Which Monetary Shocks Matter in Small Open Economies? Evidence from Canada*

Jongrim Ha[a] and Inhwan So[b]
[a]World Bank
[b]Bank of Korea

We investigate the monetary policy transmission in a representative small open economy—Canada—over the 2000–17 period. By using a novel set of external instruments, we identify the impacts of domestic (Canada) and foreign (United States) monetary shocks on financial and macroeconomic variables in Canada in a unified structural VAR framework. Our results first confirm that domestic monetary policy transmission operates through interest rate, foreign exchange, and credit channels in Canada. The results further suggest that U.S. monetary policy shocks also have sizable effects on financial conditions in Canada, in line with the credit and risk-taking channels of international monetary spillovers. That said, the U.S. monetary spillovers into Canadian macroeconomic variables could be offset by the fluctuations in exchange rates and net exports in line with the trilemma hypothesis. Finally, our results are robust to various types of instrumental variables on monetary policy shocks.

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1. Introduction

In a Mundell-Fleming world, with a flexible exchange rate, domestic monetary autonomy and open capital accounts are simultaneously compatible. As global financial markets become increasingly integrated and global factors become crucial drivers of local financial market developments, however, there have been extensive debates on the effectiveness of domestic monetary policy in small open economies with floating exchange regimes (Obstfeld 2015; Rey 2015, 2016; Aizenman, Chinn, and Ito 2016; among many others).[1] To shed some more light on this issue, this study reexamines domestic and cross-border monetary policy transmission in a novel structural vector-autoregressive (SVAR) model. To our knowledge, this paper is one of the first studies that investigate the impacts of local and foreign monetary policy shocks in a unified framework.

The different views on the Mundell-Fleming "trilemma" may reflect different perspectives on monetary policy independence and inconsistent empirical frameworks across studies. First, the existing studies on international monetary spillovers often focus on a single type of transmission channel—for instance, either the financial or the trade channel. The dilemma hypothesis predicts that monetary shocks originating from the center country determine the international financial conditions, and spill over to financial markets (and domestic demand) in other open economies, thereby leading to synchronized macroeconomic and financial conditions across the economies. On the other hand, in line with the trilemma, the fluctuations in exchange rates and net exports may buffer the impact of the financial spillovers onto macroeconomic outcomes. It is thus crucial to consider various transmission channels to truly argue the implications of foreign monetary policy shocks.

Second, studies have often focused on a single type of financial market, without considering the consequence on a variety of financial and credit markets that play different roles in monetary policy transmission (Dedola, Rivolta, and Stracca 2017; Gai and Tong 2019).[2] In addition, there is still no consensus on the role

[1]See Section 2.3 for a more detailed review of the literature on the debates.

[2]For example, when assessing monetary policy autonomy, Rey (2015, 2016) pays attention to the covarying general financial conditions among countries and

of foreign exchange rates, a key variable in the trilemma debate. Many earlier studies pointed out that conditional movements of foreign exchange rates exhibit puzzling deviations from the predictions of Dornbusch (1976)'s overshooting hypothesis (Eichenbaum and Evans 1995; Grilli and Roubini 1996; and Cushman and Zha 1997).[3] In contrast, more recent studies find evidence of more consistent movements of exchange rates following monetary policy shocks (Bjørnland 2009; Kim, Moon, and Velasco 2017; Rogers, Scotti, and Wright 2018; Inoue and Rossi 2019).

Third, the literature has typically not considered the consequence of domestic and foreign monetary policy shocks in a unified framework. Bernanke (2017) points out that the standard Mundell-Fleming model does not predict that small open economies can completely insulate their economy from policy shifts in a center country. The model instead implies that, under a flexible exchange regime, countries can insulate the domestic macroeconomic situation from external shocks by steering interest rates. This calls for a balanced view in understanding the trilemma debates: investigating the effectiveness of domestic monetary policy is equally as important as examining the transmission of international monetary shocks. However, it is econometrically challenging to distinguish the impact of foreign and domestic monetary policy shocks—in particular, if the monetary policies are correlated across countries.

Against this background, we contribute to the literature by investigating both international spillovers and domestic transmission of monetary policy shocks into various financial markets, trade, and macroeconomic variables in Canada, based on a single, open-economy SVAR framework. The model allows us to compare the impact of domestic (for which monetary spillovers from the center country are controlled) and foreign (for which the United States is

concludes that non-U.S. central banks lose their control over local financial conditions. Conversely, Obstfeld, Ostry, and Qureshi (2019) focus on the movements in short-term interest rates by implicitly assuming frictionless transmission of monetary shocks to the macroeconomy through capital and financial markets.

[3]The Mundell-Fleming model predicts that the cross-border transmission of the shocks is attenuated by adjustments in exchange rates. However, despite many results on the puzzling movements of exchange rates in response to monetary policy shocks, only a few studies reconcile the empirical results with the theory (Bruno and Shin 2015a).

the proxy) monetary shocks on multiple market interest rates at a variety of maturities, currency rates, credit costs, and capital flows, as well as effective exchange rates, export and import, in Canada.[4]

Our empirical findings are summarized as follows. First, as the trilemma hypothesis predicts, domestic monetary policy transmission appears to operate through a variety of channels in Canada. Both short- and long-term rates react significantly to domestic monetary policy shocks, confirming the role of the conventional interest rate channel. Foreign exchange rates in this process also respond significantly to monetary policy shocks, as the overshooting theory would predict. Contrary to a group of earlier findings that report counterevidence for the overshooting theory by Dornbusch (1976), we find that an increase in local policy rates causes the nominal exchange rate to appreciate instantaneously, and then to depreciate gradually. The shocks generate an increase in credit spreads in Canada, consistent with the predictions of the credit channel of monetary policy transmission.

In tandem, international spillovers of monetary policy shocks also play an important, and possibly stronger, role in driving financial conditions in Canada. Following U.S. monetary tightening, market interest rates (with both short- and long-term maturities) significantly rise, and the impacts persist for a prolonged period. More interestingly, overnight rates, which are monetary policy instruments in Canada, also respond significantly to U.S. monetary policy shocks. Following a contractionary U.S. monetary policy shock, credit spreads increase substantially, along with an immediate outflow of international capital investments. This is consistent with the predictions by the credit and risk-taking channels of international monetary policy transmission (Rey 2015, 2016; Hofmann, Shim, and Shin 2016). The correlated movements of U.S. and Canadian financial asset prices are also consistent with the international portfolio rebalancing channel as in Blanchard et al. (2016) and Alpanda and Kabaca (2020).

Finally, the response of macroeconomic variables in Canada diverges across the two types of monetary policy shocks. According

[4]As will be seen in Section 5, our results based on a counterfactual analysis suggest that the omission of U.S. monetary policy shocks can bias the estimated impact of domestic monetary policy transmission.

to our empirical results, following a domestic monetary tightening, output and price levels decline significantly, as New Keynesian theory would predict. On the other hand, U.S. monetary tightening leads to expansionary consequences on both output and prices in Canada. This result may have been partly driven by the expenditure-switching effects of U.S. monetary shocks, as the subsequent currency depreciation and the improvement in net exports offset the negative impacts of tightened financial conditions on the real economy in Canada. In line with the predictions by Mundell-Fleming's trilemma, the insulation of foreign monetary spillovers appears to have contributed to the Bank of Canada's successful policy operation for macroeconomic stabilization.[5]

Our empirical results offer a somewhat nuanced perspective on the trilemma debate. The results suggest that domestic monetary policy is still effective in stabilizing domestic financial and macroeconomic conditions when exchange rates freely float (i.e., the trilemma hypothesis has not been violated in Canada, at least for the sample period of this paper). At the same time, the effects of U.S. monetary spillovers on domestic financial and credit conditions are also evident, although the macroeconomic consequences of the spillovers could be offset by the fluctuations in exchange rates and external transactions. The upshot is that, depending upon the extent to which different types of transmission channels operate in the open economy, the macroeconomic consequences of foreign monetary policy spillovers could be quite different. This also highlights the crucial role of exchange rate in small open economies, in a financially globalized world: it can be either a shock amplifier or a shock absorber.

In this paper, we seek to avoid the potential simultaneity issue involving monetary policy actions and other macroeconomic or financial variables. To do so, we use a novel set of external instruments, instead of imposing arbitrary assumptions about

[5]Admittedly, however, this result can be mainly specific to the Canadian economy, which heavily depends on bilateral trades with the United States—in particular, trade in commodities. As argued by some earlier studies—including Iacoviello and Navarro (2019) and Ca' Zorzi et al. (2020)—the macroeconomic consequence of international spillovers could be highly dependent on country characteristics, as well as the sample period that governs the degree of various channels of transmission.

causal relationships among endogenous variables.[6] The identification scheme, initially proposed by Stock and Watson (2012) and Mertens and Ravn (2013), has considerable appeal because it exploits the attractive features of SVARs while addressing the identification issues raised above by using information from external instruments. Recent studies on monetary policy transmission combine an SVAR setup with such an identification scheme, exploiting high-frequency external instrument variables, obtained from futures rates on monetary policy instruments (Gertler and Karadi 2015; Nakamura and Steinsson 2018; Jarociński and Karadi 2020). Unlike the findings in the literature on the United States, this method has not yet been widely applied to the cases of other economies, including Canada.[7]

To overcome the issue, we test three different types of novel instrumental variables for monetary policy shocks in Canada: so-called (i) market based, (ii) model based, and (iii) narrative based. These types of instrumental variables have been widely employed in the literature to identify U.S. monetary policy shocks, but not for the case of Canada with only a few exceptions. First, we measure daily changes in spot overnight interest rates on monetary policy decision dates as a monetary policy surprise (IV1). Second, we calculate the conditional expectations for future short-term interest rates in Canada using a standard affine term structure model and take the changes around monetary policy announcements as the proxy for monetary policy shocks (IV2). Finally, benchmarking the approach in Romer and Romer (2004) and Champagne and Sekkel (2018), we use residuals in the forward-looking Taylor-rule equation as a proxy for monetary policy shocks (IV3). To the extent that each instrumental variable may deliver different information about the

[6] See Faust et al. (2003), Bjørnland (2009), and Gertler and Karadi (2015) on the endogeneity issues.

[7] One critical reason for this omission may be that there are no futures markets with active trading for the operating targets of monetary policy in those countries, and thus high-frequency identification of monetary surprise is not easily applicable. However, there are a few recent studies that employ high-frequency external instruments in other countries, including the case of the United Kingdom as in Cesa-Bianchi, Thwaites, and Vicondoa (2020). Using high-frequency movements in three-month sterling futures rates in the United Kingdom as a proxy for monetary policy surprise, the paper finds a significant impact from U.K. monetary policy shocks on its own economy.

monetary shocks, we employ these instrumental variables together in our analysis.[8]

We focus on the case of Canada as the best candidate country for this study. First, Canada is an advanced economy equipped with highly developed financial and credit markets. This allows us to test a variety of channels of monetary transmission. Second, Canada has adopted inflation targeting since the 1990s, when it adopted the flexible exchange rate regime and used short-term interest rates as the operating target for monetary policy. The records of monetary policy reports since then enable us to extract information on the Bank of Canada's own expectations of future macroeconomic situations and monetary policy stances. These features help obtain different types of instrumental variables on monetary policy shocks. Finally, compared with other small open economies, Canada shows the greatest macroeconomic and financial connections with the United States, which helps validate our selection of the United States as a center country (e.g., Cushman and Zha 1997).

