables have a weight of roughly 15 per cent of the U.K.'s country-specific foreign variables, while under financial weights they have a 31 per cent weight. Thus, a larger weight would be a larger effect of the United States on the United Kingdom, for example. Moreover, the United Kingdom's importance in Canadian-specific foreign variables is also much larger under financial weights than under trade weights {21 per cent versus 3 per cent). Similar dynamics are also at play with respect to the euro area. These two facts suggest that the secondary effect of the U.S. shocks, through perhaps the response of the United Kingdom, is offsetting the smaller direct effect of the U.S. shocks on Canada, such that the overall response of the Canadian economy to the U.S. shocks is relatively unchanged compared to that observed under time-varying trade weights.

5 Conclusions

As the recent global financial crisis has highlighted, financial shocks can be quickly transmitted across countries, with important implications for both financial conditions and real economic activity. In this paper, we investigate financial spillovers from the United States to Canada within the framework of a GVAR model. Using this framework, we show that contemporaneous financial linkages between Canada and its major trading partners are strong. The impact elasticities between Canadian financial variables and their foreign counterparts are positive and significant, suggesting that shocks to financial variables in other countries are transmitted relatively quickly to financial conditions in Canada. Canadian equity prices tend to respond by more than the initial shock to their foreign counterpart, which may be attributed to the important relationship between Canadian equity markets and oil prices. The Canadian short-term interest rate responds by less to financial conditions in other countries than other Canadian financial variables, perhaps reflecting the independence of Canadian monetary policy.

Using the GVAR model, we also investigate the effect of shocks to real activity and financial conditions in the United States on Canada. These results suggest that both shocks to U.S. real activity and to U.S. financial conditions can have important implications for financial conditions and real activity in Canada. Movements in U.S. financial conditions, in particular, tend to spill over to Canadian financial conditions. Following a negative shock to U.S. equity prices, Canadian equity prices tend to decline and the amplitude of the decline tends to be larger than the initial shock to U.S. equity prices. Moreover, negative shocks to U.S. equity prices tend to lead to lower interest rates in both Canada and the United States. We also investigate the transmission of shocks to the stock of U.S. credit to Canada and find that shocks to U.S. credit also have important implications for financial conditions in Canada. This result suggests that financial shocks are transmitted from the United States to Canada through the quantity of credit as well as through movements in the price of credit and asset prices. Finally, we study the importance of second-round effects in the transmission of U.S. shocks to Canada, since U.S. shocks affect other economies and therefore Canada through trade and financial linkages. We find evidence of important second-round effects following shocks to U.S. output and equity prices.

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Table 1: Countries in the GVAR Model

Canada	Austria	Turkey
U.S.	Belgium	U.K.
Japan	Finland	Argentina
China	France	Australia
India	Germany	Brazil
Indonesia	Italy	Chile
Korea	Netherlands	Mexico
Malaysia	Peru	New Zealand
Philippines	Spain	Norway
Singapore	Sweden	South Africa
Thailand	Switzerland	Saudi Arabia

Table 2: 2008 Trade Weights in the GVAR Model

Country/Region	Canada	United States	Euro area	China	Japan	Mexico	United Kingdom
Canada	0.000	0.224	0.017	0.020	0.020	0.027	0.021
United States	0.727	0.000	0.181	0.217	0.223	0.708	0.145
Euro area	0.056	0.153	0.000	0.174	0.116	0.072	0.532
China	0.058	0.149	0.118	0.000	0.223	0.057	0.053
Japan	0.032	0.087	0.054	0.175	0.000	0.037	0.031
United Kingdom	0.027	0.042	0.208	0.026	0.024	0.007	0.000
Mexico	0.027	0.136	0.015	0.010	0.012	0.000	0.004
Other	0.073	0.433	0.424	0.398	0.402	0.119	0.237

Notes: Trade weights, calculated as the share of exports and imports in total trade, are shown for 2008. The time-varying trade weights shown are calculated as a 3-year moving average of each year's trade weights. Trade shares in rows, rather than columns, sum to one. Trade weights are displayed for Canada's six largest trading partners. The complete time-varying trade matrix used in the GVAR is available upon request from the authors.

Source: Direction of Trade Statistics, International Monetary Fund

Table 3: Contemporaneous Effects of Foreign Variables on their Domestic Counterparts

		y	*n*	*isr*	hr	*q*
Canada	**Coefficient**	0.241	0.770***	0.274**	1.031 ***	1.044***
	Standard error	0.248	0.073	0.127	0.073	0.056
	t-ratio	0.973	10.533	2.164	14.201	18.542
U.S.	**Coefficient**	0.380***	0.004	-	-	-
	Standard error	0.099	0.044	-	-	-
	t-ratio	3.850	0.089	-	-	-
Euro area	**Coefficient**	0.491 ***	-0.005	0.098***	0.633***	1.130***
	Standard error	0.137	0.022	0.015	0.088	0.069
	t-ratio	3.577	-0.238	6.297	7.166	16.403
China	**Coefficient**	-0.120	-0.014	0.026	-	-
	Standard error	0.077	0.040	0.036	-	-
	t-ratio	-1.557	-0.348	0.727	-	-
Japan	**Coefficient**	0.234	0.004	-0.003	0.530***	0.649***
	Standard error	0.182	0.047	0.032	0.087	0.104
	t-ratio	1.286	0.084	-0.100	6.090	6.255
U.K.	**Coefficient**	0.291 **	0.317**	0.145	0.812***	0.749***
	Standard error	0.129	0.153	0.123	0.122	0.040
	t-ratio	2.250	2.069	1.181	6.663	18.947
Mexico	**Coefficient**	0.199	0.556***	-0.539	-	-
	Standard error	0.391	0.163	0.742	-	-
	t-ratio	0.509	3.404	-0.726	-	-

Notes:*,, and*** indicate statistical significance at the 1, 5, and 10 per cent levels, respectively. Standard errors shown are computed using White's heteroscedasticy-consistent methodology. Country-specific foreign variables for the short-term interest rate, the long-term interest rate and equity prices are not included in the U.S. model. Although country-specific foreign variables for the long-term interest rate and equity prices are included in the Chinese and Mexican models, due to data limitations there are no domestic counterparts.**

Table 4: Standard Errors in the GVAR Model

Country	Variable	Standard error
Canada	*y*	0.80
	n	0.49
	isr	0.19
	hr	0.12
	q	7.23
United States	*y*	0.55
	n	0.52
	isr	0.19
	hr	0.12
	q	5.84
	oil	13.49

Table 5: Generalized Forecast Error Variance Decomposition: Canadian GDP

Quarters	0	2	4	8	12	16	40
Canadian GDP	0.656	0.404	0.322	0.292	0.293	0.298	0.269
Canadian inflation	0.005	0.012	0.014	0.011	0.010	0.009	0.009
Canadian equity	0.034	0.102	0.154	0.193	0.200	0.202	0.205
Canadian ER	0.004	0.016	0.030	0.053	0.067	0.076	0.091
Canadian SIR	0.004	0.002	0.002	0.001	0.001	0.001	0.001
Canadian UR	0.000	0.011	0.010	0.010	0.013	0.014	0.017
U.S. GDP	0.010	0.095	0.085	0.053	0.036	0.027	0.011
U.S. inflation	0.041	0.010	0.005	0.003	0.001	0.001	0.001
U.S. equity	0.021	0.108	0.153	0.155	0.132	0.113	0.068
U.S. SIR	0.007	0.026	0.016	0.010	0.014	0.017	0.024
U.S. UR	0.009	0.037	0.032	0.018	0.011	0.009	0.003
Oil price	0.007	0.007	0.013	0.017	0.016	0.017	0.017
Other	0.203	0.169	0.165	0.184	0.205	0.216	0.284
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: ER is the exchange rate, SIR the short-term interest rate and LIR the long-term interest rate.

