International transmission of quantitative easing policies: Evidence from Canada*

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Abstract

This paper explores cross-border spillovers from major economies' quantitative easing policies to their trading partners. We provide evidence by concentrating on spillovers from the US to Canada during the ZLB period when QE policies were actively used. We identify QE shocks in the US, estimate their impact on a large number of Canadian macroeconomic and financial variables, and analyze transmission channels of foreign QE shocks to the domestic economy. Our results suggest that US QE shocks are expansionary for Canada despite a currency appreciation. This is because they spill over to domestic borrowing costs, lowering long-term rates and financial premiums, and increasing asset prices. We find evidence for both portfolio balance and risk channels.

Keywords: Unconventional monetary policy, transmission channels, portfolio balance channel, risk channel

JEL classification codes: E52, F41, F44

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1 Introduction

Major advanced economies have been conducting quantitative easing (QE) policies for more than a decade now. These policies are, in fact, no longer deemed to be unconventional, and are included in monetary policy toolkits across all advanced economies. Many studies show that QE policies stimulate aggregate demand by lowering long-term interest rates and improving financial conditions (Bernanke, 2020; Bhattarai and Neely, forthcoming; Joyce et al., 2012). It is of no surprise that such policies could also have significant impact on global financial markets, and influence business cycles fluctuations in smaller economies by altering their financial variables and trade. Therefore, understanding the international spillovers and transmission channels of QE is crucial for policy-making in small open economies.

Foreign QE policies can transmit to domestic economy via financial variables such as exchange rates, long-term interest rates and risk spreads, all of which could have offsetting effects on domestic macroeconomic variables such as GDP and inflation. First, the exchange rate channel, which is the main channel in canonical models of Mundell-Fleming-Dornbusch (MFD), tends to imply negative spillovers from expansionary monetary policies abroad to domestic inflation and economic activity (Kim, 2001; Blanchard et al., 2016). In such models, domestic rates are in control of monetary authority thanks to flexible exchange rates; thereby, a long-term interest rate differential following a foreign QE shock leads to an appreciation of the domestic currency through the uncovered interest parity condition. Currency appreciation then puts downward pressures on inflation via a lower level of import prices. In addition, exchange rate appreciation tends to deteriorate the trade balance and exert recessionary pressures in the domestic economy. This is why some of the capital-recipient countries started the debate of currency wars in response to QE policies in the United States.

Second, foreign QE can directly affect domestic long-term interest rates through international portfolio balancing channel (Alpanda and Kabaca, 2020; Kolasa and Wesołowski, 2020). In such models, when the foreign monetary authority takes away long-term foreign bonds from private portfolios, investors replace these bonds with domestic bonds driving domestic term premium and long-term rates down. The reason why capital flows affect

bond prices, rather than the exchange rate as in MFD, is because there is a segmentation between short and long-term bond markets, which limits arbitrage opportunities across these asset classes. A fall in long-term rates lowers borrowing costs and stimulates domestic demand, which could fully or partly offset the negative spillovers stemming from the deterioration of trade balance. For instance, Alpanda and Kabaca (2020) predict positive spillovers to domestic activity on the net as a result of significant financial spillovers while Kolasa and Wesołowski (2020) predict the opposite, suggesting trade dominates financial spillovers.

Thirdly, foreign QE can transmit via risky rates over and above its impact on safe rates, implying a fall in risk premia, improving financial conditions further and putting additional upward pressures on asset prices. For instance, Dedola et al. (2013) show that the integration of banks across countries can lead to loosening of bank balance sheets in both foreign and domestic country following a foreign QE shock. In turn, domestic firms face a lower financial premium when they borrow from banks. In addition, prolonged periods of low interest rates as a result of QE may induce investors to search for yield by investing on assets that deliver higher rates of return, known as risk-taking channel (Borio and Zhu, 2012). In the international context, the risk-taking channel can lead financial intermediaries to increase their global leverage and cross-border lending (Bruno and Shin, 2015b). Bruno and Shin (2015a) show that the risk-taking channel is amplified by currency appreciation of the recipient country which leads to a dampened exchange rate volatility and further decline in measured risk. Finally, US monetary policy could affect domestic credit costs in other countries through its effect on global investors' risk perceptions (Kalemli-Özcan, 2019).

In this paper, we assess the international transmission channels of QE by concentrating on spillovers from US QE policies to Canada. We rely on the structural identification of US QE shocks within a Bayesian structural vector autoregression (SVAR) model. Then, we compute the associated impulse response functions (IRFs) for both US and Canada. Our identification strategy follows closely Weale and Wieladek (2016), where sign restrictions are used to identify US QE shocks. We, therefore, extend their model by including a small

open economy to the SVAR model by imposing block exogeneity. It is also worth mentioning that we do not impose any restriction on the responses of the Canadian variables. Thus, the domestic IRFs are entirely driven by data and assumptions on the US QE shock identification.

Our findings indicate that a US QE shock has expansionary effects on Canada by increasing both domestic activity and inflation despite the appreciation of the Canadian dollar. The expansion is mainly due to the fall in domestic long-term yields and risk premia as well as the increase in asset prices, which highlights the strength of financial spillovers. We observe increases in gross trade flows but the net trade balance plays a minor role in this expansion. Moreover, short-term rates tend to increase to offset the expansionary effects of the foreign shock. This suggests that domestic policy can still influence the financial conditions even though global factors have direct effects on domestic rates.

We also look at the impact of US QE shocks on foreign investment in Canada. Similar to the impact on term and risk spreads, foreign holdings of Canadian assets also provide evidence for both portfolio and risk channels. Particularly, foreigners tend to increase their Canadian long-term government bond holdings while they decrease those in short-term maturities. On the other hand, they increase their risky Canadian corporate bond holdings in both maturities. In addition, we find that US investors tend to rebalance their portfolios towards Canadian assets more than other foreign investors do, suggesting that US investors perceive a higher degree of substitution between US and Canadian assets.