Our research is closely related in its methodology and empirical results to the fast-growing body of recent studies on international spillovers of monetary policy (Rey 2015, 2016; Rogers, Scotti, and Wright 2018; Kearns, Schrimpf, and Xia 2020). Expanding on these studies, but diverging from them, our paper seeks to find commonality and heterogeneity in the impact of domestic and foreign monetary policy shocks on domestic financial and goods markets, and policy implications for the effectiveness of monetary policy implementation. Our study is also different from earlier studies in that our sample periods cover both pre- and post-global financial crisis periods, and, to that end, we resort to multiple sets of instrumental variables for domestic monetary policy shocks. Our paper is closely related, regarding domestic monetary policy transmission in Canada, to the

[8]For instance, movements in financial prices (IV1) are the closest in nature to the high-frequency futures data. However, they can include information shocks (Jarociński and Karadi 2020). In addition, when interest rates were close to their effective lower bounds or when unconventional policies were implemented, high-frequency variables may reveal merely limited information about the policy. The other type of IVs may exploit the policy information embedded in the yield curve irrespective of monetary policy regime (IV2) or distinguish the central bank information shocks (IV3).

analyses by Roldós (2006) and Champagne and Sekkel (2018). However, this paper differs from the earlier studies in that our focus is on the monetary transmission through multiple financial markets in Canada. Our work expands the discussion on the various channels of international monetary spillovers as in Iacoviello and Navarro (2019) and Ca' Zorzi et al. (2020), although we focus on a focal economy rather than multiple economies. Finally, this paper supplements a large group of studies on the trilemma debates. Our study is differentiated in the sense that we discuss hypotheses on both views of trilemma and dilemma within a single country framework while earlier studies mostly provide cross-country evidence that supports either of the two opposing views. In addition, while many earlier studies resort to regression analysis or event-study framework, we employ SVAR models with a novel identification scheme to examine dynamic impacts of local and foreign shocks.

The rest of this paper is organized as follows. In Section 2, we provide an overview of the theoretical channels of domestic and international monetary policy transmissions in the context of open-economy structural models. In Section 3, we specify an SVAR model and its identifying restrictions. Section 4 summarizes the empirical results. Section 5 presents the results of the robustness exercises and Section 6 concludes.

2. Monetary Policy Transmission in an Open Economy

In this section, we justify our SVAR framework by reviewing the theoretical channels of domestic and international transmission of monetary policy shocks in a small open economy. Our main focus is to understand the role of each transmission channel on the monetary policy independence of the economy in the context of the trilemma or dilemma hypothesis.

2.1 Domestic Monetary Policy Transmission

We first unravel the channels of domestic monetary policy transmission. Standard New Keynesian models, which assume sticky prices and frictionless financial markets, posit that monetary policy shocks are transmitted to credit costs and thus to aggregate spending operations via yield curves. Given the expectations hypothesis of the term structure, the effect of monetary policy decisions on the paths of current and expected short-term interest rates is summarized in (1):

$$r_t^m = m^{-1} E_t \left[\sum_{j=0}^{m-1} r_{t+j} \right] + \xi_t^m, \tag{1}$$

where r_t^m is an m-period zero-coupon government bond yield at time t, r_t is a short-term interest rate (e.g., the central bank policy rate), and ξ_t^m is an m-period term premium.

The term premium captures additional compensation for the interest rate (duration) risk inherent in medium- or long-term bond positions, as well as the residual effects of idiosyncratic market factors. If the premium is assumed to be constant over time, changes in the path of short-term rates will dominate changes in long-term rates, and allow central banks to influence output and inflation (*interest rate channel*).

When there is a degree of financial friction, credit markets would play an important role in the transmission of monetary shocks into financial and macroeconomic conditions (Bernanke and Gertler 1995). For instance, corporate bond yields (r_t^{cb}) usually exceed sovereign bond rates with the same maturity (r_t^m) to compensate for external finance premium (x_t^m), as in (2):

$$r_t^{cb} = r_t^m + x_t^m. \tag{2}$$

The *credit channel* particularly highlights the accelerating effect of monetary policy shock; for instance, contractionary monetary policy shocks tighten financial constraints in the private credit market and thus raise credit spreads (e.g., Gertler and Karadi 2015).

Finally, monetary policy shifts in a small open economy affect the value of domestic currency as indicated in the uncovered parity condition in (3).

$$r_t = r_t^* + E_t [\Delta e_t] + \rho_t, \tag{3}$$

where e_t is the nominal exchange rate vis-à-vis U.S. dollar and ρ_t is the currency risk premium in open economies at time t. Changes in foreign exchange rates then bring about changes in the relative price of tradable goods and in the value of assets denominated in foreign currency, and finally foreign demand for domestic products (*exchange rate channel*).

2.2 International Monetary Policy Spillovers

2.2.1 Financial Channel

The impact of foreign monetary shock on the domestic economy is another key issue in understanding monetary policy independence. This is because the extent of a central bank's control over macroeconomic developments, especially when looking through the lens of a small open economy in a financially integrated world, is controversial; policy and other monetary shocks can migrate from other countries under financial globalization, possibly causing monetary spillovers even when exchange rates float freely (Bruno and Shin 2015a; Passari and Rey 2015; Rey 2016). Taking this into account, we first consider international monetary transmission mechanisms which operate through short- and long-term yield structures.

With a high level of capital and financial market integration, a country's manipulation of short-term rates (r_t^*), especially if it is a large open economy such as the United States, directly affects short-term rates (r_t) in the other country following the interest-parity relationship represented in (3). Although, according to the Mundell-Fleming model, changes in the interest rate differential between the two countries are assumed to be absorbed mainly by adjustments in exchange rates, market interest rates in an open country are likely to be influenced by foreign monetary policy shocks, depending on the behavior of the exchange rate and the risk premium. For instance, the international connection between each country's long-term bond yields can be navigated in the form of (4) which combines Equations (1) and (3):

$$r_t^m = \underbrace{r_t^{*m}}_{(i)} + m^{-1} E_t \left[\sum_{j=0}^{m-1} \left(\underbrace{\Delta e_{t+j}}_{(ii)} + \underbrace{\rho_{t+j}}_{(iii)} \right) \right] + \underbrace{\xi_t^m - \xi_t^{*m}}_{(iv)}. \qquad (4)$$

Equation (4) implies that unexpected monetary policy shocks in a center country at first adjust market interest rates in a certain open economy (i). They also put additional pressure on market rates depending upon the responses of exchange rates and risk (term) premiums. If the balance sheets of borrowers and lenders in the open economy are denominated in U.S. dollars, for instance, the strong dollar caused by contractionary U.S. monetary shocks can tighten credit conditions in the open economy as well (*ii*). This is because a debtor's balance sheet becomes weak due to high liabilities relative to assets, and a creditor's lending capacity also drops. This retards economic activity and deteriorates the government fiscal position in the open economy. U.S. monetary tightening may also raise perceived risk and uncertainty in international financial markets. Consequently, the tightening can boost tail risks for the sovereign bonds of small open economies (*iii*), and compress capital flows into those bonds (*iv*), thereby leading to potentially unintended procyclical dynamics in their bond markets (*risk-taking channel*; Bruno and Shin 2015a; Hofmann, Shim, and Shin 2016, 2020). These channels work in the reverse in the case of monetary policy easing in the United States.

Finally, in a highly integrated financial market, particularly where the U.S. dollar is predominant as a funding and an investing currency, U.S. monetary policy shocks can also affect the net worth of agents through corporate bond markets in small open economies, thus making their financial conditions co-move (*international credit channel*; Rey 2016; Cesa-Bianchi and Sokol 2017).[9]

2.2.2 Trade and Aggregate Demand Channels

On top of the aforementioned financial channel, there are other types of transmission channels of U.S. monetary policy into open economies via trade and aggregate demand.[10]

The trade channel is based on the predictions of demand substitution between home- and foreign-produced goods and services, followed by the shifts of monetary shocks and the subsequent changes in the terms of trade. For instance, U.S. monetary tightening is

[9] As in Bernanke (2017), if r_t denotes a shadow price of credit, Equation (3) or (4) captures foreign credit availability in an open economy and ρ_t reflects the external finance premium.

[10] Note that some other studies refer to these channels as exchange rate channel and trade channel, respectively.

expected to lead to an appreciation (depreciation) of the U.S. dollar (other currencies) and, in turn, to enhance the competitiveness of open economies with flexible exchange rates. Output in the open economy will then rise, boosted by cheaper exports.[11] Thus the trade channel implies that the effects of monetary policy shocks on domestic and foreign economies are in an opposite direction in the case of open economies with flexible exchange rates such as Canada.

The aggregate demand channel rests on the idea of cross-border real spillover through trade. For an open economy which trades actively with the rest of the world, a substantial part of its aggregate demand is affected by its trading partners' business cycle. For instance, higher U.S. interest rates reduce incomes and expenditures in the United States, leading to lowered U.S. demand for both domestically produced and imported goods, and reducing activity and GDP abroad (Erceg, Guerrieri, and Gust 2005). Unlike the trade channel, the aggregate demand channel thus induces the effects of monetary policy shocks on domestic and foreign economies in the same direction.

Overall, the relative strength of each channel should depend on the share of exports and imports in economic activity, especially with the United States. In addition, more recent studies focus on the exchange rate pass-through to import (and export) prices in determining the strength of the trade channel. In this theory, currency invoicing in import and export prices plays a crucial role in the transmission of foreign monetary policy shocks into trades, output, and inflation in open economies (Cao, Dong, and Tomlin 2015; Gopinath 2015; Devereux, Dong, and Tomlin 2017; Gopinath et al. 2020).[12]

In the case that export items are priced mostly in the currency of the producer (commonly referred to as *producer-currency pricing*), as the Mundell-Fleming model predicts, a strong effect of expenditure switching is expected. For instance, a U.S. monetary tightening widens U.S. trade deficit (while exports fall, imports

[11]By contrast, a country that pegs its exchange rate against the U.S. dollar could experience the pressure of a currency appreciation that ultimately lowers its gross domestic product (GDP).

[12]For a detailed literature review of the relation between currency invoicing and exchange rate pass-through, see Ha, Stocker, and Yilmazkuday (2019) and Ca' Zorzi et al. (2020).

expand towards foreign goods in the United States) and trade surplus in its trading partners. On the contrary, if exports are priced in the currency of the importer (*local-currency pricing*), U.S. monetary policy spillovers through expenditure switching and exchange rate pass-through to inflation could be largely muted in non-U.S. economies. Finally, when all exports are priced in a single currency (*dominant-currency pricing*), the effects of U.S. dollar appreciation are inconsequential in the United States, specifically on its imports from abroad, since the prices of imported goods are unchanged. In a non-U.S. economy, however, a widespread rise in import prices is expected because of currency depreciation against the U.S. dollar, which induces expenditures switching away from imports and towards domestically produced goods.[13]

2.3 Dilemma vs. Trilemma Debates

The different nature of theoretical channels of international monetary policy spillovers leads to an active debate over the effects of foreign monetary shocks on the domestic financial market and macroeconomic conditions and the effectiveness of domestic monetary policies in open economies.