Table 6: Generalized Forecast Error Variance Decomposition: Canadian Short-Term Interest Rate

Quarters	0	2	4	8	12	16	40
Canadian GDP	0.004	0.007	0.006	0.004	0.004	0.004	0.004
Canadian inflation	0.018	0.019	0.022	0.021	0.021	0.021	0.021
Canadian equity	0.032	0.011	0.006	0.003	0.002	0.002	0.001
Canadian ER	0.008	0.002	0.001	0.001	0.001	0.001	0.001
Canadian SIR	0.586	0.242	0.184	0.153	0.146	0.144	0.137
Canadian UR	0.039	0.019	0.016	0.016	0.016	0.016	0.016
U.S. GDP	0.026	0.154	0.188	0.204	0.204	0.205	0.208
U.S. inflation	0.029	0.020	0.014	0.007	0.005	0.004	0.002
U.S. equity	0.003	0.034	0.081	0.131	0.152	0.161	0.182
U.S. SIR	0.054	0.239	0.240	0.229	0.222	0.221	0.216
U.S. UR	0.000	0.105	0.112	0.099	0.091	0.087	0.081
Oil prices	0.000	0.006	0.005	0.003	0.002	0.002	0.002
Other	0.201	0.140	0.125	0.129	0.134	0.134	0.130
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: ER is the exchange rate, SIR the short-term interest rate and LIR the long-term interest rate.

Table 7: Generalized Forecast Error Variance Decomposition: Canadian Equity Prices

Quarters	0	2	4	8	12	16	40
Canadian GDP	0.020	0.030	0.029	0.026	0.025	0.025	0.026
Canadian inflation	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Canadian equity	0.176	0.146	0.106	0.062	0.045	0.036	0.021
Canadian ER	0.000	0.006	0.007	0.004	0.003	0.003	0.002
Canadian SIR	0.005	0.002	0.003	0.004	0.004	0.005	0.005
Canadian UR	0.000	0.002	0.001	0.001	0.001	0.000	0.000
U.S. GDP	0.043	0.067	0.058	0.039	0.029	0.024	0.015
U.S. inflation	0.026	0.009	0.005	0.003	0.002	0.002	0.001
U.S. equity	0.569	0.577	0.600	0.616	0.611	0.607	0.605
U.S. SIR	0.006	0.008	0.007	0.004	0.003	0.003	0.002
U.S. UR	0.001	0.019	0.035	0.062	0.082	0.092	0.109
Oil prices	0.028	0.020	0.036	0.059	0.068	0.074	0.084
Other	0.125	0.113	0.112	0.120	0.127	0.128	0.130
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000

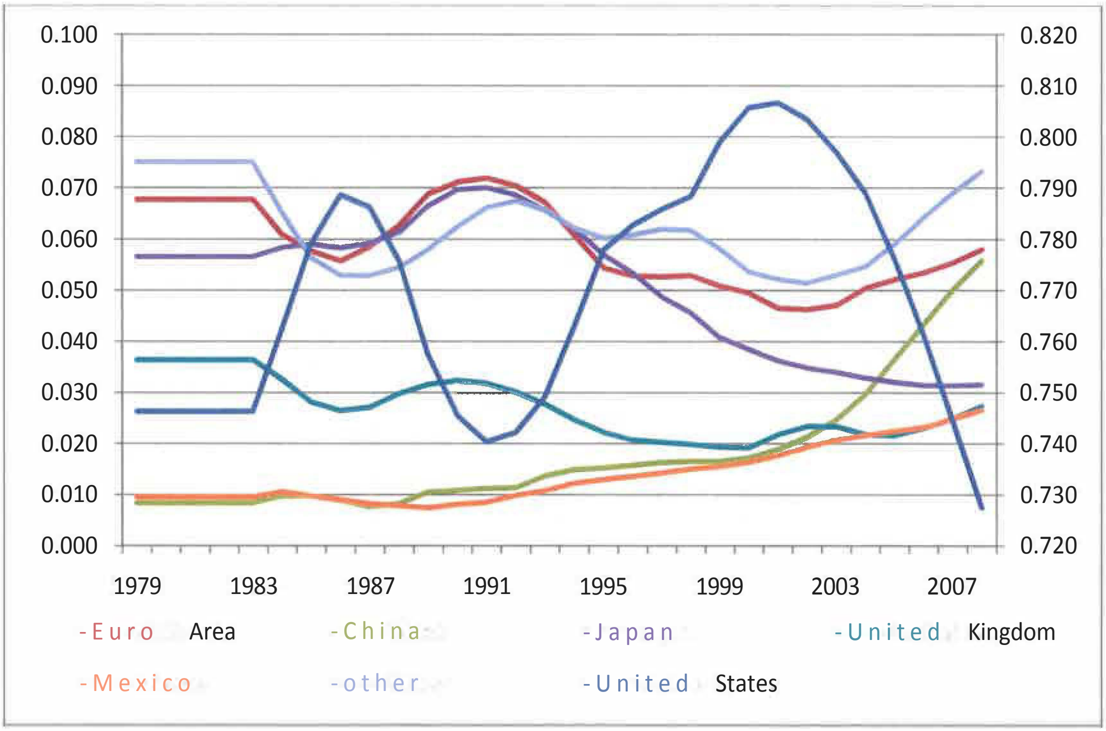
Note: ER is the exchange rate, SIR the short-term interest rate and UR the long-term interest rate.

Table 8: Financial Weights in the GVAR Model

Country/Region	Canada	United States	Euro area	Japan	United Kingdom	Mexico
Canada	0.000	0.026	0.015	0.027	0.020	0.065
United States	0.468	0.000	0.275	0.432	0.310	0.671
Euro area	0.173	0.397	0.000	0.283	0.424	0.181
Japan	0.014	0.048	0.042	0.000	0.037	0.039
United Kingdom	0.208	0.246	0.449	0.110	0.000	0.027
Mexico	0.015	0.024	0.011	0.003	0.005	0.000
Other	0.122	0.259	0.208	0.145	0.204	0.018

Notes: Financial weights in rows, rather than columns, sum to one. Financial weights are shown for Canada's six largest trading partners in order to compare with the trade weights in Table 2. The complete fixed financial weight matrix is available from the authors.
Source: International Locational Banking Statistics database, Bank for International Settlements

Figure 1: Time-Varying Canadian Trade Weights



Notes: The time-varying trade weights shown are calculated as a 3-year moving average of each year's trade weights. U.S. right axis, all other countries left axis.
Source: Direction of Trade Statistics, International Monetary Fund