Within the international spillovers literature, our paper is closest to Chen et al. (2016), Dahlhaus et al. (2018), Horváth and Voslarova (2017), Bluwstein and Canova (2018), and Carrera and Ramírez-Rondán (2020). They, too, measure the impact of quantitative easing policies in major advanced economies on macroeconomic and financial variables of small open economies. However, our study differs from others by the shock identification approach and scope of the transmission channels examined. For instance, Dahlhaus et al. (2018), and also partially Chen et al. (2016), use a counterfactual scenario analysis to assess the impact of the US QE, which requires extensive assumptions on the paths of key US variables over several years, whereas in our approach we rely merely on a few theory-driven

sign restrictions. Moreover, we identify the US QE shocks from a variable – asset purchase announcements – that is directly linked to the QE policies instead of inferring its shocks through indirectly-linked variables such as shadow rates or term spreads as in Chen et al. (2016), Horváth and Voslarova (2017), and Carrera and Ramírez-Rondán (2020). Finally, focusing on Canada – a close trading partner with strong financial integration to the US – allows us to assess several international transmission channels. Data availability and the fact that, after controlling for commodity prices, the US is the only major source of international spillovers to Canada help us clearly identify the transmission channels, which is an advantage compared to the settings of other studies incorporating several countries that are open also to other international shocks.

There is also a large literature on spillovers to emerging market economies focusing predominantly on financial linkages that are perhaps a reflection of risk channel (Anaya et al., 2017; Bhattarai et al., 2021; Kucharčuková et al., 2016; Lim and Mohapatra, 2016; MacDonald, 2017; Tillmann, 2016). The financial variables used in these studies, generally, are at a relatively aggregate level such as total portfolio or capital flows. In contrast, we have data on foreign investment in Canadian bonds with a decomposition at different durations (long-term versus short-term), risk levels (government versus corporate), and regional origins (from the US versus rest of the world). These bond classes provide us a precise distinct between the risk and portfolio balance channels.

Finally, our paper is also related to an earlier literature that finds significant spillovers from QE policies to global yields and currencies (Dedola et al., 2021; Fratzscher et al., 2018; Neely, 2015; Rogers et al., 2018). These studies concentrate on particular financial markets, mostly using high-frequency data, while our approach allows us to analyze the impact of such policies on both macro and financial variables and assess different international transmission channels.

The remainder of the paper proceeds as follows. Section 2 introduces the econometric model, explains the sample data and the shock identification restrictions. Section 3 reports the results together with a discussion on various robustness checks. Finally, Section 4 concludes.

2 A Small Open Economy SVAR model and Data

To quantify the effects of the US quantitative easing policies on the Canadian economy, we develop a structural vector autoregressive (SVAR) model at the monthly frequency for the time period between 2008 November and 2015 November. In this period, the conventional monetary policy is silent (the policy rate was at the zero lower bound), while the unconventional monetary policy (the asset purchases) is the active policy. Following Cushman and Zha (1997) and Zha (1999), we impose block exogeneity on the VAR coefficients assuming that the Canadian variables do not affect the US variables either contemporaneously or with lags, while the US variables can affect the Canadian ones. In other words, the Canadian economy is modeled as a small open economy with no impact on the US variables. Thus, we estimate a reduced-form VAR model $\mathbf{Y}_t = \boldsymbol{\alpha} + \mathbf{A}(L)\mathbf{Y}_{t-1} + \mathbf{u}_t$ for $t = 1, \ldots, T$ with the following specifications:

$$\begin{bmatrix} \mathbf{Y}_t^{US} \\ \mathbf{Y}_t^{CA} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\alpha}^{US} \\ \boldsymbol{\alpha}^{CA} \end{bmatrix} + \begin{bmatrix} \mathbf{A}_{11,1} & \mathbf{0} \\ \mathbf{A}_{21,1} & \mathbf{A}_{22,1} \end{bmatrix} \begin{bmatrix} \mathbf{Y}_{t-1}^{US} \\ \mathbf{Y}_{t-1}^{CA} \end{bmatrix} + \begin{bmatrix} \mathbf{A}_{11,2} & \mathbf{0} \\ \mathbf{A}_{21,2} & \mathbf{A}_{22,2} \end{bmatrix} \begin{bmatrix} \mathbf{Y}_{t-2}^{US} \\ \mathbf{Y}_{t-2}^{CA} \end{bmatrix} + \begin{bmatrix} \mathbf{u}_t^{US} \\ \mathbf{u}_t^{CA} \end{bmatrix},$$

where the superscripts denote the US and Canadian variables. The $(N \times 1)$ vector of endogenous variables $\mathbf{Y}_t = (\mathbf{Y}_t^{US}, \mathbf{Y}_t^{CA})$ contain macro-financial variables from the US and Canadian economy, respectively. The reduced-form errors $\mathbf{u}_t$ are serially uncorrelated and normally distributed with the covariance matrix $\boldsymbol{\Sigma}$, i.e., $\mathbf{u}_t \sim \mathcal{N}(0, \boldsymbol{\Sigma})$. The zero-restrictions in the lag matrices $\mathbf{A}(L)$ imply that the Canadian variables do not Granger-cause the US variables, i.e., Canada is a small open economy with respect to the US.

We use Bayesian techniques to estimate the model. In particular, we utilize independent Normal-Wishart priors with shrinkage. We need some degree of shrinkage in this medium-scale VAR model since the time dimension is not long ($T = 85$). To ensure the block exogeneity, we impose extremely tight priors centered around 0 for the coefficients in $\mathbf{A}_{12,l}$, for $l = 1, 2$. The priors for other coefficients are less tight and resemble Minnesota-type priors where the diagonal elements in $\mathbf{A}(1)$ are shrunk towards 1 and other coefficients in $\mathbf{A}(L)$ are shrunk towards zero. The shrinkage of the diagonal elements toward 1 makes sense since we are using nonstationary (log-levels) data with possibly unit roots. We choose

relatively loose priors for the off-diagonal elements in $\mathbf{A}(L)$ not to affect the posterior of the coefficients that are responsible for the shock transformation from the US to Canada, i.e., $\mathbf{A}_{21,l}$, for $l = 1, 2$. For the estimation, a total of 15000 Monte Carlo Markov Chain iterations are used where the first 5000 are discarded as a burn-in period. We also conduct convergence checks on each parameter à la Geweke (1992), the results indicate that around 95% of the parameters converge in each estimation.[1].

The following two subsections discuss the data for the US and Canadian variables and the shock identification strategy.