A group of recent studies emphasizing the role of global factors in driving domestic monetary policies has received much attention (Rey 2015, 2016). They argue that flexible foreign exchange regimes do not necessarily guarantee monetary policy independence in a world of open financial and capital markets. This is because monetary policy decisions in large economies inevitably affect global financial conditions, in turn affecting small open economies which typically have a high dependency on foreign currency borrowing. To the extent that market interest rates in small open economies are significantly affected by global financial conditions, their movements often deviate from a central bank's policy stance (Turner 2013). More recent literature highlights this aspect by focusing on international credit or the risk-taking channel (Bruno and Shin 2015a, 2015b; Passari and

[13]Note that the dominant-currency paradigm relies on the key assumptions that exporters have a substantial degree of monopoly power and U.S. dollar prices are sticky. Recent studies raise questions if these assumptions can hold outside the United States. See McLeay and Tenreyro (2020), for example.

Rey 2015),[14] or the international portfolio rebalancing channel as in Blanchard et al. (2016) and Alpanda and Kabaca (2020). As a result, central banks in small open economies can face a dilemma, rather than a trilemma, if the fluctuations in the exchange rate cannot fully insulate domestic economy from the impacts of external shocks, and if the policies designed considering only domestic conditions can result in unintended results including some trade-offs between output and inflation or between macroeconomic stabilization and financial stability.

Another strand of studies maintains that the trilemma remains alive (Obstfeld 2015; Aizenman, Chinn, and Ito 2016; Bekaert and Mehl 2019; Obstfeld, Ostry, and Qureshi 2019). These studies argue that exchange rate flexibility is still crucial in preserving the independence of monetary policy; as the Mundell-Fleming model predicts, the effects of foreign monetary spillovers on a small open economy are expected to be mitigated when adjustments in exchange rates change the terms of trade and trade balance in the economy. The studies thus argue that changes in monetary policy still can steer domestic inflation and output gap targets regardless of external developments (Bernanke 2017). Increased co-movement of interest rates across countries may be largely attributable to business cycle synchronization rather than intensified financial interconnection across jurisdictions (Klein and Shambaugh 2015; Aizenman, Chinn, and Ito 2016; Caceres et al. 2016). According to their views, financial integration can even enhance the effectiveness of monetary policy because currency appreciation after policy rate rises debases the value of foreign assets, thereby having an aggregate-demand-reducing negative wealth effect (Georgiadis and Mehl 2015).

Finally, a group of recent studies (among them, Han and Wei 2018; Cheng and Rajan 2020) focuses on asymmetric effects of foreign (or global) shocks and suggests the hypothesis of "2.5-lemma" or something between a trilemma and a dilemma.

[14]These studies suggest that changes in credit condition or risk appetite in international financial markets translate into local financial markets in open economies through the global financial factor or global financial intermediaries.

3. Estimation of SVAR Model

3.1 SVAR Modeling

We assume the economy is described by a structural form equation (5):

$$AY_t = \sum_{i=1}^{g} B_i Y_{t-i} + \varepsilon_t, \tag{5}$$

where Y_t is an $n \times 1$ vector of macroeconomic and financial variables. A and $B_i(\forall i \geq 1)$ are non-singular coefficient matrices. ε_t is an $n \times 1$ structural disturbances vector and serially uncorrelated. $E(\varepsilon_t \varepsilon_t') = I$ where I is the identity matrix (i.e., structural disturbances are assumed to be mutually uncorrelated). g denotes the optimal number of VAR lags, which can be set based on the information criteria.[15] For notational brevity, the specification in (5) omits deterministic terms and exogenous regressors.

Pre-multiplying each side of the equation by A^{-1}, we obtain a reduced-form representation (6):

$$Y_t = \sum_{i=1}^{P} \alpha_i Y_{t-i} + e_t, \tag{6}$$

where $\alpha_i = A^{-1} B_i$, and e_t are the reduced-form residuals which are related to the structural shocks by (7):

$$e_t = \begin{bmatrix} e_t^p \\ e_t^q \end{bmatrix} = S\varepsilon_t = [s^p s^q] \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^q \end{bmatrix} \tag{7}$$

with $S = A^{-1}$. e_t^p are the residuals of domestic and foreign monetary policy instruments (i.e., $e_t^p = \left[e_t^{MP*} e_t^{MP}\right]'$) and e_t^q is a vector for the residuals of the other variables. The analogous definition applies to structural shocks ε_t^p and ε_t^q. s^p and s^q denote the column in matrix S that corresponds to the impact of structural policy

[15] We consider the Schwarz information criteria or Hannan-Quinn information criteria. In our estimation, we set two lags ($g = 2$) and find no serial correlation of VAR residuals.

shocks ε_t^p and ε_t^q, respectively, on the vector of reduced-form residuals (e_t). The variance-covariance matrix of the reduced-form VAR is $\Sigma = E[e_t e_t'] = E[SS']$.

The structural moving average representation as a function of structural shock is given as (8):

$$Y_t = \sum_{j=0}^{\infty} C_j S \varepsilon_{t-j} = \sum_{j=0}^{\infty} C_j s^p \varepsilon_{t-j}^p + \sum_{j=0}^{\infty} C_j s^q \varepsilon_{t-j}^q, \tag{8}$$

where C_j denotes the coefficients of the structural moving average (MA) form. Accordingly, if the endogenous variable responds to monetary policy innovations, the impulse response function (IRF), which is the dynamic response of the k-th element of vector Y (Y_k) to a unit shock of ε_t^p at time $t+j$, can be obtained by (9):

$$IRF_{k,j} = \frac{\partial Y_{k,t+j}}{\partial \varepsilon_{k,t}^p} = C_{k,j} s^p, \tag{9}$$

where $C_{k,j}$ is the k-th row of C_j.

3.2 Data

Open-economy monetary SVAR models in the literature typically consider short-term interest rates, foreign exchange rates, and macroeconomic variables such as output and price as endogenous variables for domestic economy in studying the monetary policy transmission (Kim 2001; Bjørnland 2009; Passari and Rey 2015; Rey 2015, 2016). Expanding on this, we employ 11 monthly macroeconomic and financial variables in the SVAR, reflecting the theoretical setup described in Section 2: logs of seasonally adjusted U.S. and Canadian consumer price index (P* and P), logs of seasonally adjusted U.S. industrial production (Y* and Y), U.S. and Canadian policy interest rates (MP* and MP), three-month and five-year Canadian government bond yields (R3m, R5y),[16] short- and long-term credit spreads (CS3m, CS3y), capital inflows to Canada (in Canadian dollar; CF), and logs of the nominal foreign exchange rate

[16]The variables are specified in levels to implicitly determine any potential co-integrating relationship between them; see Hamilton (2020).

Table 1. List of Data

Category	Variables
United States	Y*: Industrial Production (S.A.) P*: PCE Inflation (S.A.) MP*: Effective FFR
Canada	Y: Industrial Production (S.A.) P: Consumer Price Index (S.A.) MP: Money Market Financing Rates R3m: TB (Three-Month) Yields R5y: TB (Five-Year) Yields CS3m: Corporate Paper Rate – TB Rate (Three-Month) CS3y: Mortgage Bond Rate – TB Rate (Three-Year) CF: Net Capital Inflow to Canada (in Mil. Canadian Dollar) FX: Nominal Foreign Exchange Rate per U.S. Dollar
Control Variables	Commodity Price Index; U.S. Dollar Index; CBOE VIX Crisis Dummy Variable with 1 for the Period between September 2008 and June 2009

against one unit of the U.S. dollar (FX).[17] Following the prior literature, four external variables are included in the SVAR system to isolate exogenous latent factors that can affect endogenous variables simultaneously: the international commodity price index, a dummy variable for the global financial crisis, the Chicago Board Options Exchange (CBOE) volatility index (VIX), and the dollar index.[18] The sample period is January 2000–December 2017.[19] Table 1 summarizes the description of the data.

[17]In Section 5, we additionally test the robustness of main results by replacing foreign policy rates (effective federal funds rates) with shadow overnight rates as proposed in Wu and Xia (2016) and U.S. T-bill yields with one-year maturity.

[18]Unlike Rey (2015, 2016), we consider the VIX as an external variable because we focus more on the direct spillovers of U.S. monetary shocks. However, our robustness test (as shown in Section 5) which includes the VIX as an endogenous variable confirms that the main results are not sensitive to this alteration.

[19]Note that part of the sample considered in the paper was the period when U.S. interest rates were stuck at or close to the zero lower bound and when U.S. monetary policy involved unconventional measures, including quantitative easing (QE) and various forms of forward guidance. Thus, we compare the result with the ones in pre- and post-crisis periods to verify the robustness. See Section 4.2.2 for the results.

3.3 Identification of Monetary Policy Shocks

We employ the external instrument identification strategy, which avoids imposing any strong assumptions on the contemporaneous interactions among endogenous variables. Expanding on the recent studies, we recover structural parameters related to monetary policy shocks using a variety of instrumental variables. The novel part of our analysis is that we consider the transmission of domestic and foreign monetary policy shocks together in a single framework while avoiding the simultaneity problem. This enables us to evaluate and compare the overall impacts of each shock in an open economy. More specifically, this unified empirical setup also helps analyze the impact of domestic monetary shocks while we isolate the impact of foreign shocks, and vice versa. Without considering both types of monetary policy shocks, especially in a highly open economy such as Canada, the identification of monetary policy shocks and their dynamic impacts may be biased due to the omitted-variables problem. In identifying domestic and foreign monetary policy shocks, we follow Mertens and Ravn (2013)'s approach to orthogonalize the two shocks by assuming that U.S. monetary policy shocks have a contemporaneous impact on local (Canada) monetary policy but not vice versa.[20] The procedures for the identification of monetary policy shocks are summarized in Appendix A.2.

3.4 Instrumental Variables

A valid instrument for monetary policy shocks should satisfy the following two conditions as in (10) and (11):

$$rank(E[Z_t \varepsilon_t^p]) = L \qquad \text{(relevancy)} \qquad (10)$$

$$E[Z_t \varepsilon_t^q] = 0 \qquad \text{(orthogonality)}, \qquad (11)$$

where L is the number of endogenous variables, and Z is the instrumental variables.

[20]In this two-country VAR model, we also impose a block exogeneity restriction in Equation (6). In other words, we assume that a small open economy, Canada, does not have any feedback effects on a foreign country or the world economy, the United States. See for example, Cushman and Zha (1997), Kim and Roubini (2000), Cesa-Bianchi and Sokol (2017), and Dedola, Rivolta, and Stracca (2017).

Given that the effects of monetary policy on the economy are determined by the reaction of market participants to monetary policy shocks, the literature has extensively used the changes in short-term futures rates around the announcements of monetary policy decision as a proxy for monetary policy surprise (Kuttner 2001; Gürkaynak, Sack, and Swanson 2005; Gertler and Karadi 2015; Miranda-Agrippino 2016; Cesa-Bianchi, Thwaites, and Vicondoa 2020).[21] Such variations reflect changes in the expectations of market participants regarding future interest rates (or monetary policy stance).

Following Gürkaynak, Sack, and Swanson (2005) and Gertler and Karadi (2015), in identifying U.S. monetary policy shocks, we use changes in the federal fund futures rates and Eurodollar futures rates (MP1, FF4, ED2, ED3, and ED4) with a variety of maturities, within a narrow (30-minute) window around FOMC meetings. These variables are now extensively employed in the literature as proxies for U.S. monetary surprises in that they capture exogenously the revisions in market participants' expectation around the monetary policy announcements. We extend the high-frequency series of U.S. monetary policy shocks from that of Gertler and Karadi (2015) to 2017.[22]

On monetary policy shocks in Canada, since the country is not yet equipped with derivative markets for monetary policy instruments with ample depth, we instead use an alternative set of high-frequency measures of short-term interest rates (repo rates, prime rates, overnight rates, three-month government bond yields) (classified as IV1). However, the recent literature argues that the high-frequency data may contain information not only about policy

[21] This includes high-frequency movements (e.g., 30-minute window) of short-term futures rates (federal funds futures rates and three-month sterling futures rates) around monetary policy decision meetings.