Figure 2: A One Standard Error Negative Shock to U.S. Real Output

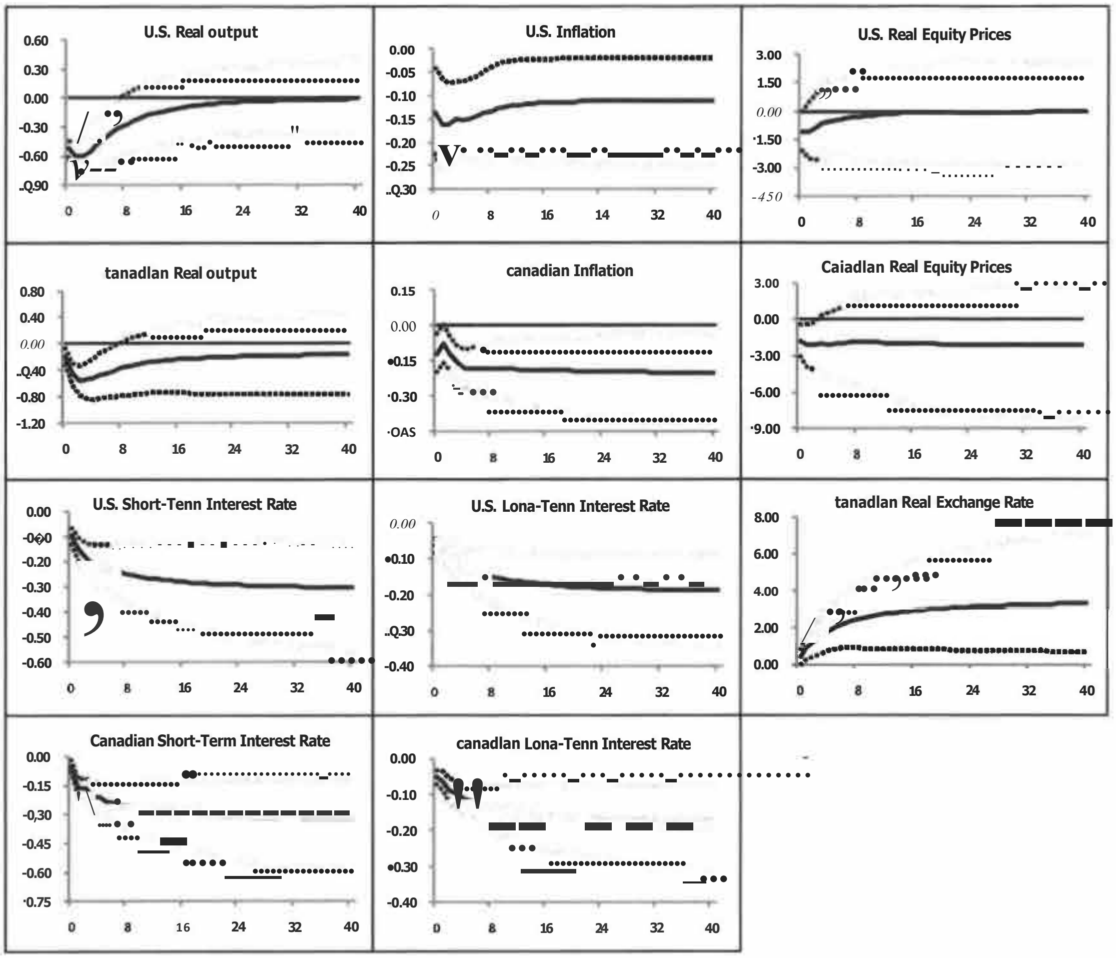


Figure 3: A One Standard Error Negative Shock to U.S. Real Output: Second-Round Effects (black= U.S. effect, blue= Total effect)

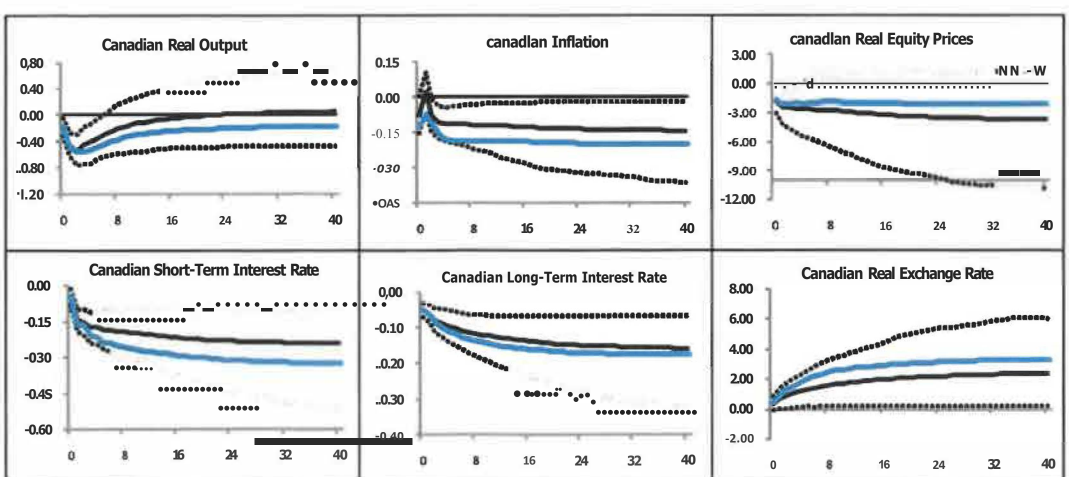


Figure 4: A One Standard Error Positive Shock to the U.S. Short-Term Interest Rate

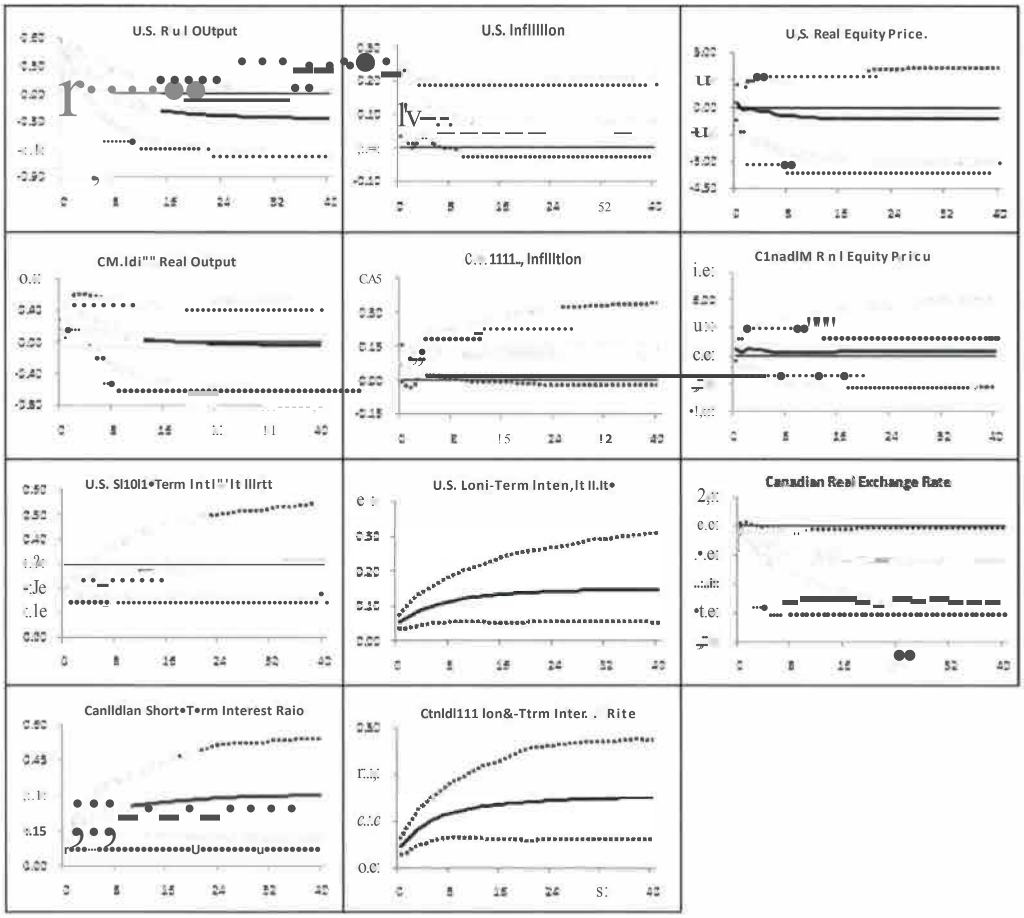


Figure 5: A One Standard Error Positive Shock to the U.S. Shon;-Term Interest Rate: Second-Round Effects (black = U.S. effect, blue = Total effect)