2.1 Data

The US variables contain the logarithm of the real gross domestic product (GDP), logarithm of the consumer price index (CPI), 10-year Treasury bond yields, cumulative asset purchase announcements, logarithm of the real S&P 500 stock price index, and the logarithm of the nominal commodity price index. All these variables can be obtained from the FRED database except that the monthly real GDP is acquired from the Macroeconomic Advisers. The cumulative asset purchase announcements – our quantitative easing policy variable – entails the announcements by the Federal Reserve about the purchases of treasuries, mortgage-backed securities (MBS), and agency debt under the three large-scale asset purchase programs and maturity extension program. We normalize this variable by the 2009 US GDP. The selection of these US block variables relies mainly on Weale and Wieladek (2016) and Hesse et al. (2018). Compared to these two studies, we also include the commodity price index since it is an important international variable for the Canadian economy.

The selection of the Canadian block has two considerations: we want to assess the impact of the US QE shocks on a large number of Canadian variables but, at the same time, we do not want the model to further grow into a large-scale VAR. Therefore, we first design a baseline model that includes 5 main Canadian variables, and then, one by one,

[1]The estimation and sign restriction algorithms are performed by the BEAR toolbox (Dieppe et al., 2016). The specific choices for the hyperparameters are available upon request.

one of the 18 Canadian variables enter the model. As a result, the baseline model has $N = 6 + 5 = 11$ variables whereas the extensions have $N = 6 + 6 = 12$. The baseline Canadian variables contain the logarithms of the real GDP and CPI, 10-year and 1-year Canadian government bond yields, and the logarithm of the CAD/USD exchange rate where a decrease means appreciation of the Canadian Dollar. Even though the overnight rate – the policy rate of the Bank of Canada – is not entirely at the ZLB throughout the time period of our data set, we use the 1-year government bond yields for the short-term rate since there is not enough variation in the overnight rate.

Next, let us discuss the 18 additional Canadian variables and the rationale to include them. To assess the trade channel, we include the logarithms of the real exports and imports. For measuring further real economy effects, we include the unemployment rate. We utilize overnight swap rates over a 2-year horizon, together with long-term yields in the baseline model, to assess portfolio balance and signalling channels. For asset prices, we use equity prices – the logarithm of the real Toronto Stock Exchange composite index (TSX) – and house prices – the logarithm of the house price index measured by the Teranet-National Bank National Composite House Price Index. For financial risk channels, we include the corporate spread measured by the difference between 3-month corporate bond yields and the 3-month risk-free rate, excess bond premium measured by Leboeuf and Hyun (2018) using the same calculation approach of Gilchrist and Zakrajšek (2012), and the Canadian Financial Stress Index measured by Duprey (2020). To further assess the portfolio balance and risk channels, we include 8 variables on foreign holdings of Canadian assets. In particular, we have foreign investments in the long- and short-term government and corporate bonds, as well as US and Rest of the World (ROW) foreign investments in long- and short-term Canadian bonds. Unless otherwise noted, all the Canadian variables can be downloaded from the Statistics Canada and HAVER Analytics.

2.2 Shock Identification

We assume that the structural economic shocks $\boldsymbol{\varepsilon}_t$ are related to the reduced-form errors $\mathbf{u}_t$ by $\mathbf{u}_t = \mathbf{B}\boldsymbol{\varepsilon}_t$, where $\mathbf{B}$ is called the contemporaneous impact matrix. Different

assumptions on $\mathbf{B}$ will result in different structural shocks. Since we are interested in the transmission of the US shocks into the Canadian economy, we identify only the US shocks. This means that we make assumptions only on the upper-left block of the $\mathbf{B}$ matrix and leave the other parts of $\mathbf{B}$ free. Specifically, we follow the sign restrictions suggested in Weale and Wieladek (2016) for the identification of the structural US asset purchase announcement shocks.[2] We adopt the sign restriction methodology proposed by Arias et al. (2018). Table 1 summarizes the identification restrictions.

Table 1: Sign restrictions in the US block

	QE Shock	Demand Shock	Supply Shock
Log real GDP		+	+
Log CPI		+	-
Long interest rate	-	+	+
Asset purchase announcements	+		
Log real equity price	+	+	+
Log nominal commodity price			

Notes: This table shows the sign restrictions imposed on the corresponding US block of the impact matrix $\mathbf{B}$. Empty cells indicate coefficients that are not restricted. The impact of the QE shock on the asset purchase announcements is restricted to last for 6 months while all other restrictions are imposed for 2 months.

We identify three structural US shocks: quantitative easing (QE) shock, demand shock, and supply shock. While the QE shock has a positive effect on the asset purchase announcements, it decreases the long rates on the grounds that such announcements will reduce the term premia and signals that the short term rates will stay at the ZLB for longer periods.[3] Finally, as an expansionary unconventional monetary policy shock, it increases the demand for equities, thus increases real equity prices. The US demand and supply shocks are identified by traditional sign restrictions where demand and (negative) supply shocks have expansionary effects increasing the real GDP, long rates, and real equity prices. Their identifying assumption is that the demand shock is inflationary while the supply shock is deflationary. Following Weale and Wieladek (2016) and Hesse et al. (2018), all of the signs

[2]The results are robust to alternative restrictions such as the sign and zero restrictions suggested in Hesse et al. (2018). See Section 3.3.

[3]The reduction in long-term rates is consistent with theoretical QE models that assume imperfect asset substitution between short- and long-term government liabilities (Chen et al., 2012; Vayanos and Vila, 2021).

are imposed for two months (on impact and one month thereafter) except the response of the asset purchase announcements, which is imposed for 6 months (on impact and 5 months thereafter).