[22] Here we use the instrumental variables by Gertler and Karadi (2015) considering their relevancy. Nakamura and Steinsson (2018) and Jarociński and Karadi (2020) differentiate central bank information shocks with pure monetary policy effects. As a robustness check, we test the instrumental variables, decomposing the series into the pure monetary policy shocks and central bank information shocks, similar to Jarociński and Karadi (2020). The results are not qualitatively different. The details are provided in Section 5.

Table 2. Instrumental Variables

Country	Category	Description
United States	MP1	Changes in the expectations of current-month federal funds futures rates (FFFRs)
	FF4	Changes in 3-month-ahead FFFRs
	ED2	Changes in 6-month-ahead Eurodollar futures rates (EDs)
	ED3	Changes in 9-month-ahead EDs
	ED4	Changes in 12-month-ahead EDs
Canada	Market Based (IV1)	MP surprise = daily change in the short-term spot rates on MP decision date (overnight, repo, and prime rates)
	Model Based (IV2)	Change of expected sum of short-term rates (EH) (computed by the affine term structure model)
	Narrative Based (IV3)	Residuals from policy reaction function of the Canada central bank (Romer and Romer 2004; Champagne and Sekkel 2018)

but also about central banks' assessment on the economic outlook (Jarociński and Karadi 2020) and that they provide only limited information when unconventional policies were adopted. To overcome these limitations, we also test other types of instrumental variables: changes in expected future short-term rates implied by the term structure model (IV2), and residuals of central bank policy reaction functions (IV3). The instrumental variables tested for Canada and the United States are explained in detail below and summarized in Table 2.[23]

[23]Following Gertler and Karadi (2015), we construct monthly-frequency instrumental variables by taking the following steps. First, for each day of the month, we compute cumulative monetary surprises over the recent 31 days; and second, we compute monthly surprise series using the sum of the cumulated daily surprises within each month.

3.4.1 IV1: Daily Short-Term Spot Rate Changes Around Monetary Policy Announcements

Following Cochrane and Piazzesi (2002) and others, we first consider the daily movements of short-term interest rates around monetary policy decision announcements, by defining the daily change in the spot rates as a monetary policy surprise. Financial market participants anticipate monetary policy decisions before actual policy announcements, and short-term rates may have already been adjusted beforehand. Conversely, if the monetary policy announcement is a mere surprise, market rates will adjust only after the announcements.[24]

This approach rests on the following two assumptions. First, asset prices move according to the efficient market hypothesis. In such market conditions, new information, including a monetary policy decision, is reflected in the asset prices as soon as it is released. Second, short-term rates are more sensitive to monetary policy news than long-term rates because central banks typically adjust short-term rates to steer macroeconomic variables. This indicates that news other than a monetary policy decision on the dates can be regarded as white noise. Figure A.1 in Appendix A shows the movements of representative short-term rates for the United States and Canada. Short-term rates deviate significantly from policy targets when markets expect adjustments in the monetary policy stance.

3.4.2 IV2: Monetary Policy Surprise Implied in Term Structure Model

We calculate the conditional expectation for short-term interest rates using a standard affine term structure model, and take its changes around monetary policy decisions as the proxies of monetary policy shocks. The expectations hypothesis assumes that long-term interest rates consist of the expected path of short-term rates and term premium, as illustrated in Equation (1). Given that the

[24] Another possible market-based instrument for monetary surprise is a measure of the shifts in overnight index swap (OIS) rate in Canada. We test these instruments as an alternative to our IV1 and find that overall results do not change despite the wider confidence bands with the use of these instruments that mostly reflect the shorter sample periods. See Section 5 for the details.

current and future paths of short-term interest rates are directly linked to the effects of the interest rate channel and forward guidance, changes in the expected future path of short-term interest rates around monetary policy decisions will mirror the changes in a market participant's expectations of the monetary policy stance of central banks (Chari, Stedman, and Lundblad 2017; Curcuru et al. 2018; etc).[25]

We compute the changes in the expected future path of short-term interest rates from zero-coupon bonds with the maturities of 3, 6, 9, and 12 months. Data for zero-coupon rates are obtained from Bank of Canada. For the estimation, we follow Adrian, Crump, and Moench (2013) considering that the methodology has some computational advantages over typical estimation strategies such as maximum likelihood especially when yields of high frequency are used. See Appendix A.3 for technical details of the estimation.

3.4.3 IV3: Residuals from Policy Reaction Functions

Benchmarking the approach in Romer and Romer (2004), and the extension of the methodology to Canada as in Champagne and Sekkel (2018), we use residuals in the forward-looking Taylor-rule equation as a proxy variable for Canadian monetary policy shocks (IV3). The main idea is that by using internal forecast information in the central bank, we can extract a measure of unanticipated movement in monetary policy target rates (or surprise component) which is orthogonal to information about past, current and future economic developments.

We follow Champagne and Sekkel (2018) and take two steps in estimating the Taylor-rule equation. First, using the minutes of

[25] Conventional monetary policies are believed to affect bond yields mostly through current and expected future paths of short-term rates. Unconventional policies, including balance sheet policies, affect the expected path of short-term interest rates by signaling that short-term rates will remain low for long (signaling channel), and the term premium by influencing supply-demand imbalances in bond markets (portfolio balance channel). When measuring the impacts of monetary policy shifts using the moves of expected short rates, we consider the fact that the Bank of Canada had not adopted balance sheet policies over the sample period. In light of this, our approach is different from that of Inoue and Rossi (2019), who focus on the effects of monetary policy on the whole yield curve.

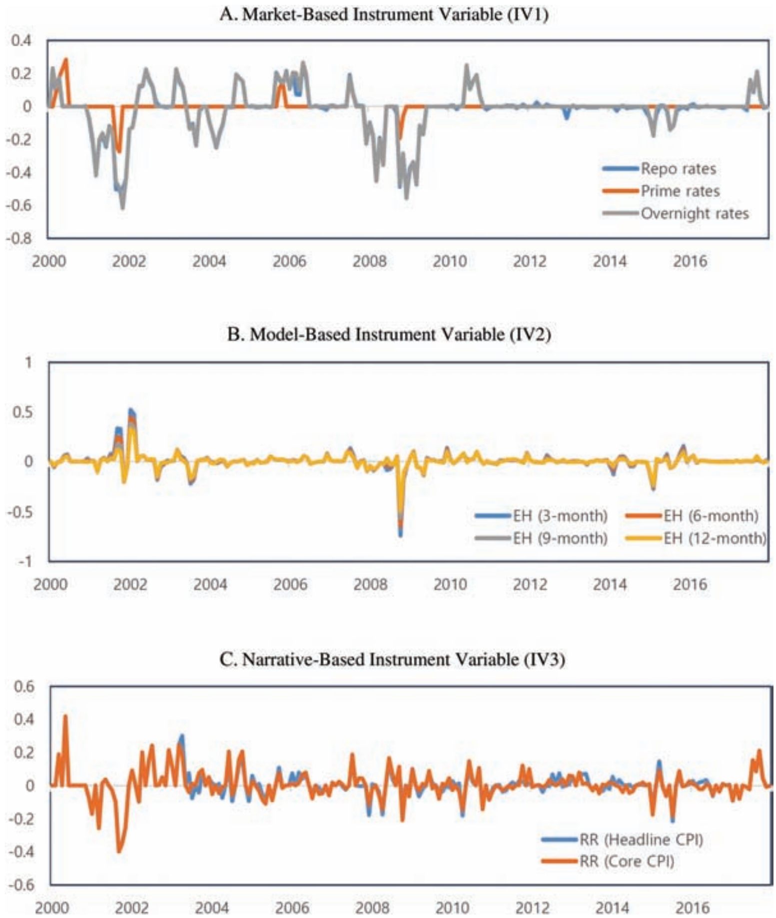
monetary policy reports (source: Bank of Canada Monetary Policy Reports), we collect real-time forecasts for output and inflation in Canada. We use both headline and core consumer price index (CPI) inflation for the inflation forecast. Second, we regress changes in monetary policy target rates from the previous monetary policy decision meeting to the current meeting (Δr_m) on a set of explanatory variables that purge the intended policy rate. Technical details of the estimation are presented in Appendix A.4.

3.4.4 Properties of Instrumental Variables

Figure 1 depicts the movements of selected instrumental variables over the sample period. In panel A, we show the monthly series of changes in representative three short-term rates in Canada—repo rates, overnight rates, and prime rates—around monetary policy decision dates (IV1). The series shows distinct movements in principle after the dot-com crash in early 2000 and the global financial crisis around 2008–09; however, the prime rates exhibit relatively less variation around the events than the other two rates. Panel B describes the instrumental variables related to the changes in the sum of expected short-term rates for the maturities of 3, 6, 9, and 12 months (IV2). All the variables follow a similar path, and the changes for the three-month bond move with larger variation over time. Panel C exhibits the residuals from the central bank's policy reactions functions, using the headline and core CPI as anchoring price measures (IV3). It is notable that the variables show comparatively less reaction during major episodes such as the global financial crisis, indicating that some of the variation in policy rates is already anticipated by economic agents.

Figure A.2 in Appendix A.1 summarizes the cross-correlations of the instrumental variables in the format of a heatmap. The figure suggests that the instrumental variables are highly and positively correlated to each other but with different degrees, which validates our use of multiple instrumental variables. The positive correlations are relatively higher among the same types of variables, and among the variables with the same countries (the average coefficients of the instrumental variables: the United States 0.74, Canada 0.42). The cross-correlations of instrumental variables between the United

Figure 1. IVs for Canadian Monetary Policy Shocks



States and Canada are 0.10 on average, which are smaller but not trivial.[26]

[26]By reporting strongly positive correlations among cross-country monetary policy shocks obtained from 280 macroeconomic models, Georgiadis and Jančoková (2020) argue that the multilateral monetary policy shocks can co-vary due to strong financial spillovers. In this context, given the close economic relationship between the two countries, the positive cross-correlation among shocks is not surprising. Reflecting this aspect, we also consider the monetary policy spillovers from the United States to Canada in identifying the monetary policy shocks, as explained further in Appendix A.2.

Next, we report t-statistics, F-statistics (in the case of multiple instrumental variables), and R^2s from the first-stage regression of residual of policy indicators projected on the instrumental variables to test the relevance of the instrumental variables. The results are summarized in Table 3 for the United States (panel A) and Canada (panel B).[27] To the extent that "F-statistics > 10" is commonly regarded as a rule-of-thumb criterion to protect against the weak instrumental-variable problem in practice, the instrumental variables for which F-statistics in the first-stage regression are higher than 10 are strongly relevant to the exogenous monetary policy shocks. The instrumental variables are finally chosen considering their relevancy and the type of data used for the construction.

4. Empirical Results

To investigate how the domestic and international monetary policy transmissions operate in Canada, we now present the impulse responses of financial, capital flow, and macroeconomic variables to domestic monetary policy shocks, and then to U.S. monetary policy shocks.

4.1 Effects of Canadian Monetary Policy Shocks on the Economy

Figure 2 displays the impulse response of Canadian variables to a contractionary monetary policy shock that increased overnight rates in Canada by 1 percentage point. Panels A through C in the figure sequentially report the empirical results using three different types of instrumental variables, as explained in the previous section. Figure 3 shows the results where we employ the three types of instrumental variables together. As the results are consistent across different types of instrumental variables, we focus on those with all types of instrumental variables that report the highest explanatory power (i.e., R^2) in the first-stage regression.