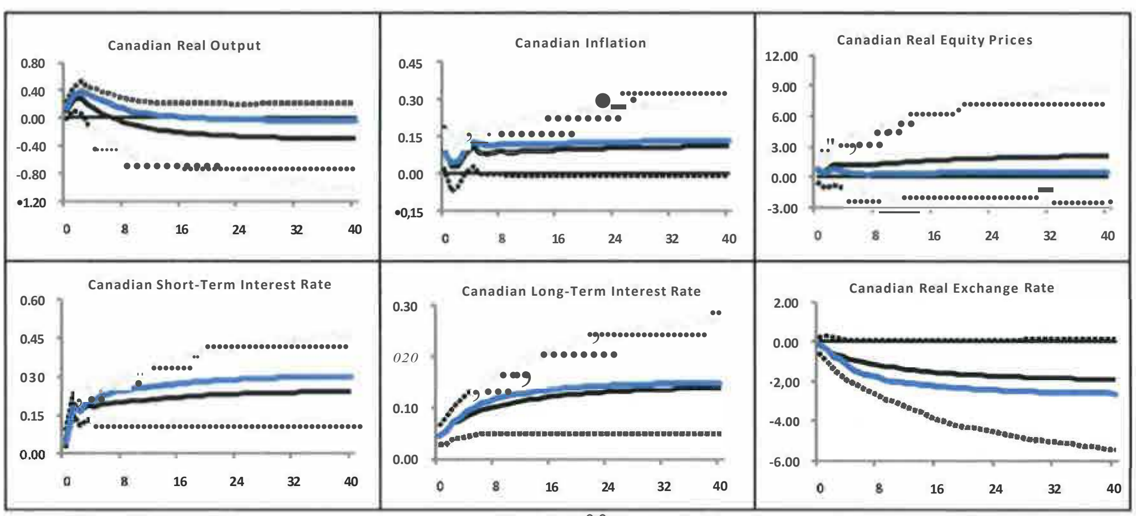


Figure 6: A One Standard Error Negative Shock to U.S. Equity Prices

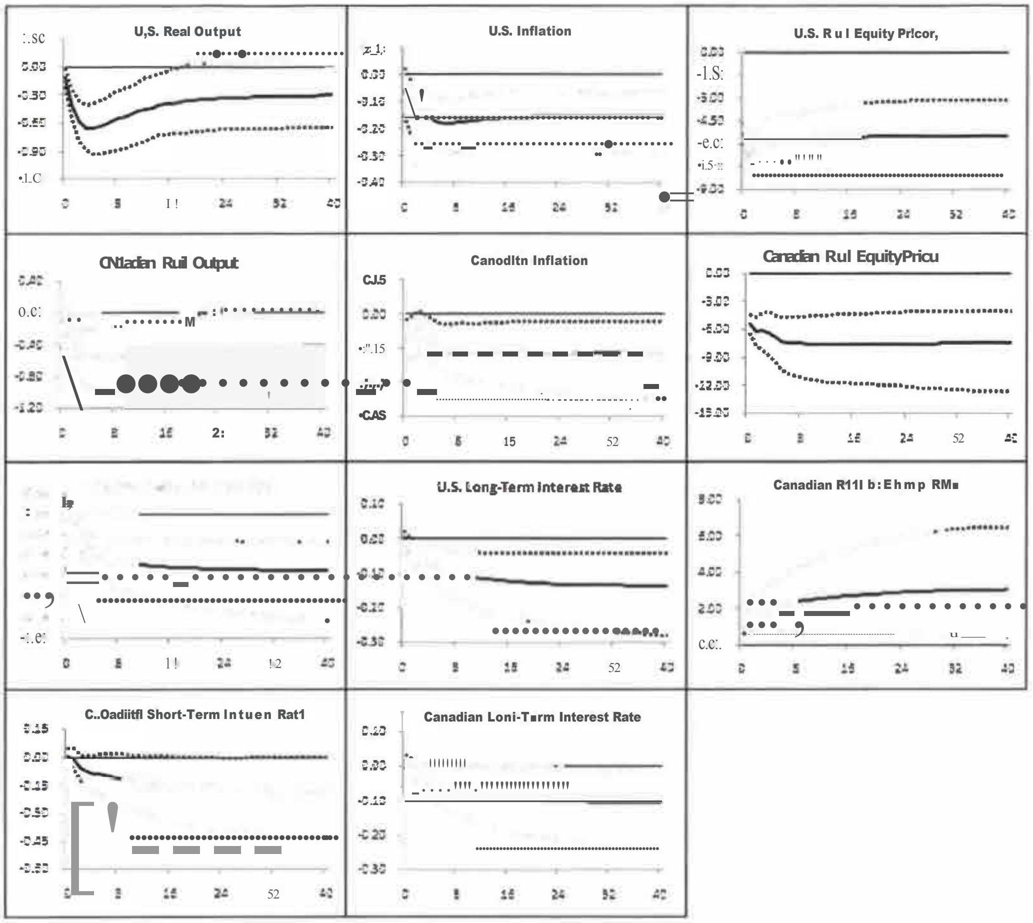


Figure 7: A One Standard Error Negative Shock to U.S. Equity Prices: Second-Round Effects (black= U.S. effect, blue = Total effect)

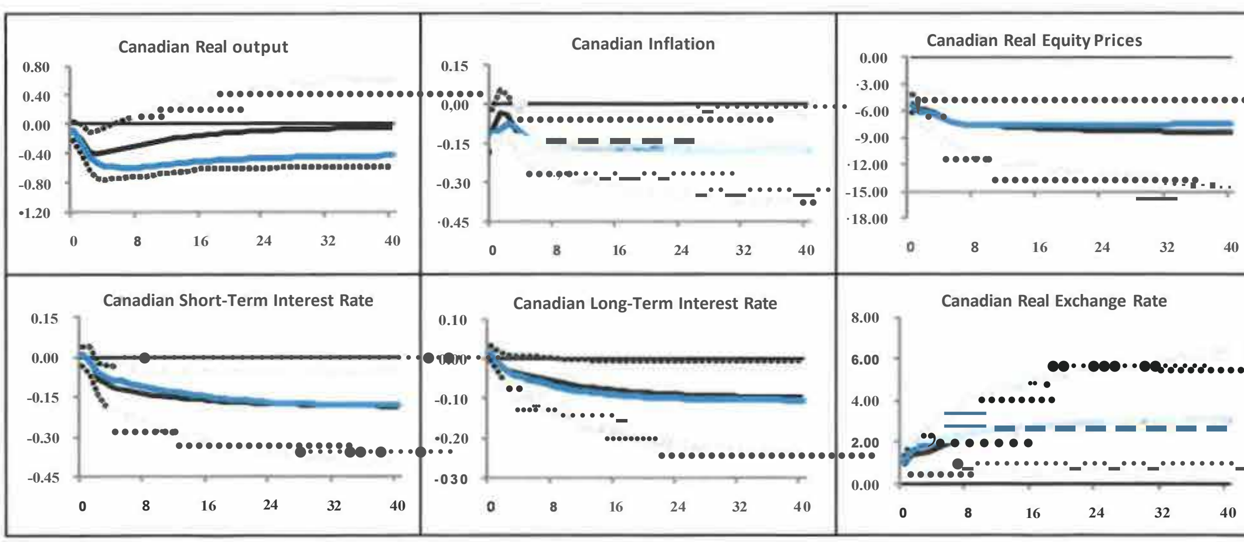


Figure 8: A One Standard Error Positive Structural Shock to the U.S. Short-Term Interest Rate