3 Results

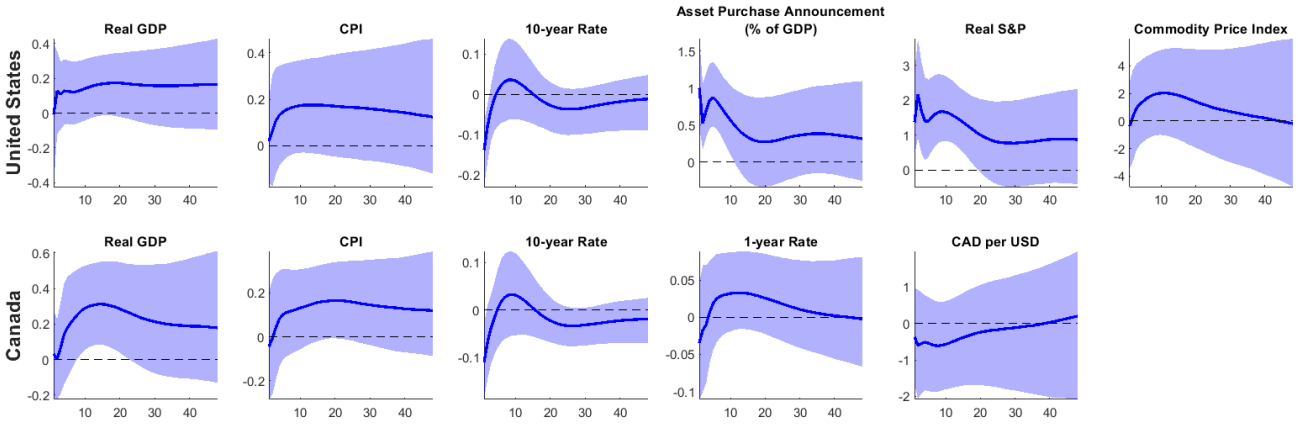
In this section, we present the impulse responses associated with the US QE shocks. First, we show how the shocks affect the US economy, then we demonstrate responses of numerous Canadian macro-financial variables and discuss various transmission channels.

3.1 Responses of the US variables

The first row of Figure 1 shows the impulse responses of US variables to a QE shock. The QE shock is scaled so that purchase announcements are equivalent to 1% of the US GDP. Shaded areas represent the equi-tailed 68% Bayesian credible sets. The QE shock is expansionary, increasing GDP and price level by about 0.20%. The expansion is consistent with favorable financial conditions following the shock, as predicted from portfolio balance models (Harrison, 2012; Andres et al., 2004). Particularly, long-term interest rates fall by 14 bps and equity prices increase by 2%. Lastly, the shock inflates commodity prices by slightly higher than 2%.

These results, qualitatively, are consistent with those papers studied US QE shocks in a closed-economy VAR such as Weale and Wieladek (2016) and Hesse et al. (2018). Quantities are much closer to Hesse et al. (2018) even though we use the same identification scheme in Weale and Wieladek (2016). This is mainly because we use asset purchase announcement series calculated as in Hesse et al. (2018), which also includes MBS purchases and QE3 announcement relative to those in Weale and Wieladek (2016). Finally, as in aforementioned studies, IRFs have large confidence bands possibly due to a short span of data, moderately large number of variables, and set identification by sign restrictions (as opposed to a point identification).

Figure 1: Impulse responses to an unexpected 1% asset purchase announcement in the United States as a fraction of US GDP



Note: Solid lines denote the median impulse responses while the shaded regions denote the 68% equal-tailed confidence bands.

3.2 Responses of the Canadian variables

We now discuss the impulse responses from the Canadian block in the baseline model, which are shown in the second row of Figure 1. The US QE shock is expansionary also for Canada, increasing GDP by about 0.30%. It increases the price level by about 0.15%. As in the case of the US, long-term rates fall by about 11 bps. Note that we do not restrict this variable in our VAR, which suggests that there is significant spillovers from US long-term rates to Canadian ones. Moreover, the increase in long-term rates is not driven by domestic monetary policy reaction. In fact, short-term rates increase, rather than fall, reflecting the expansionary phase that domestic economy is passing through.

Figure 1 also shows that US QE shock appreciates the Canadian dollar at the median although the response is not significant even though current short-term rates slightly increase in Canada. The noisy response in the Canadian dollar might reflect large spillovers from US long-term rates to Canadian long-term rates, which leaves a small and insignificant interest rate differential between US and Canadian long-term government bonds. Note also that consumer prices increase despite exchange rate appreciation, implying that the exchange rate pass-through plays a minor role in CPI inflation. Domestically-produced

goods, rather than imported goods, are the main reason for higher prices.

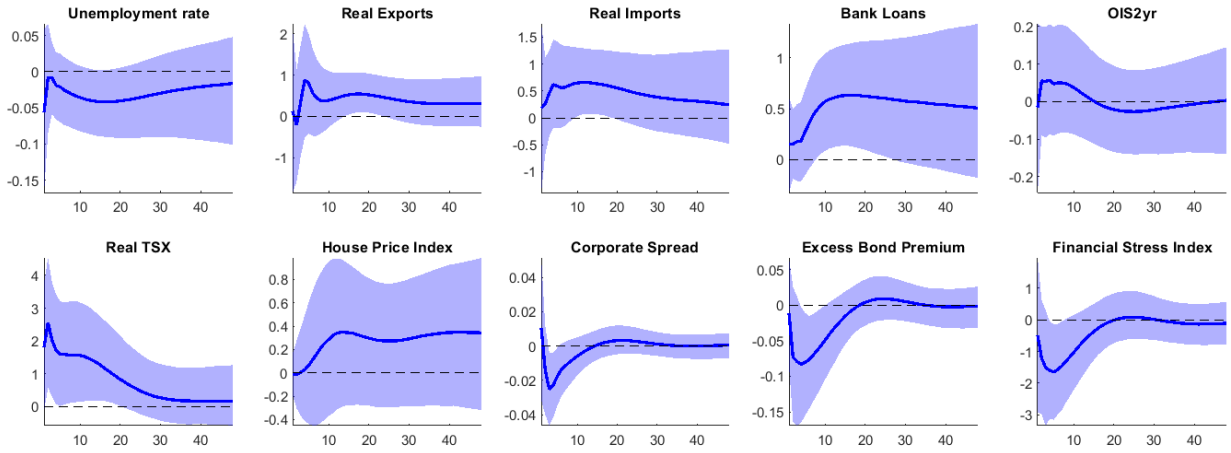
Regarding the decline in long-term rates, we also examine the impact on policy rate expectations using OIS futures, illustrated in Figure 2. Expected policy rates also increase, similar to the reaction of short-term rates, albeit the response is not as significant as current short-term rates. Nevertheless, the non-negative response coupled with positive response of current short-term rates imply that term premium component of long-term rates fall, as predicted from international portfolio balance models (Alpanda and Kabaca, 2020; Kolasa and Wesołowski, 2020). The reduction in term spread reflects that portfolio balance channel, rather than signalling channel, is the dominant factor when US long-term rates spill over to Canadian ones.[4] This is in contrast to Bauer and Neely (2014), which find signalling effects to Canadian long-term rates when policy rate expectations are estimated in a dynamic term structure model.