[27] Staiger and Stock (1997) suggest that the F-statistics of the instrumental variables should be greater than 10 to ensure that the maximum bias in the IV estimators is less than 10 percent. In the case of a single instrumental variable, the F-statistics should be replaced by t-statistics.

Table 3. Relevancy Test Results

A. U.S. IV						
		t				
F	R^2	*MP*1	*FF*4	*ED*2	*ED*3	*ED*4
17.51	0.30	5.81	–1.53	–0.63	0.98	–1.05
B. Canada IV						
Market-Based Instrument Variable (IV1)						
				t		
		F	R^2	*overnight*	*repo*	*prime*
$IV_{CA,1} =$						
{overnight}		58.31	0.22	7.64	—	—
{repo}		55.04	0.21	—	7.42	—
{overnight, repo}		**29.64**	**0.22**	**1.89**	**–0.99**	—
{overnight, repo, prime}		21.05	0.23	1.94	–1.15	1.80
Model-Based Instrument Variable (IV2)						
			t			
	F	R^2	EH_{3m}	EH_{6m}	EH_{9m}	EH_{12m}
$IV_{CA,2} =$						
$\{EH_{3m}\}$	7.50	0.03	2.74	—	—	—
$\{EH_{6m}\}$	11.36	0.05	—	3.37	—	—
$\{EH_{3m}, EH_{6m}\}$	**31.59**	**0.23**	**–7.02**	**7.34**	—	—
$\{EH_{3m}, EH_{6m}, EH_{9m}, EH_{12m}\}$	17.50	0.25	1.71	–1.75	1.78	–1.79

(*continued*)

Table 3. (Continued)

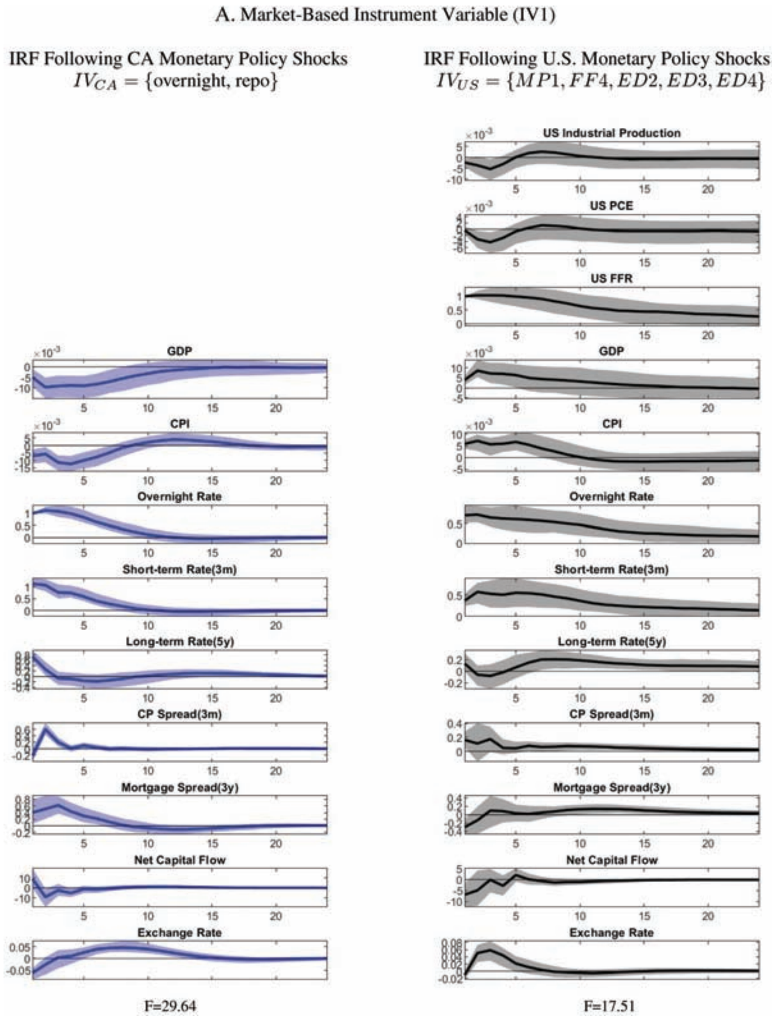
B. Canada IV

Narrative-Based Instrument Variable (IV3)

			t			
	F	R^2	RR_{hcpi}	RR_{ccpi}	CS_{new}	CS_{full}
$IV_{CA,3} =$						
$\{RR_{hcpi}\}$	81.10	0.28	9.01	—	—	—
$\{RR_{ccpi}\}$	92.55	0.30	—	9.62	—	—
$\{CS_{new}\}$	17.44	0.08	—	—	4.18	—
$\{CS_{full}\}$	27.87	0.08	—	—	—	5.28
$\{RR_{hcpi}, RR_{ccpi}\}$	**46.23**	**0.30**	**0.48**	**2.91**	—	—
$\{CS_{new}, CS_{full}\}$	14.86	0.14	—	—	1.32	3.37

Note: F, R^2, and t denote F-statistics, R^2, and t-statistics based on the first-stage regression of the instrumental variable(s) on the VAR residuals for the U.S. or Canada MP variable. Bold parts are the finally chosen IV sets for each category. Each instrumental variable name represents the type of data used for construction, which is explained in Table 2. For instance, "$IV_{CA,1}$\{overnight\}" and "$IV_{CA,1}$\{repo\}" indicate market-based instrumental variables (IV1) for Canadian monetary policy shocks based on overnight rates and repurchase rates, respectively. Similarly, "$IV_{CA,2}\{EH_{3m}\}$" indicates model-based instrument variables (IV2) based on the changes in expected sum of short-term (three-month) rates. "$IV_{CA,3}$" indicates narrative-based instrument variables, i.e., residuals from policy reaction function of the Canada central bank, benchmarking Romer and Romer (2004) ("*RR*") or Champagne and Sekkel (2018) ("*CS*").

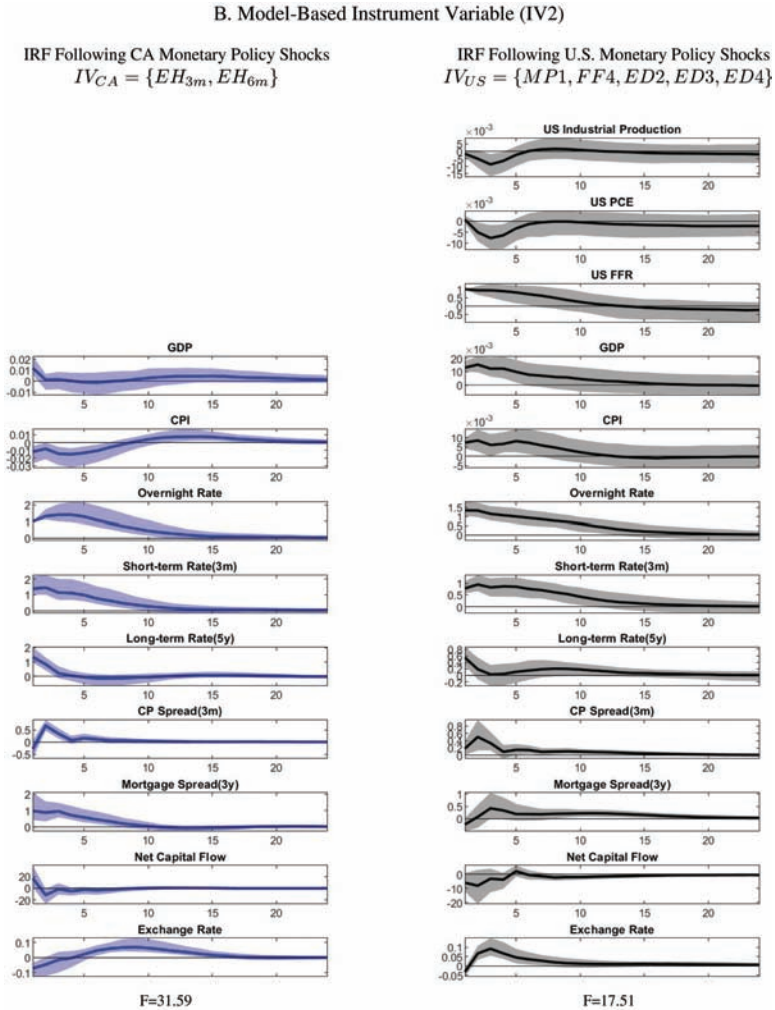
Figure 2. Impulse Response of Canada Variables to Monetary Shocks



(*continued*)

Market Interest Rates. An interest rate channel of monetary policy operates in Canada; following a contractionary domestic monetary policy shock, Canadian market interest rates respond significantly, although the magnitude and persistence of the impact

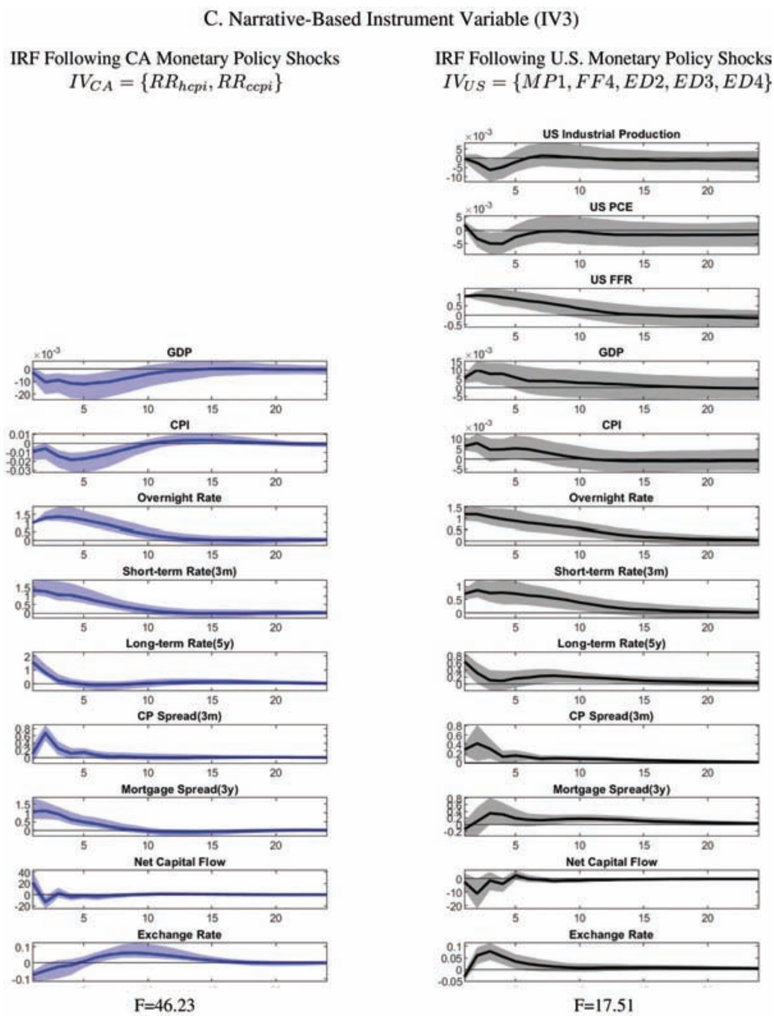
Figure 2. (Continued)