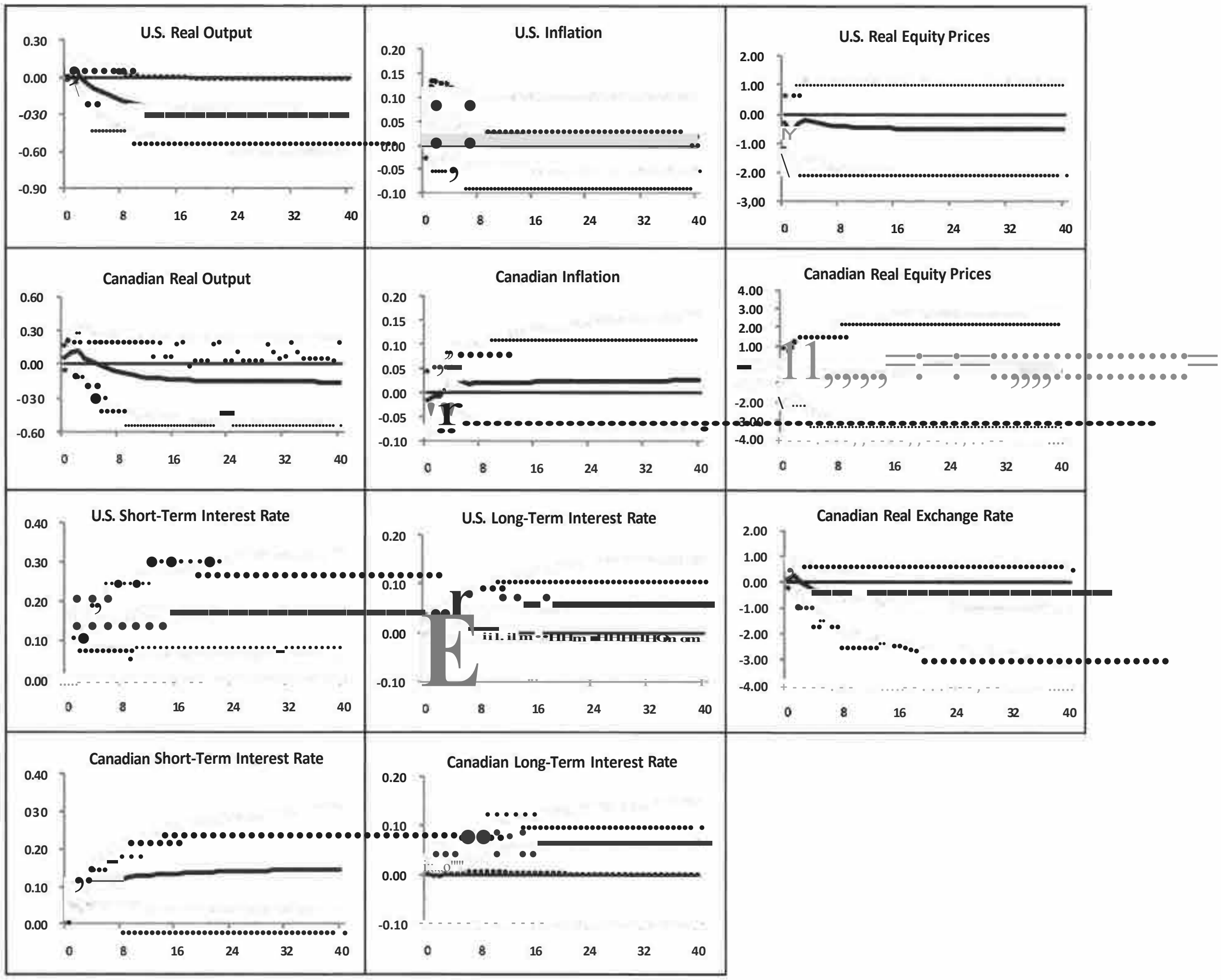


Figure 9: A One Standard Error Negative Shock to U.S. Credit

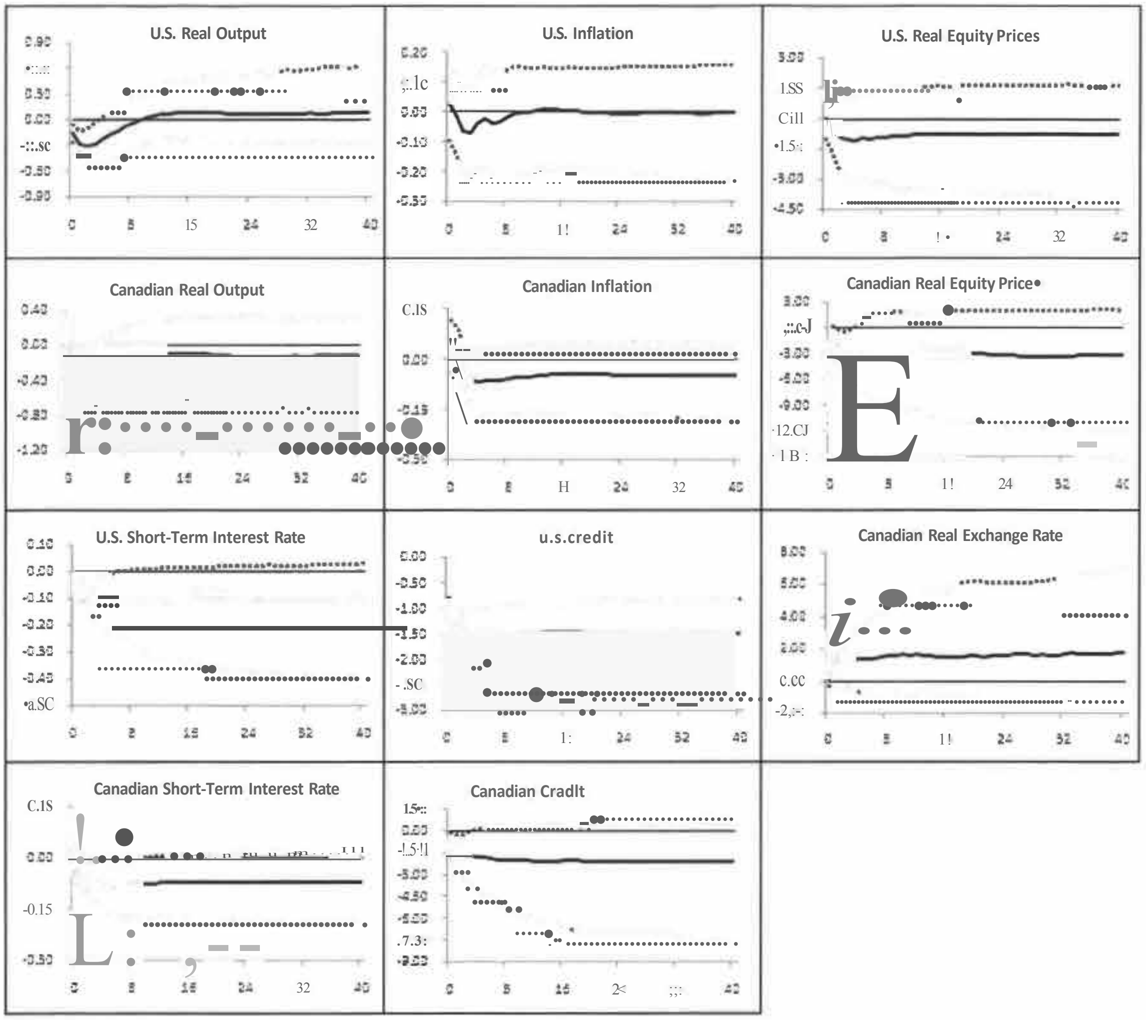