Real economy Figure 2 shows additional responses for Canada. Firstly, unemployment rate falls by 0.04 pp consistent with a GDP expansion. This result shows that the expansion is broad-based including labor markets; albeit, unemployment rate falls less than a traditional Okun's law relation would suggest[5]. We then ask the source of this expansion in Canada: trade or domestic demand? Starting with trade variables, first, we observe a significant increase in Canadian imports. The response is also persistent and tracks the response of the Canadian GDP well, albeit the quantity is about twice as large as the response of the Canadian GDP. This is consistent with the fact that not only incomes rise in Canada, but also currency appreciates, which leads to expenditure switching from domestic to foreign goods. For export, we observe an increase as well, suggesting that the increased US demand dominates the negative impacts of appreciation on Canadian exports. However, the response is smaller, less persistent, and noisier compared to the response of imports. These results imply that gross trade flows are positively affected by US QE shock; however, net trade balance cannot be the reason for the expansion. This leaves domestic absorption to be the main driver for the increase in the economic activity.

[4]The result on long-term yields also consistent with previous empirical studies that find significant spillovers to government bond yields across the world following US asset purchases.

[5]Okun's law would imply a 0.15 pp fall in unemployment rates for a 0.30% increase in GDP.

Figure 2: Impulse Responses of Other Canadian Macro and Financial Variables

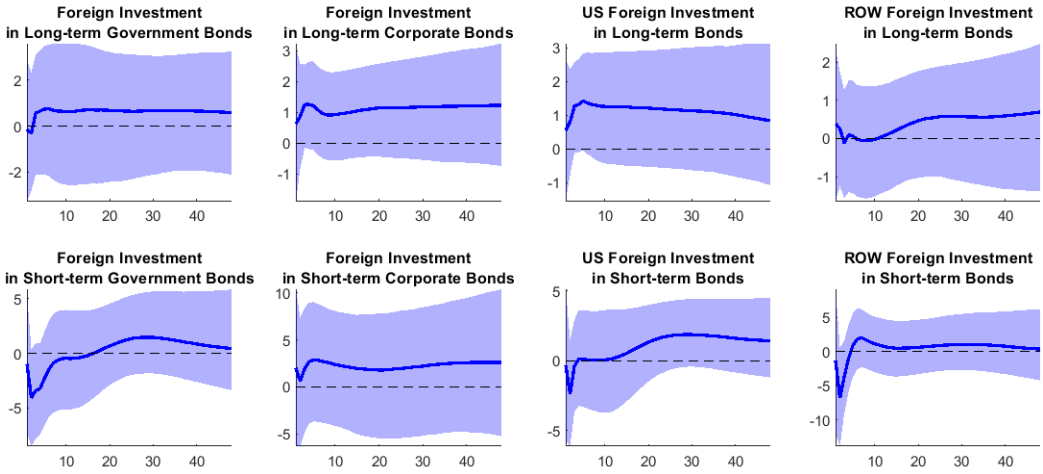


Note: Solid lines denote the median impulse responses while the shaded regions denote the 68% equal-tailed confidence bands.

Turning to financial variables, US QE shock increases bank lending by about 0.65%. It also lowers risk premia in Canadian financial markets, whether it is measured by corporate spread, excess bond premium, or financial stress index. Particularly, US QE shock lowers corporate spread and excess bond premium by 3 bps and 8 bps, respectively; and it decreases the financial stress index by 2 bps. It also significantly increases asset prices. Real equity prices increase by more than 2% and house prices increase by more than 0.1%. Overall, these results indicate a looser financial conditions in Canada, and are consistent with the risk-taking channel or the theoretical implications of highly-integrated financial intermediaries as discussed in section 1.

Our findings mainly emphasize the importance of financial spillovers following a foreign QE shock whether it be through risk-free long-term rates or risky asset classes. The financial spillovers are expected to particularly affect domestic demand, which is consistent with the fact that domestic absorption is the main driver of the expansion in Canada.

Figure 3: Impulse Responses of Foreign Investment in Canadian Bonds



Note: Solid lines denote the median impulse responses while the shaded regions denote the 68% equal-tailed confidence bands.

Foreign bond holdings So far, we have examined the *price* implications of international portfolio balancing and risk channels. How do the quantities, in other words, foreign holdings of Canadian assets change following a US QE shock? Figure 3 shows the responses of foreign investment in Canadian bonds.

The median responses indicate that foreign investment in long-term government bonds increases following the shock, in line with portfolio balancing channel. Faced with a fall in their long-term portfolios, investors tend to replace their US long-term government bonds with Canadian ones. Note, however, that there is quite a noise in this response perhaps reflecting almost one-to-one return reaction between Canadian and US long-term government bonds. Investors might be less reluctant to change their positions if the price reacts quickly leaving no-arbitrage between close substitutes. This is akin to the standard case of perfectly-substitutable assets under an uncovered interest parity (UIP) condition, where asset holdings cannot be pinned down at the equilibrium (Devereux and Sutherland, 2011). Furthermore, the uncertainty around this investment class could also reflect a stronger appetite for search-for-yield, thus, a stronger risk-taking channel.

In contrast to long-term investments, foreign holdings of short-term government bonds

decreases. This is also in line with portfolio balancing in that US QE increases short-term instruments in portfolios, leading global investors to lower their short-term asset positions in other countries to avoid large increases in short-to-long ratio portfolio shares. Note, however, that the response is short-lived and turns to positive after a year and a half. This is consistent with the fact that short-term policy rates increase in Canada. Moreover, monetary tightening is expected to increase holdings of short-term bills through open market operations.

Corporate bond holdings increase in both short- and long-term maturities. Thus, foreign investment in riskier Canadian bonds increase regardless of maturity, consistent with an increase in investors' risk appetite and search-for-yield. This result is in line with the literature that finds significant flows to risky asset classes such as emerging market securities (Fratzscher et al., 2018; Bhattarai et al., 2021; Anaya et al., 2017).