(*continued*)

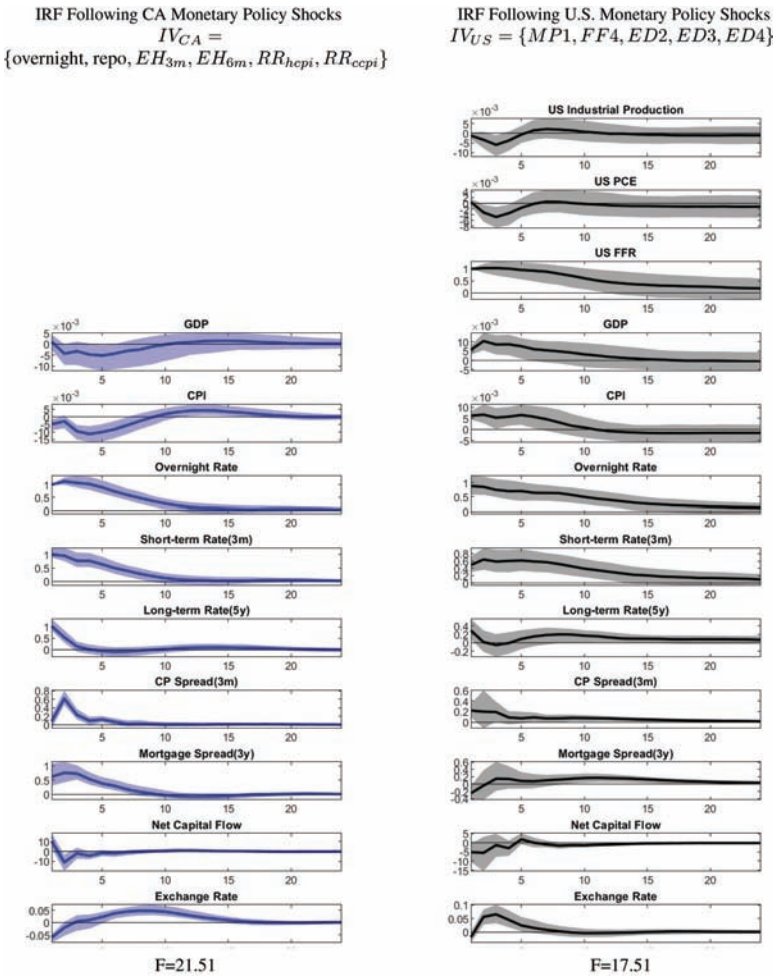
weaken with the bond yields with longer maturity. Short-term interest rates (three-month T-bill rates) move in tandem with overnight rates, by rising around 100 basis points (bps) on impact, and the effects persist for a year. Long-term rates (five-year bond yields)

Figure 2. (Continued)



Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for capital flow). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

Figure 3. Impulse Response of Canada Variables to Monetary Shocks



Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for trade). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

also increase sizably, but the impact dies out quickly—within two to three months after the shock.

More short-lived responses of long-term interest rates may reflect the offsetting effects of various factors that determine the level of long-term interest rates, as illustrated in Section 2. First, the impact of monetary tightening could be dampened due to the subsequent exchange rate appreciations and weakened future inflation expectations. Also, as a country with a high level of foreign currency debt, especially in U.S. dollars, currency appreciations can enhance the borrowing capacity in Canada, thereby reducing the tail risks associated with currency risk premium (Hofmann, Shim, and Shin 2016).[28]

Exchange Rates. Following the contractionary (+100 bps) monetary policy shock, the Canadian dollar immediately appreciates by around 5 percent, and then depreciates gradually until it reaches the original level. This is in line with the predictions of the overshooting theory in Dornbusch (1976), which is based on the uncovered interest rate parity (UIP) condition. Earlier studies often find that, following a contractionary monetary policy shock, domestic currency either depreciates (exchange rate puzzle; see Grilli and Roubini 1996), or if it appreciates, it does so for a prolonged period of up to three years, thereby exhibiting hump-shaped behavior that violates the UIP condition (delayed overshooting; see Eichenbaum and Evans 1995; Cushman and Zha 1997; Kim, Moon, and Velasco 2017). Unlike the foregoing findings, our results show that the initial appreciation of Canadian currencies on a contractionary monetary shock is not followed by long and persistent appreciation.

Capital Flows. Net foreign capital inflows to Canada increase immediately following a contractionary domestic monetary policy shock, partially reflecting the subsequent increase in domestic-foreign interest rate differentials as well as the appreciation of the domestic currency. This impact quickly dissipates, however, as the domestic currency starts to depreciate, and the negative impact of

[28]The ratio of foreign liability, including portfolio investment and loans, over nominal GDP has persistently increased in Canada (2000:Q4: 123.5% → 2018:Q4: 199.3%; source: Statistics Canada). U.S.-dollar-denominated debt is one of the dominant foreign-currency debts, which is 32.3 percent of total foreign liability.

monetary tightening is transmitted to macroeconomic variables over time.

Credit Spreads. A credit channel of monetary policy transmission also appears to operate in Canada, notably, through both short- and long-term financing premiums. Following a contractionary monetary policy shock, credit spreads increase up to 60 bps in short-term instruments (three-month CP spreads), with statistical significance. The credit spread under long-term instruments (three-year mortgage bond spreads) demonstrates a similar magnitude of response, but the impact persists for a prolonged period, seven to nine months after the shock.

Output and Prices. Following a contractionary monetary policy shock, both output (monthly GDP) and consumer prices in Canada significantly decrease by up to 1 percent. The impacts are maximized around two quarters after the shock, and persist for around a year. These results are consistent with New Keynesian theories that highlight the role of financial and credit markets in the monetary policy transmission.[29] The results are also in line with earlier empirical studies on monetary policy transmission in Canada, including Roldós (2006) and Champagne and Sekkel (2018), despite the different sample periods and different identifying assumptions of monetary policy shocks.

4.2 Effects of U.S. Monetary Policy Shocks on the Canada Economy

Next, we examine the effects of U.S. monetary policy shocks on the financial markets, trade, and macroeconomic variables in Canada. On the right-hand sides of Figures 2 and 3, we plot the impulse responses of the variables to a 1 percentage point increase in U.S. federal funds rates.[30] Again, our focus is mainly on the results with all types of instrumental variables for Canada monetary policy shocks.

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[29] The response of output is weaker than expected and less statistically significant than prices, partly reflecting the capital inflows caused by exchange rate appreciation.

[30] As shown in Figures 2 and 3, U.S. monetary tightening is unambiguously followed by declines in U.S. output and prices levels, which are standard in the literature. In this section, we focus on the transmission of the shocks into the Canadian economy.

4.2.1 Financial Market Indicators

Policy Rates in Canada. There appears to be monetary policy synchronization between the United States and Canada. Overnight interest rates in Canada significantly increase following a contractionary U.S. monetary policy shock, and the impact persists longer than a year. The response is comparable in light of the magnitude and persistence of what follows domestic monetary policy shock.

What does this imply? Does it mean that the Canadian central bank does not have monetary autonomy? Given our significant results on the effects of domestic monetary policy, as shown in the previous subsection, the answer will be no. This result may instead reflect the economic dependence of Canada on the United States in the aspects of trade and financial transactions. On the one hand, the consequences of U.S. monetary policy shocks on the economy could spill over to Canada. Alternatively, this result may reflect synchronized monetary policy actions in Canada and the United States, to neutralize the impact of U.S. monetary policy shocks on Canadian financial markets by reducing the volatility in exchange rates and capital flows (Turner 2013). It is also likely that as an inflation-targeting country, Bank of Canada responds to inflation fluctuations driven by U.S. monetary shocks.

Market Interest Rates. In line with the interest rate parity condition, as illustrated in Equation (4) in Section 2, U.S. monetary tightening raises interest rates in Canada with both short- and long-term maturities; a 1 percentage point increase in the federal funds rates raises three-month T-bill rates and five-year bond yields in Canada by up to around 60 and 30 basis points, respectively, consistent with the findings in Ehrmann, Fratzscher, and Rigobon (2011). The increase in the Canadian market interest rates could be driven by several factors, as discussed in Section 2: the increase in U.S. bond rates and correlated movements in term premiums, the consequent increase of currency risk premium in Canada, or correlated movements in Canadian overnight rates.

The above results are different from some earlier findings in the literature, such as those of Kim (2001), who finds that short-term interest rates in non-U.S. G-6 countries do not react strongly to U.S. monetary policy shocks. The difference in the results may partly reflect structural changes over time, including the integration of financial markets. Our results suggest that the endogenous reaction of monetary policy instruments and market interest rates in Canada to U.S. monetary surprises is substantial and lasts longer than the response following domestic monetary shocks, consistent with what is found in Faust et al. (2003) and, more recently, in Rey (2015, 2016), Cesa-Bianchi, Thwaites, and Vicondoa (2020), and Miranda-Agrippino (2016) in the United Kingdom and Germany.[31]

Exchange Rates. Following a contractionary U.S. monetary policy shock, the Canadian dollar depreciates (i.e., U.S. dollar appreciates) up to 6 percent within three to four months, and it appreciates gradually, reverting toward long-term levels. Again, such a response, consistent with what was found in the response of the Canadian dollar following domestic monetary policy shocks, is compatible with the predictions of the overshooting hypothesis without any evidence of exchange rate puzzle or delayed overshooting. In line with Kim and Roubini (2000), Rogers, Scotti, and Wright (2018), and Inoue and Rossi (2019), this result suggests that the inappropriate identification of monetary policy shocks may account for the puzzles observed in the previous literature.

This finding is also important in the sense that the trilemma-related debates are closely related to different views on the role of the exchange rate as a shock absorber. In particular, the conventional Mundell-Fleming model predicts that the international monetary spillovers into a small open economy are mitigated due to adjustments in local-currency values, which in turn change the terms of trade and trade balance in the economy. The flexible reactions of the exchange rate to U.S. monetary policy shocks therefore suggest that the variable can act as a shock absorber. The effects on Canadian trade are discussed further in the next section.

Capital Flows. Net capital inflows to Canada decline following contractionary U.S. domestic monetary policy shocks. Despite the increase in market interest rates in Canada following U.S. monetary tightening, the depreciation of Canadian currency and increase in credit costs in international financial markets could play a negative role in capital inflows to Canada.

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[31] The results are also consistent with Rogers, Scotti, and Wright (2018) in the context of the size and persistence of U.S. monetary policy shocks, although the study focuses on the zero lower bound period.

Credit Costs. Short-term credit spreads significantly increase by around 20 basis points following a U.S. monetary tightening shock. Long-term credit spreads also increase to a similar degree, but with some lags, around 10 months after the shock. Indeed, a growing number of studies report empirical evidence that an international credit channel operates significantly, as there is a rapidly growing dependence on U.S.-dollar-denominated liabilities by small open economies, especially after the global financial crisis (Passari and Rey 2015; Rey 2015). Credit conditions in Canada are thus expected to be significantly affected by U.S. monetary tightening given that the Canadian economy demonstrates high reliance on the United States and a considerable portion of foreign debt is raised in U.S. dollars.