Figure 10: A One Standard Error Positive Structural Shock to the U.S. Short-Term Interest Rate (Financial Weights)

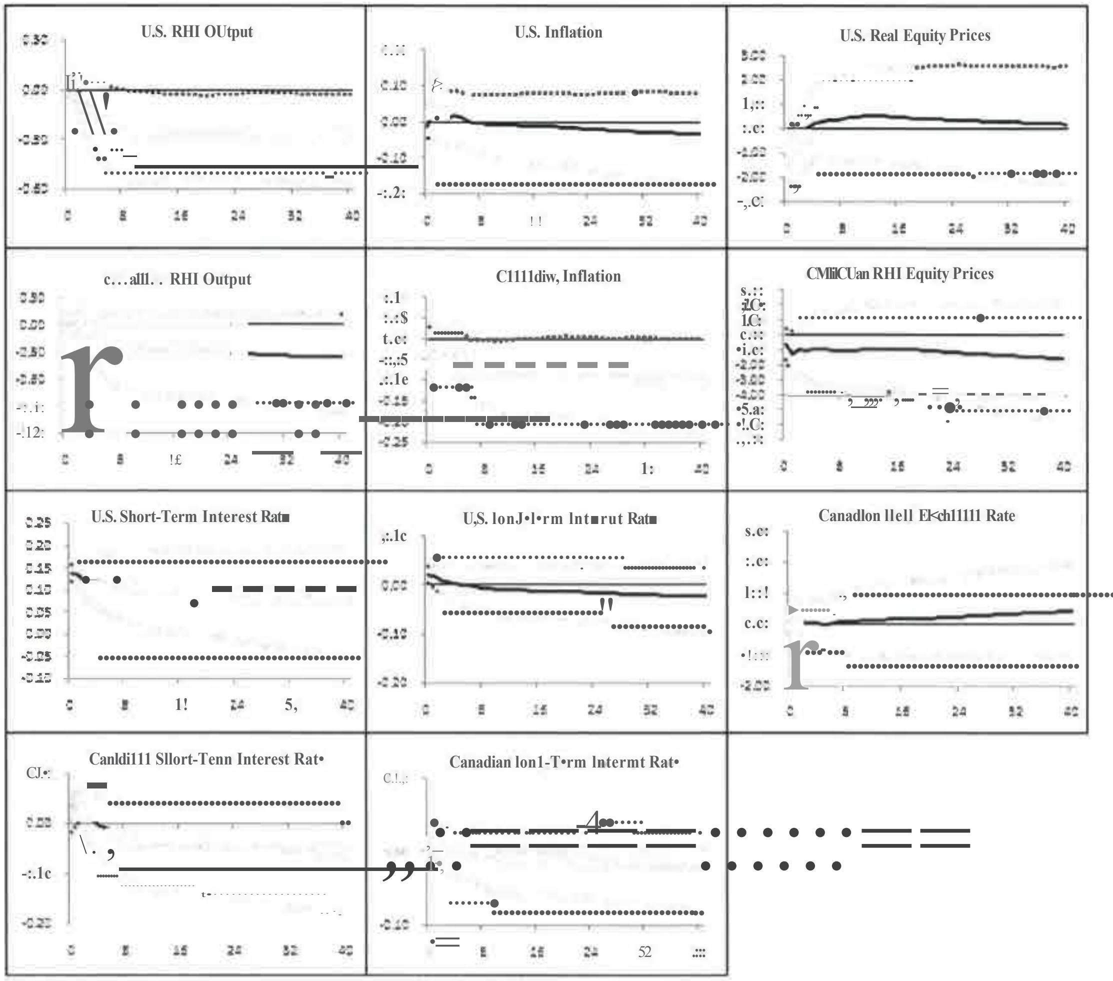
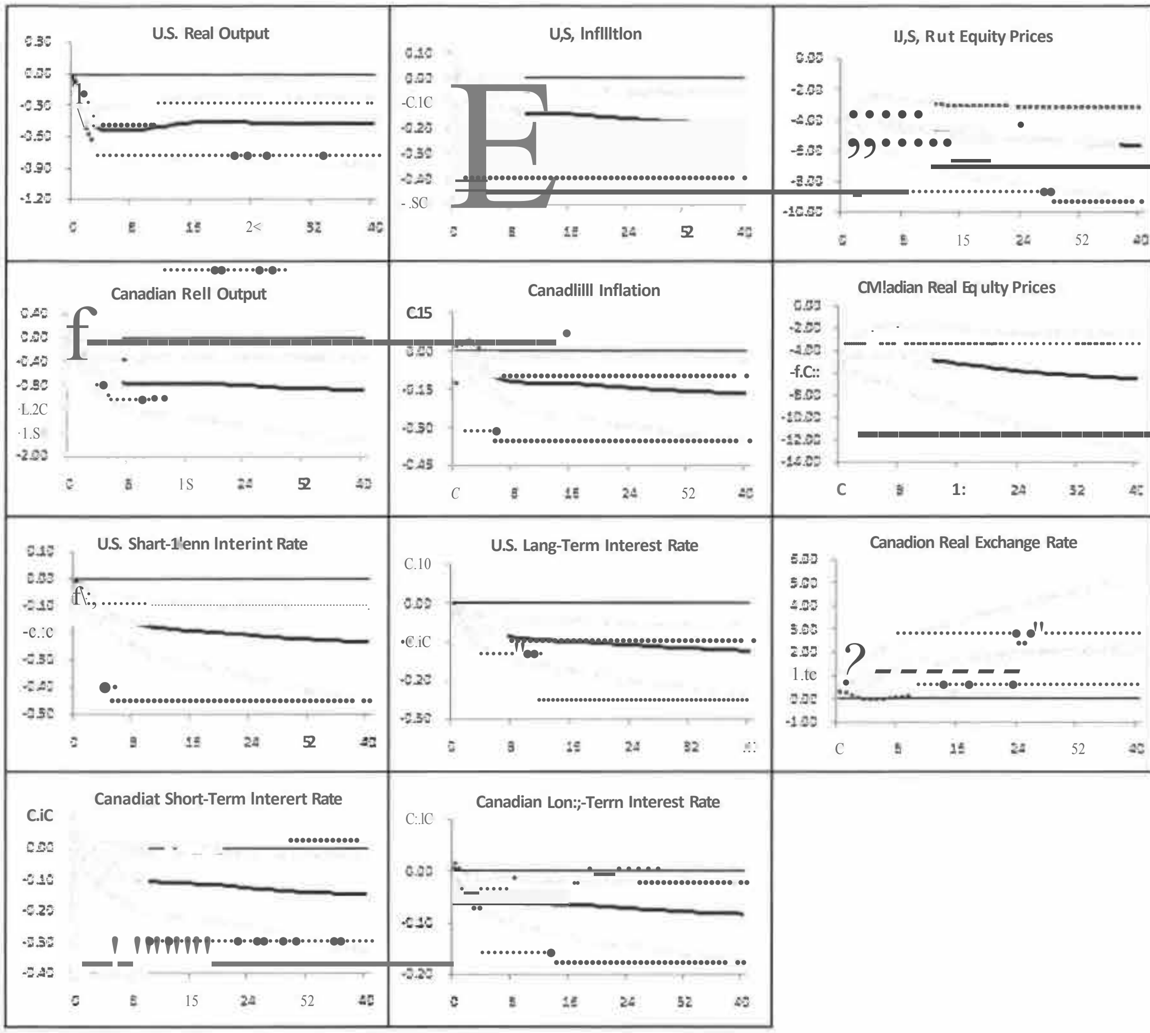