We now turn to the origin of foreign investment in Canadian bonds: US versus the rest-of-the-world countries. Here we aim to see whether there are differences across investors from different origins, which could possibly point to differences in the degree of asset substitution. Figure 3 indicates that while US investors increase their holdings of Canadian long-term bonds, the increase is much milder and noisier in the case of ROW investors. The difference can be explained by much higher substitution between Canadian and US long-term bonds in the eyes of US investor. ROW investors, on the other hand, could possibly look for bonds from closer countries for hedging purposes, where business cycles comove more with their home countries.

Both US and ROW investment in short-term Canadian bonds initially fall reflecting the fact that government bonds make up more of the short-term Canadian portfolios of foreigners.[6] Here the key distinction between US and ROW investors is that the increase in short-term Canadian bond holdings one year later is much apparent in the case of US investors. This could reflect the tighter links between US and Canadian baking system, where US banks respond to Canadian monetary tightening by increasing their holdings of

[6]Government bonds make up 68% of foreigners' short-term Canadian portfolios. Note that while we can break down the total foreign investment into safe and risky asset classes, the data on international transactions do not allow us to do such a breakdown within US and ROW investments

Canadian short-term bills.[7]

3.3 Robustness

We perform a number of important robustness checks. First, we change our identification strategy and use a combination of zero and sign the restrictions to identify the QE shocks. In particular, we assume that the US QE shocks generate positive asset purchase announcements but do not have a contemporaneous impact on the real economy – output and prices. This assumption disentangles the QE shocks from the demand and supply shocks. Additionally, we assume that the QE shocks decrease the long-term rates while having a positive effect on the equity prices. These identifying restrictions are exactly the same to those in Hesse et al. (2018), and very similar to those in Gambacorta et al. (2014), Bluwstein and Canova (2018), and Carrera and Ramírez-Rondán (2020). The results of the alternative identification strategy are plotted in Figure A.1. Compared to our benchmark results, the median responses are almost identical while the alternative approach provides slightly smaller confidence bands for most of the IRFs since zero restrictions provide a tighter admissible set.

Our second robustness check is replacing the QE announcement variable with the Federal Reserve's actual long-term asset holdings. This is an important robustness check since several studies use this central bank balance sheet variable as the key QE policy variable (Gambacorta et al., 2014; Anaya et al., 2017; Dahlhaus et al., 2018). The results can be found in Figure A.2. We, first, note that the magnitudes are much larger since 1% purchase shock indicate much higher increase in the Fed's asset over the first year. Second, we observe that financial variables – such as bank loans, TSX, corporate spread, excess bond premium, and foreign investments – respond generally with a lag of a few months and less stronger compared to the benchmark case. This indicates that the QE shocks obtained from the FED balance sheet variable could miss the rapid response of financial markets to announcements without waiting for actual purchases. Third, foreign invest-

[7] Temesvary et al. (2018) also find that US bank affiliate claims respond to host country monetary conditions.

ment responses have smaller confidence bands, especially for longer term maturities. This is likely because actual purchases might be more important for active portfolio balancing, while QE announcements could mostly lead to passive portfolio balancing effects, where market value of holdings increase because of asset price effects. Nevertheless, in terms of response directions, the IRFs are overall very similar reflecting the robustness of our results to the choice of the QE policy variable.

Our third robustness check is the inclusion of the ratio of the ECB's total assets to the Euro Area GDP in the foreign block as a control variable to make sure that the benchmark results are not driven by other international quantitative easing policies that were conducted around the same time. These IRFs are given in Figure A.3. Our final robustness check is replacing the nominal exchange rate with the real one since it is the key variable that affects the real economy in theoretical open-economy models (Gali and Monacelli, 2005). These IRFs can be found in Figure A.4. Overall, a comparison to the benchmark IRFs shows that the results are practically identical.

4 Conclusion

In this paper, we analyze the effects of the US quantitative easing policies on the Canadian economy and assess various international transmission channels. We first identify unexpected US asset purchase announcements by sign restrictions and quantify their impacts on a large number of Canadian macro-financial variables by conducting impulse-response analysis. Our results suggest that the US QE shocks have expansionary effects on both the real and financial aspects of the Canadian economy. The main propagation mechanisms appear to be the portfolio balance and the risk channels, both leading to favorable financial conditions and increasing domestic demand. We find that gross trade increases too; however, the role of trade balance in the expansion of aggregate demand is muted. Finally, we do not find any signalling channel.

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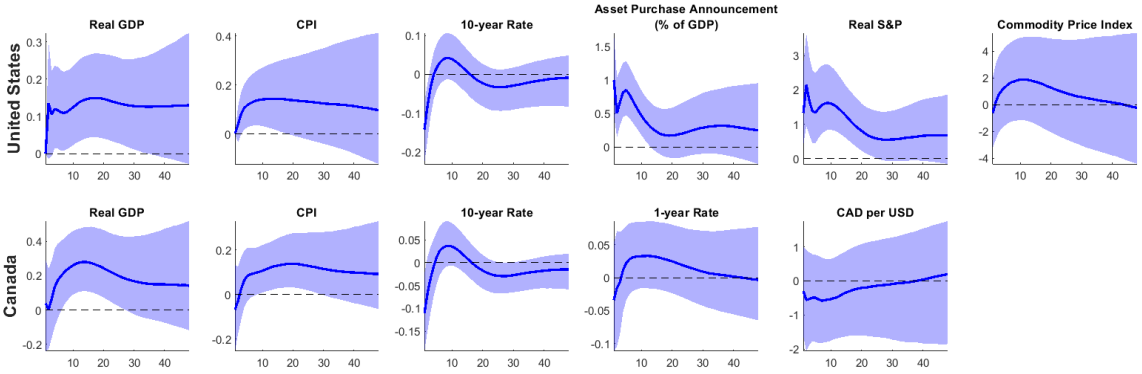
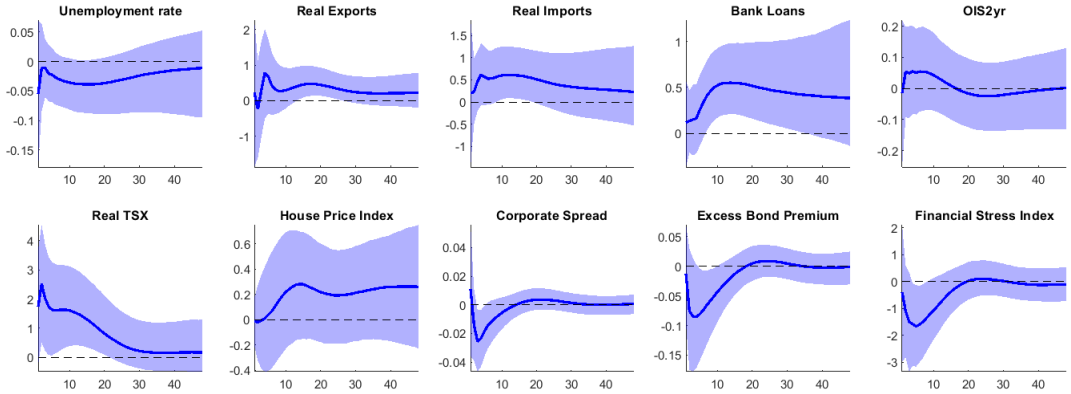
A Online Appendix [Not for Publication]