4.2.2 Trade Variables

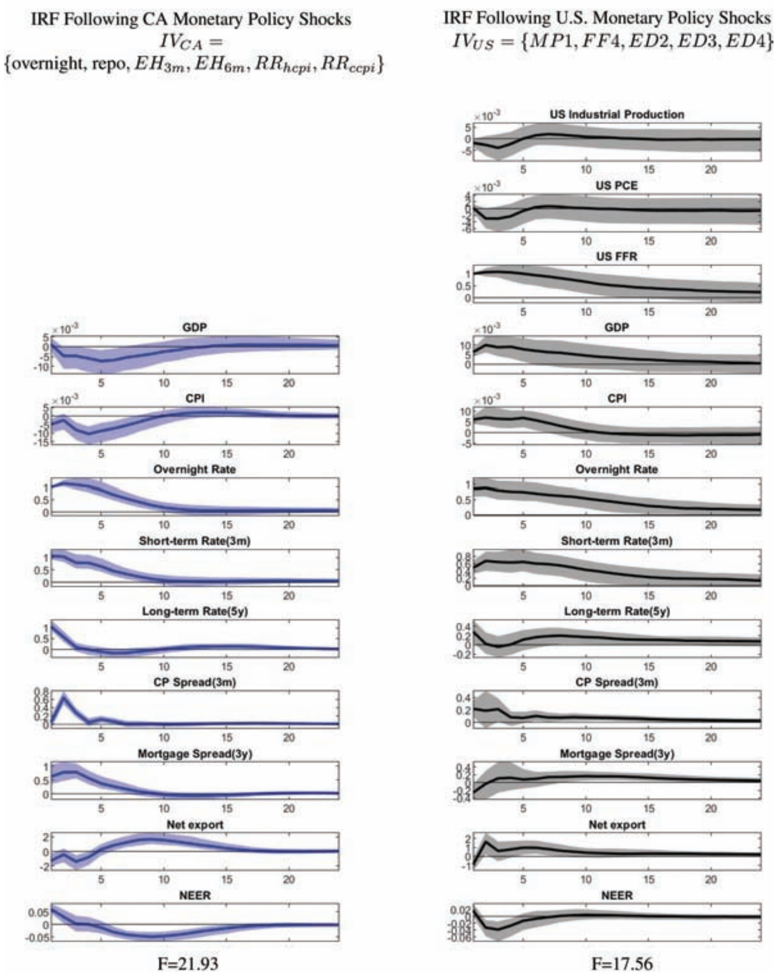
We now turn our focus to the impact of U.S. monetary policy shocks on trades in Canada. Compared with the baseline model in the previous section, we substitute bilateral nominal exchange rate per U.S. dollar and net capital flows with nominal effective exchange rates (NEER) and trade balance (or net export). This exercise aims to test the role of exchange rates (NEER) at the occurrence of external monetary shocks as predicted by the Mundell-Fleming trilemma. The conventional Mundell-Fleming model predicts that spillovers from foreign monetary policy are dampened in a small open economy largely by the sequential adjustments in exchange rates and net exports.

Consistent with the results for bilateral exchange rates, as shown in panel A of Figure 4, the response of NEER does not exhibit any puzzling movements that deviate from the predictions of the overshooting hypothesis.[32] Following a contractionary U.S. monetary policy shock, Canadian NEER depreciates by around 4 percent within three months, and the impacts dissipate in a few months. The depreciation in domestic currency leads to an improvement in the competitiveness of Canadian goods and services in the

[32]Note that, by definition, the increase of NEER indicates an appreciation of currency while a decrease indicates depreciation, which is opposite to the bilateral exchange rates (CAD/USD).

Figure 4. Impulse Response of Canada Variables to Monetary Shocks

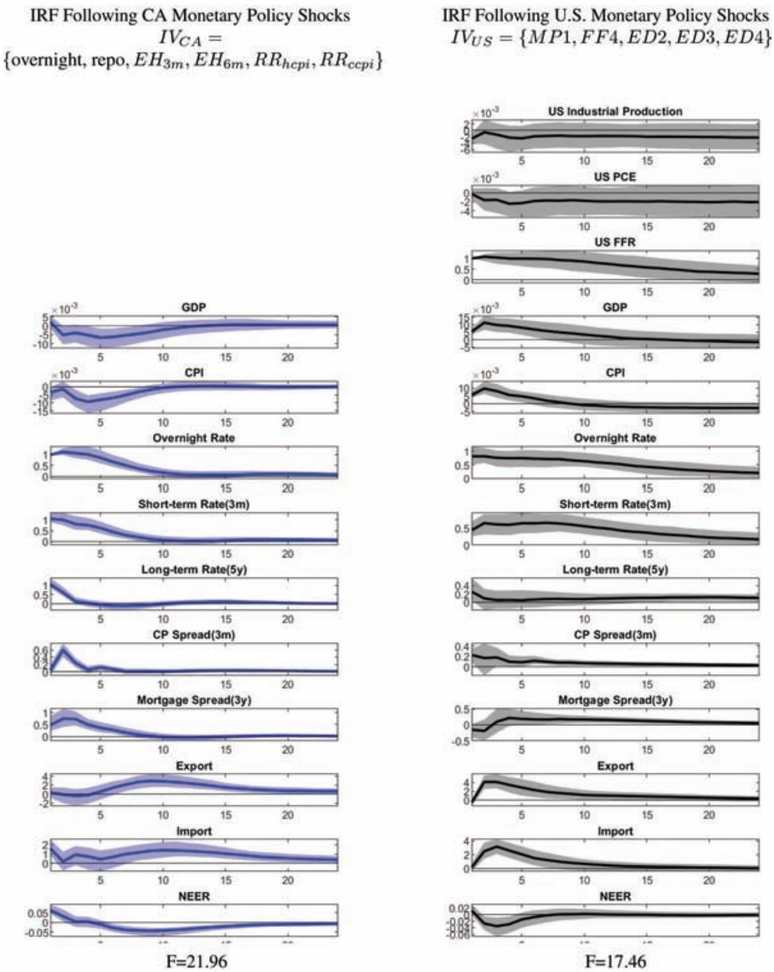
A. Alternative Exchange Rates (NEER) and Trade (Net Export Studio)



(*continued*)

Figure 4. (Continued)

B. Alternative Exchange Rates (NEER) and Trade (Export and Import) Variables

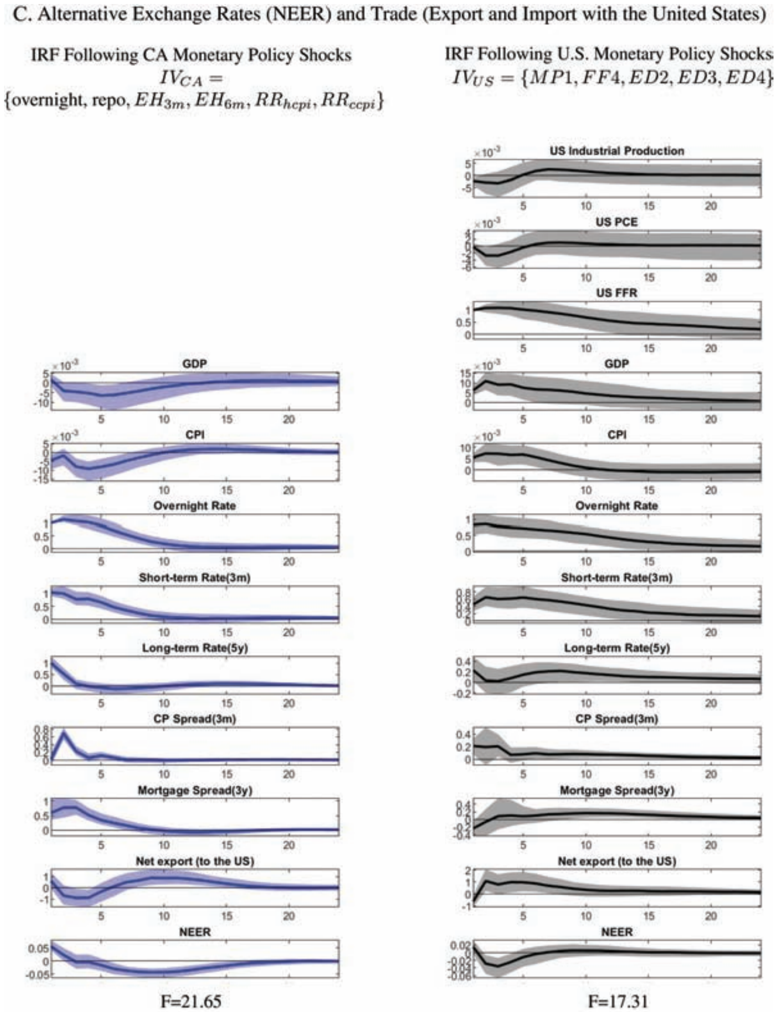


(*continued*)

international market. This finally raises net exports, defined as exports minus imports, and its impacts persist for around a year.[33]

[33]Interestingly, Canadian GDP rises on impact, while net exports instantly drop, followed by a gradual rise. Such an initial gap may suggest that some other potential channels than the expenditure switching are at play. For instance,

Figure 4. (Continued)



(continued)

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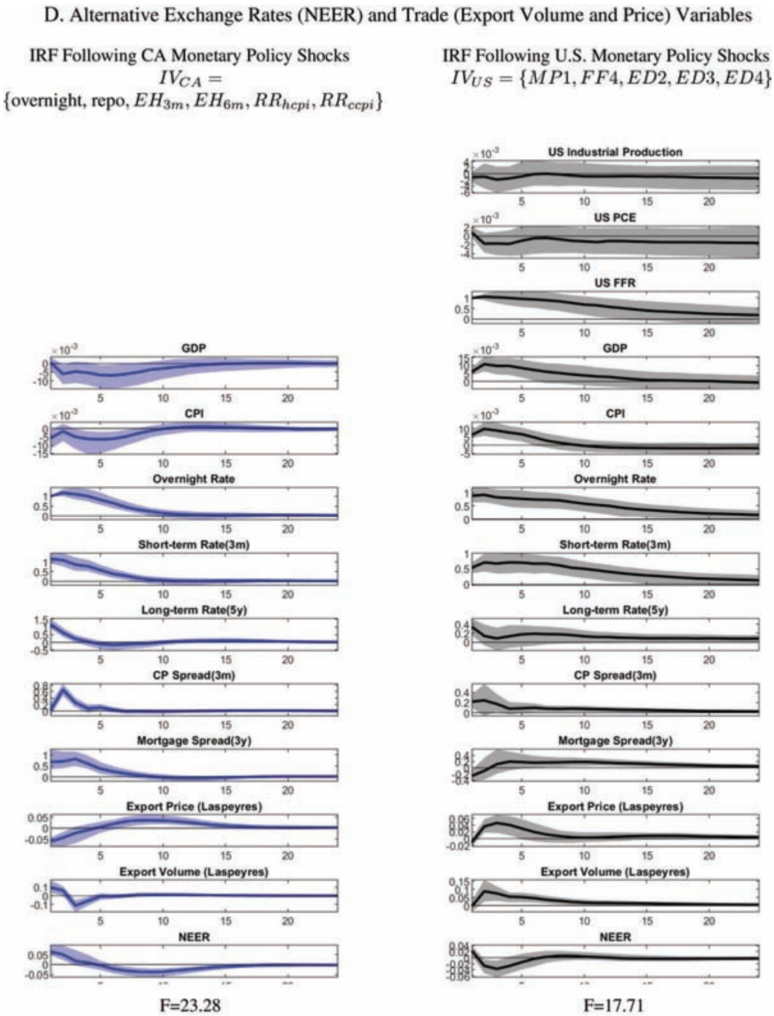
wealth effects may work in the very short term due to valuation effects in Canada's holdings of U.S.-dollar-denominated foreign assets. Alternatively, the immediate decline of the real interest rates, if any, could also lead to such responses.