Figure 11: A One Standard Error Negative Structural Shock to the U.S. Equity Prices (Financial Weights)



Appendix A: The GVAR Model

In this study, we make use of the GVAR model originally developed by Pesaran, Schuermann and Weiner (2004) and further developed by Dees et al. (2007) to assess financial spillovers between the United States and Canada.

In estimating our country-specific VARX* models, we suppose that there are N + 1 countries, indexed by i = 0,1,2, ... ,N. The endogenous country variables, x;„ have corresponding country-specific foreign variables, x;*, which consist of weighted averages of the variables for all other countries in the model. The systematic inclusion of the country-specific foreign variables in the individual country models is a crucial component of the GVAR approach, since they provide the link between all countries included in the GVAR model, enabling an analysis of the transmission of shocks across the world economy.[19] Other deterministic variables, such as a time trend, t, can also be included in the model. Moreover, the modelling approach is flexible enough that the lag length of the domestic variables, p, and of the foreign variables, q, in each VARX* model do not have to be equal. For each country, we estimate a VARX* {p,q) model where p and q may also differ across countries. For simplicity, let's consider a VARX* (1,1} specification for country i:

$$x_{it} = a_{i0} + a_{i1}t + \Phi_{i1}\, x_{i,t-1} + \Lambda_{i0}\, x^*_{i,t} + \Lambda_{i1}\, x^*_{i,t-1} + \varepsilon_{it}, \qquad (1)$$

where *aiO* is a k; X 1 vector of fixed intercepts, *ail* is a k; X 1 vector of coefficients on the deterministic time trend, *Xu* is a k; X 1 vector of domestic variables, x;i* is a k;* X 1 vector of foreign variables, Φ_{i1} is a k; X k; matrix of coefficients associated to lagged domestic variables, and A_{iO} and A_{il} are k; X k;* matrices of coefficients related to contemporaneous and lagged foreign variables, respectively. Finally, Eit is a k;X 1 vector of idiosyncratic country-specific shocks which are serially uncorrelated with mean zero and a non-singular covariance matrix *Eu* = (<1'ii,zs), where O"ii,ls = Cov(Ei!t , Eist) is the covariance of the l[th] variable in country i with the i [h] variable in country i, or written more compactly Eit ~ *i. i. d.* (0, *Eu*). Moreover, there is a non-zero contemporaneous dependence of shocks in country *ion* the shocks in country j, measured via the cross-country covariances, Eij, whereEij = Cov(Eit ,t)t) = E(EitE'), for i * j.

In the country-specific VARX* model estimation, we treat the country-specific foreign variables as 1(1) weakly exogenous with respect to the parameters of the conditional model (1). This is a key assumption underlying the GVAR modelling approach and is found to be acceptable when tested (see Appendix B). The weak exogeneity assumption implies no long-run feedback from x;i to x_{it}*, without necessarily ruling out lagged short-run feedback effects. This assumption, and how we treat the United States as a special case, is discussed in section 2.1 of the main text. The country-specific VARX* models can now be consistently, separately estimated conditional on x;i*, taking into account the possibility of cointegration both within x_{ii} and between x_{ii} and x_{ii}*. The country-specific models together with the weakly exogenous variables, which are linked across the country-specific models, provide a complete system. Due to data limitations, a full system estimation of the model is not

[19] The model can also include common global variables such as oil prices. The distinction between the foreign variables and the common global variables is not of material consequence for the estimation of the country-specific models; therefore, they can be combined and treated as jointly exogenous. Given this feature of the model, we abstract from common global variables in our model description. See Pesaran, Schuermann and Weiner (2004) for a description of how common global variables alter the model and its dynamic properties.

feasible. However, following Pesaran, Schuermann and Weiner {2004}, we can estimat the parameters of the country-specific models separately, treating the foreign country-specific variables as weakly exogenous.

Once estimated on a country-by-country basis, the second step in the GVAR model estimation procedure involves stacking the individual country-specific VARX* models and solving them as one system. This is accomplished by explicitly taking into account the time-varying weighting matrix, W_{it}, used to construct the country-specific foreign variables that link the country-specific models. The GVAR model needs to be solved for all the endogenous variables of the global economy simultaneously, due to the contemporaneous dependence of the domestic variables on the foreign variables. To do so, we first group the domestic and foreign variables as $Z_{tt} = (xit, x;;)'$, in order to write each country-specific VAR model as:

$$A_i z_{it} = a_{i0} + a_{i1} t + B_i z_{i,t-1} + \varepsilon_{it}, \tag{2}$$

where $A_1 = U_{kt}$, -AiO), $B_1 = (\triangleleft P_t, 11.11)$. The dimensions of A_1 and B_1 are k; x (k; + k;*) and A_t has a full row rank: *Rank (Ai) = kl,*

Second, by collecting all the endogenous domestic variables of all the countries, we create the global vector,

$$x_t = \begin{pmatrix} x_{0t} \\ x_{1t} \\ \dots \\ x_{Nt} \end{pmatrix}, \tag{3}$$

which is a k X 1 vector, where k $= Lf{=}o\ k_t$ is the total number of endogenous variables in the model. The country-specific variables, Z_{tt}, can thus be written in terms of the global vector, X_t:

$$z_{it} = W_{it} x_t, \tag{4}$$

for *i=l, ...* ,N, where, as mentioned previously, Wj is a country-specific linking matrix of dimensions (k;+k/) x k, constructed on the basis of the weights that each foreign country has in each country's country-specific foreign variables. This identity allows us to write each country-specific VAR model in terms of the global vector. Substitute (4) into (2), and obtain:

$$A_i W_{it} x_t = a_{i0} + a_{i1} t + B_i W_{it} x_{i,t-1} + \varepsilon_{it}, \tag{5}$$

where *i=l, ..., N* and *A;Wr* and $B_1 W_{it}$ are matrices with dimensions *k;X k* The GVAR model is thus built by stacking up each country model. The general form of the GVAR model that corresponds to the country-specific models can now be given by:

$$G_t x_t = a_0 + a_1 t + H_t x_{t-1} + \varepsilon_t, \tag{6}$$

where:

$$a_0 = \begin{bmatrix} a_{00} \\ a_{10} \\ \vdots \\ a_{N0} \end{bmatrix} \quad a_1 = \begin{bmatrix} a_{01} \\ a_{11} \\ \cdots \\ a_{N1} \end{bmatrix} \quad G_t = \begin{bmatrix} A_0 W_{0t} \\ A_1 W_{1t} \\ \cdots \\ A_N W_{Nt} \end{bmatrix} \quad H_t = \begin{bmatrix} B_0 W_{0t} \\ B_1 W_{1t} \\ \cdots \\ B_N W_{Nt} \end{bmatrix} \quad and \quad \varepsilon_t = \begin{bmatrix} \varepsilon_{0t} \\ \varepsilon_{1t} \\ \cdots \\ \varepsilon_{Nt} \end{bmatrix}.$$