Figure A.1: Impulse Responses under Alternative Identifying Restrictions

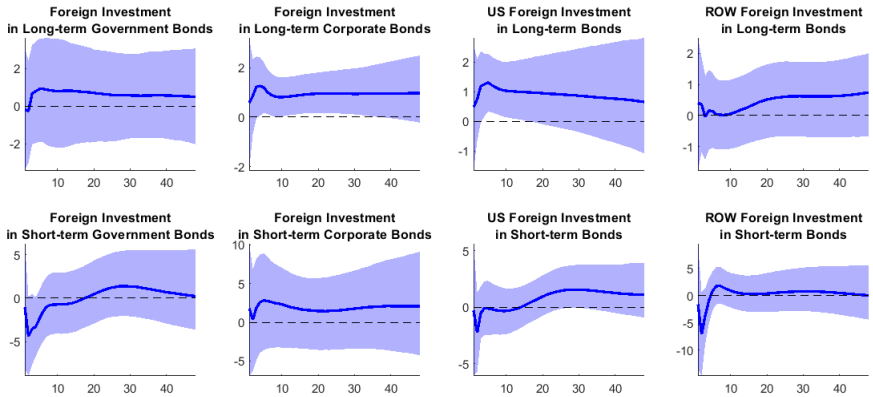
(a) Impulse responses of the US and main Canadian variables



(b) Impulse responses of other Canadian macro-financial variables



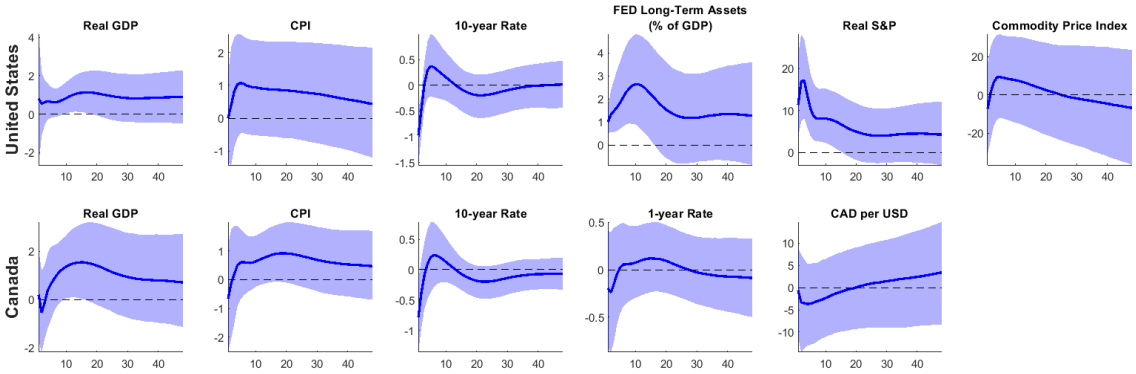
(c) Impulse responses of foreign investment in Canadian bonds



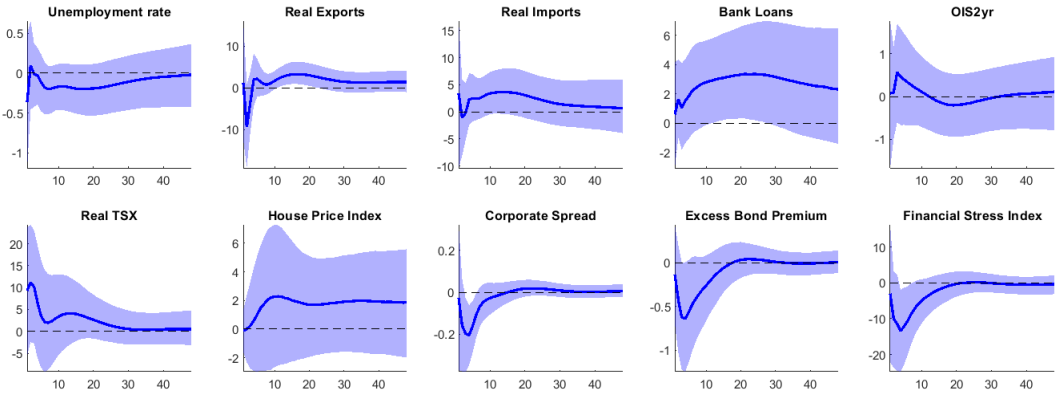
Note: We reproduce Figures 1 – 3 under alternative identification assumptions. In particular, we follow Hesse et al. (2018) and impose a zero restriction for the impact responses of the output and prices to QE shocks. Moreover, after a QE shock, the response of the long rates are assumed to be negative for two months while those of the real equity prices are positive. Solid lines denote the median impulse responses while the shaded regions denote the 68% equal-tailed confidence bands.