Given that G is a k x k dimensional matrix that will, in general, be of full rank and hence non-singular, the GVAR model can be written as:

$$x_t = G_t^{-1} a_0 + G_t^{-1} a_1 t + G_t^{-1} H_t x_{t-1} + G_t^{-1} \varepsilon_t. \tag{7}$$

Once estimated, the GVAR model provides rich dynamics, allowing for interactions among the different economies through three separate but interrelated channels. First, shocks to one country can have a large effect on other countries, depending on their importance in the country-specific foreign variables. Second, there is a dependence of domestic variables on common global exogenous variables. Finally, there is interaction through the error covariances, in that shocks in one country can have a contemporaneous affect on shocks in other countries.

Appendix B: Model Diagnostics

As part of the initial model estimation, we complete several diagnostic tests. First, we determine the lag structure of the VARX* models. Second, we determine the cointegration properties of the individual VARX* models. Finally, we formally test the weak exogeneity of the country-specific foreign variables in each of the VARX* models. This section describes each of these steps in turn.

We begin by selecting the lag length of the domestic variables in the VARX* models. This is accomplished using the Akaike information criterion (AIC), allowing for a maximum lag length of two. Given the results of the AIC, we include two lags of the domestic variables in the Canadian and U.S. VARX* models. The lag order of the foreign variables in each VARX* model is set to one, with the exception of the United States and Canada, for which the lag order is set to two. Given that these countries are the focus of our analysis, we felt that it was important to allow for additional dynamics in these models; however, data limitations prevented us from including additional lags of the foreign variables in all of the VARX* models. All the results of the tests are available from the authors.

We proceed with the cointegration analysis. The rank of the cointegrating space of the country-specific cointegrating VARX* models is tested using Johansen's (1995) trace test and following Pesaran, Shin and Smith's (2000) method for models with weakly exogenous 1(1) regressors. The number of cointegrating relationships found for each country is available from the authors. Of particular interest, we find two cointegrating relationships for the United States and three for Canada. Overall, our GVAR model includes 55 long-run cointegrating relationships.

The initial estimation of the GVAR model is completed under the assumption that the country-specific foreign variables are exogenous. As a final check of the properties of our estimated model, we test the weak exogeneity of the country-specific foreign variables in each VARX* model with respect to the long-run parameters. Weak exogeneity is tested using the approach outlined in Dees et al. (2007). The approach involves estimating auxiliary regressions of the first-difference of the foreign variables and testing the significance of the country-specific error-correction terms in the regressions. The results of the weak exogeneity tests are available from the authors. The weak exogeneity assumption for the majority of the country-specific foreign variables cannot be rejected at the 5 per cent significance level. Most importantly, the weak exogeneity of the foreign variables in Canada cannot be rejected. Thus, this result confirms that our GVAR model does not violate the weak exogeneity assumption crucial in GVAR modelling.

Appendix C: Data Sources

C1. Trade weights

The country-specific foreign variables were constructed using time-varying trade weights. Trade weights are computed as the share of the sum of exports and imports associated with each foreign country in the total trade of each economy. Source: Direction of Trade Statistics, International Monetary Fund (IMF).

C2. Financial weights

An alternative weighting scheme uses financial weights to construct the country-specific foreign variables. The financial weights are computed as shares of the consolidated foreign claims of reporting banks on individual countries by nationality of reporting banks (amounts outstanding, in millions of U.S. dollars). Because of data limitations, the weights are not time-varying and 2006Q1-2007Q4 averages are used for the weights. 2008 was omitted to avoid the distortions in financial flows caused by the financial crisis. Source: International Locational Banking Statistics database, Bank for International Settlements.

C3. Real GDP

The source for all countries is the IMF's International Financial Statistics (IFS) GDP series in 2005 constant prices (series 99bvp and 99bvr). Where recent data were not available, the IFS series were completed with growth rates derived from series provided by DataStream.[20] Where quarterly data were not available, quarterly series were interpolated linearly from the annual series. Interpolation was used on the following countries and only for the periods specified: Argentina (1979-92), Belgium (1979), Brazil (1979-89), Chile (1979), India (1979-96), Indonesia {1979-97), Malaysia (1979-87), Mexico (1979), New Zealand (1979-82), the Philippines (1979-80), Thailand {1979-92) and Turkey (1979-86). For the period before the German unification, in 1990Q4, West German growth rates were used.

C4. Consumer Price Indexes

The data source for all countries was the IFS Series 64zf, except for China (64xzf). West Germany's CPI is used for pre-unification Germany. All numbers are based in 2005.

C5. Equity Price Indexes

The data source was the IFS series 62zf (industrial share prices) for most countries. The exception is the United Kingdom, where data are from the OECD Main Economic Indicators Database. All numbers are based in 2005.

C6. Exchange Rates

The IFS series rt was used for all countries, defined as the exchange rate of country i in terms of U.S. dollars. To construct the euro area exchange rate, the exchange rate of each country member was converted to an index using 2000 as the base year and pre-multiplied by the euro/dollar rate for that year.

C7. Short-Term Interest Rates

The data source was the IFS series 60b (money market interbank rate). The exceptions are: IFS series 601 is used for Argentina, Chile, China, Saudi Arabia and Turkey; IFS 60c is used for Sweden, Mexico and the Philippines; IFS 60 is used for New Zealand and Peru; the CEIC India overnight interbank rate is used for India; 2008 data rates

[20] **GDP data for Singapore (2006Q4-2008), the Philippines (all samples) and Brazil (1990-2008) are from DataStream.**

for the Philippines are completed with the end-of-quarter 3-month Treasury bill rate from the Bangko Sentral ng Pilipinas.

For the eight euro area countries, the short-term interest rate was constructed as follows: for 1979Ql-1998Q4, the short-term country specific interbank rate from the IFS was used. From 1999Ql onwards, the overnight average EONIA middle rate was used as the common short-term interest rate for all eight countries.

CS. Long-Term Interest Rates

The data source was the IFS series 61zf for most countries. Long-term rates are not available for Argentina, Brazil, Chile, China, India, Indonesia, Mexico, Peru, the Philippines, Saudi Arabia, Turkey and Singapore.

C9. Credit (claims of the Bank on the private sector)

The data source was the IFS series 22d for all countries. The series are converted into U.S. dollars using the IFS exchange rate series rf and rebased to 2005=100.

ClO. Oil Price

The average of the West Texas Intermediate daily spot prices is used for quarterly oil prices.