Figure A.2: Impulse Responses When Federal Reserve's Long-term Asset Holdings to US GDP Ratio is Used Instead of Asset Purchase Announcements

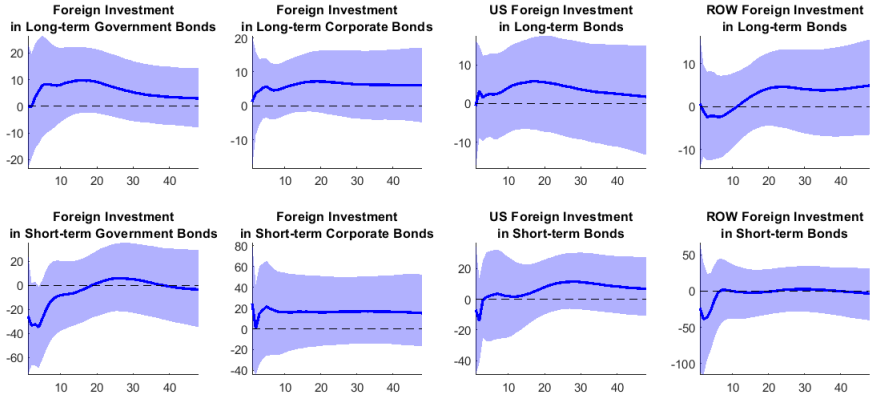
(a) Impulse responses of the US and main Canadian variables



(b) Impulse responses of other Canadian macro-financial variables

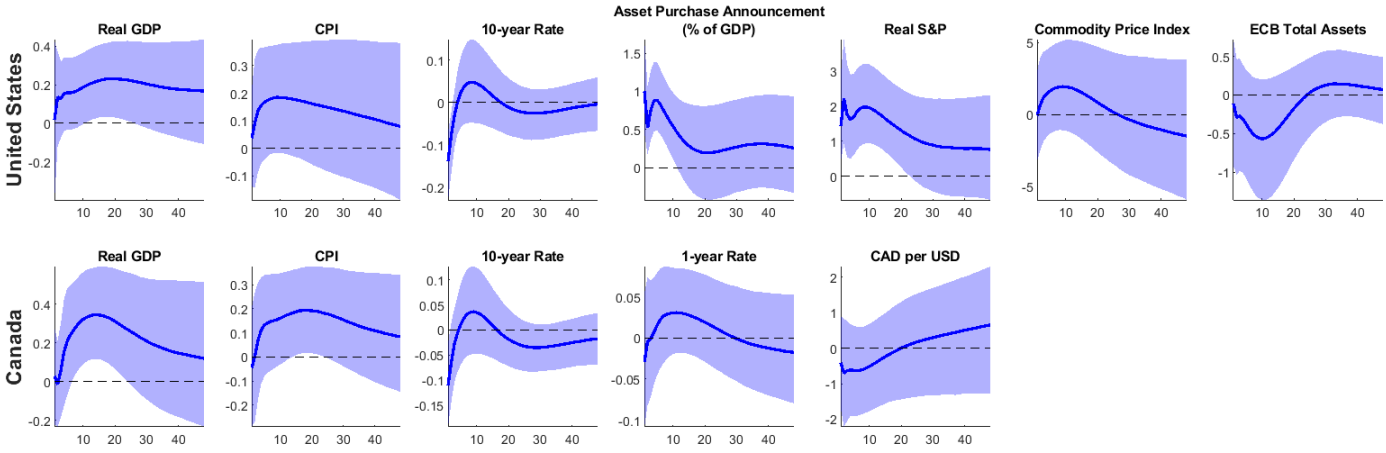


(c) Impulse responses of foreign investment in Canadian bonds



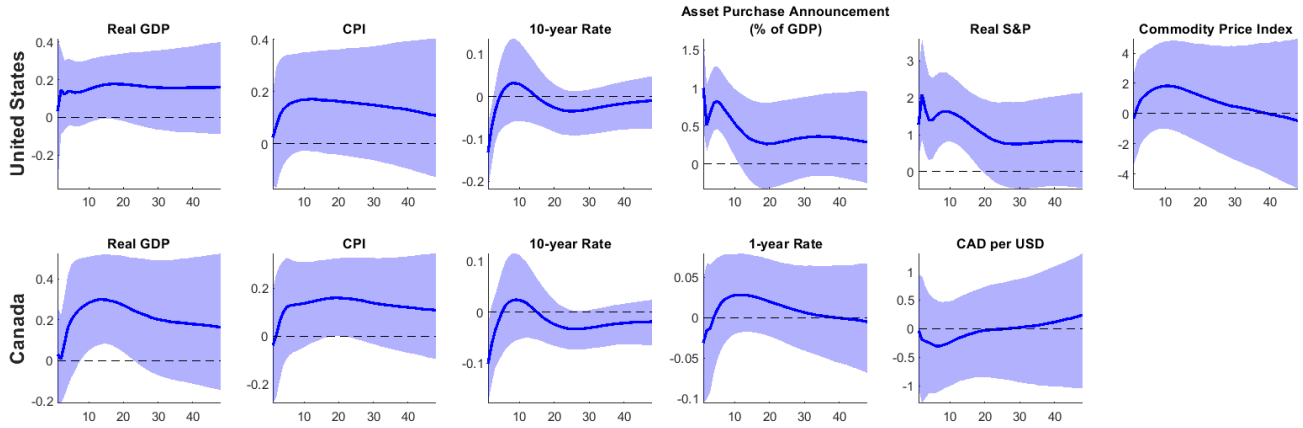
Note: We reproduce Figures 1 – 3 after changing the unconventional monetary policy variable. In particular, we use the Fed's long-term assets in lieu of the cumulative asset purchase announcements. All the identifying restrictions remain the same. Solid lines denote the median impulse responses while the shaded regions denote the 68% equal-tailed confidence bands.

Figure A.3: Impulse Responses of Main Variables with ECB Total Assets to Euro Area GDP Ratio as Control Variable



Note: We reproduce Figure 1 after including the ECB total assets into the foreign block variables. The rationale is to control for potential shocks/bias that might arise from the ECB QE. Solid lines denote the median impulse responses while the shaded regions denote the 68% equal-tailed confidence bands.

Figure A.4: Impulse Responses of Main Variables with Real Exchange Rate



Note: We reproduce Figure 1 after replacing the nominal exchange rate with the real one. Solid lines denote the median impulse responses while the shaded regions denote the 68% equal-tailed confidence bands.