Figure 4. (Continued)



Note: Y-axis indicates percent (or percentage point for interest rates). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

Meanwhile, following a contractionary domestic monetary policy shock, NEER appreciates and net exports significantly decline as expected.[34]

The increase in trade balance following U.S. monetary tightening appears to be mainly driven by an increase in exports rather than the decline in imports, as exhibited in panel B of Figure 4. The trade channel of monetary transmission is more pronounced when we consider the trades between the United States and Canada. Panel C of the figure reports that the positive impact of U.S. monetary tightening on net exports in Canada is statistically significant (i.e., confidence bands do not include zero throughout the forecasting horizons) and the impacts are somewhat more persistent compared with the total net export.

Given that a large part of Canada's imports from the United States is invoiced in U.S. dollars (Gopinath 2015; Gopinath et al. 2020), our results on the inflationary effects of U.S. monetary tightening seem quite consistent with the theory. In the dominant currency regime, domestic currency depreciation is expected to pass through into domestic import and consumer prices. Meanwhile, the expansionary effects of U.S. monetary tightening on Canadian exports and outputs seems somewhat puzzling because an appreciation of the U.S. dollar would not stimulate U.S. imports from Canada due to relative price movements, but instead, it would only depress Canadian imports from the United States.

However, it would be worth noting that the dominant currency paradigm relies on the key assumptions that exporters have a substantial degree of monopoly power and U.S. dollar prices are sticky. If the assumptions do not hold, as McLeay and Tenreyro (2020) argue, domestic currency depreciation could trigger a large increase in export volume rather than export prices. Considering that Canada is a small open economy that heavily depends on commodity exports, and that commodity prices are quite flexible while demands for commodities are elastic in global markets, the assumptions behind

[34]We also conduct a counterfactual analysis which blocks the reaction of exchange rates to monetary shocks (the results are available upon request). The responses of the variables following a U.S. monetary policy shock in this model are, by and large, greater than the ones obtained from the baseline results, especially for the financial variables. Again, this is in line with the Mundell-Fleming theory that exchange rates play an important role in mitigating the international monetary spillover.

the dominant currency invoicing may not hold strongly in Canada. Hence, if Canadian exporters are price takers with elastic demands in global markets, the expansionary consequence of U.S. monetary tightening through the trade channel could be stronger despite the dominant-currency invoicing. In light of this, panel D of Figure 4 provides the results of the model which includes Canadian export volume and export prices. U.S. monetary tightening is indeed followed by a large increase in export volume rather than export prices.[35]

4.2.3 Macroeconomic Variables

Finally, let us explore the impacts of U.S. monetary policy shocks on Canadian macroeconomic variables (output and price levels). The net impacts of U.S. monetary tightening on the variables could be, ex ante, either contractionary or expansionary. Put another way, if the negative impacts of U.S. monetary shocks on Canadian financial conditions and domestic demands (*financial channel* and *aggregate demand channel*) overshadow the positive impacts on exchange rate pass-through and net exports (*trade channel*), then output and price levels in Canada would decline after the U.S. monetary policy tightening (Iacoviello and Navarro 2019).[36] On the other hand, if the trade channel is at play more effectively than the financial and aggregate demand channels, the macroeconomic consequences of U.S. monetary tightening would be instead *expansionary*, consistent with the empirical results in Rey (2016) (for Canada) and Mirando-Agrippino and Rey (2020) (for the global economy), and the predictions by Jones, Kulish, and Rees (2018), where industrial production and price levels in Canada significantly increased following contractionary U.S. monetary policy shocks.[37]

[35]Alternatively, it could be the case that U.S. contractionary monetary spillover brings about the improvement of Canadian trade balance due to simultaneous factors such as global trade collapse around global economic slowdowns. To empirically test this possibility, we also carried out the estimation with the model which includes global trade volume as an additional control variable and confirmed that the main results did not change.

[36]Bluedorn and Bowdler (2011) report that a U.S. monetary tightening induces the expenditure-reducing effects rather than expenditure-switching effects. Di Giovanni and Shambaugh (2008) also show that high foreign interest rates have a contractionary effect on annual real GDP growth in the domestic economy, but that this effect is centered on the countries with fixed exchange rates.

[37]Similarly, Blanchard et al. (2016) show that a contractionary foreign monetary policy shock or, equivalently, capital outflows tend to result in expansionary

As was already shown in Figures 2, 3, and 4, following a contractionary U.S. monetary shock, both output and price levels in Canada unambiguously increase, and the impacts persist for around a year after the shock. The results suggest that the expansion of external demands by the trade channel outweighs the decline in domestic demands by financial and real spillovers, thus having positive net effects on the output in Canada. In addition, the positive response of price levels in Canada seems to reflect the effects of currency depreciation that are passed on to import prices, and finally to consumer prices.

To elaborate more on this, we estimate an additional model where net export and domestic demand are scaled by a ratio of GDP. In so doing, we can test whether the macroeconomic outcomes following U.S. monetary tightening result in the expenditure switching (from domestic demand to foreign demand). As shown in panel A of Figure 5, the ratio of net export per nominal GDP in Canada increases by around 2 percentage points following a U.S. monetary tightening. This indicates that the degree of increase in the net export is greater than that of total output in Canada. On the contrary, domestic demand significantly declines following a U.S. monetary policy shock, as shown in panel B. The latter point is confirmed when we employ alternative proxy variables for domestic consumption and investment (here we employ retail sales volume in panel C and industrial production in the construction sector in panel D).

4.3 Summary

Our results presented so far provide several implications for the "dilemma-versus-trilemma" debate. First, we present evidence for the significant transmission of domestic monetary policy shocks into financial and macroeconomic conditions in Canada. Our results confirm that the transmission of domestic monetary policy shocks works through various types of channels, including interest rate, exchange rate, and credit channels, which is in line with the prediction of the trilemma hypothesis.

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outcomes. Kearns and Patel (2016) provide empirical evidence that the trade channel is offset in part by the financial channel in emerging economies but the effect is smaller in advanced economies due to the weak financial channel.

That said, our empirical results find strong and persistent financial and macroeconomic spillovers from the United States to Canada, as argued by Feldkircher and Huber (2016), Georgiadis (2016), and Dedola, Rivolta, and Stracca (2017). Furthermore, the transmission of U.S. monetary policy shocks appears to operate through

Figure 5. Impulse Response of Canada Variables to Monetary Shocks

A. Alternative Exchange Rates (NEER) and Trade (Net Export to GDP) Variables

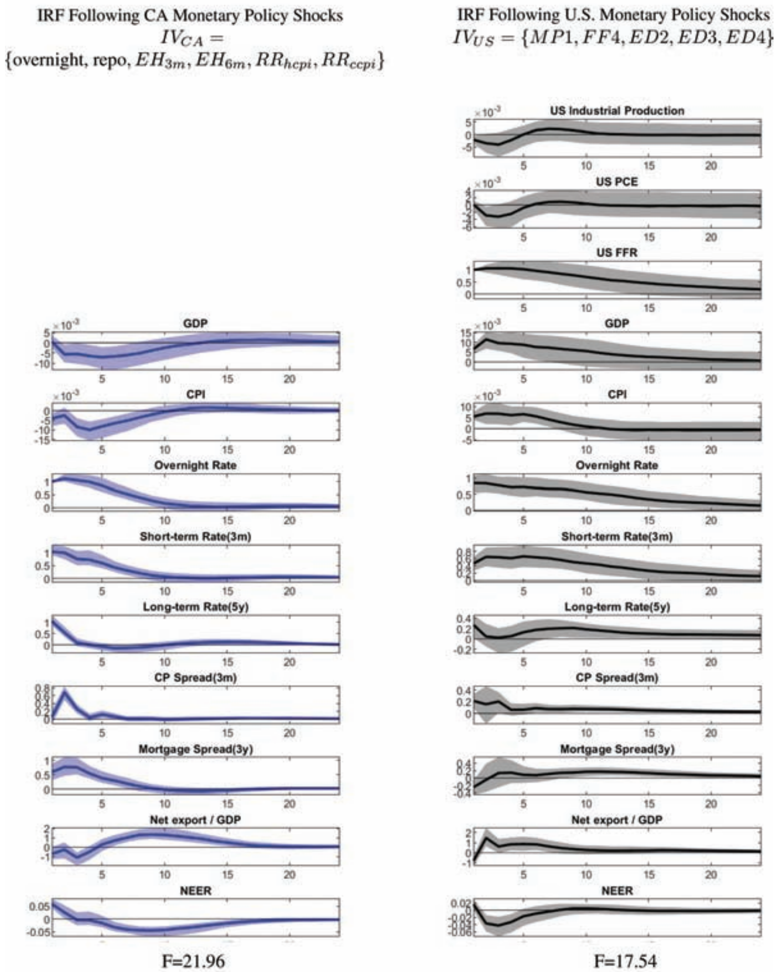

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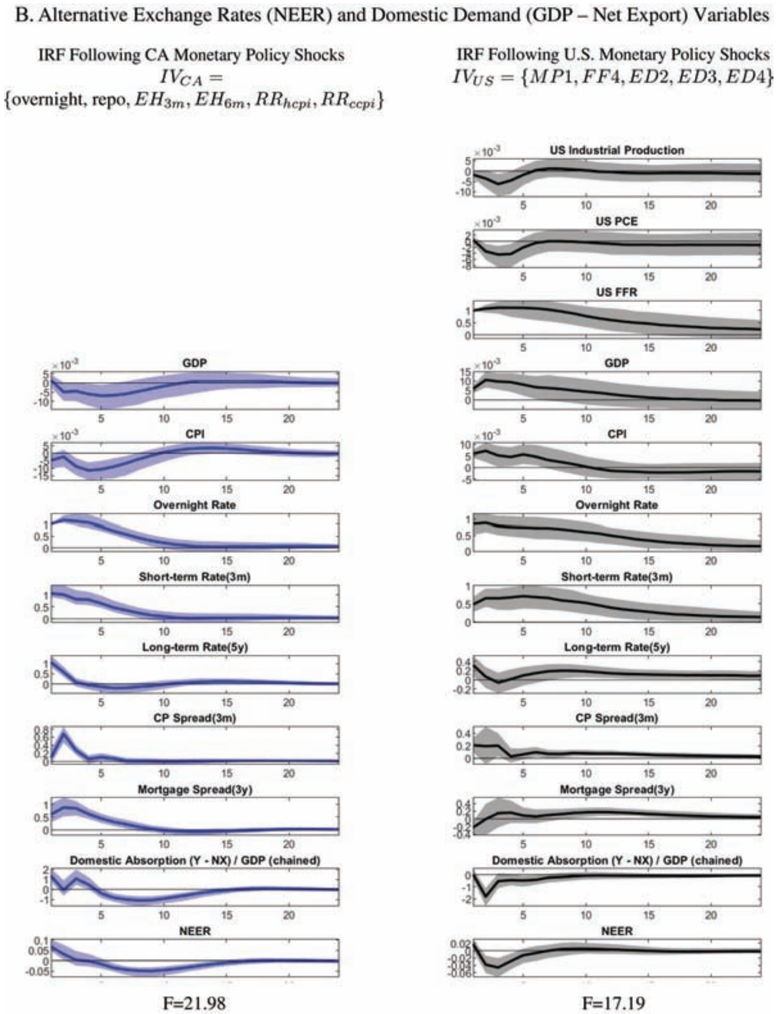
Figure 5. (Continued)



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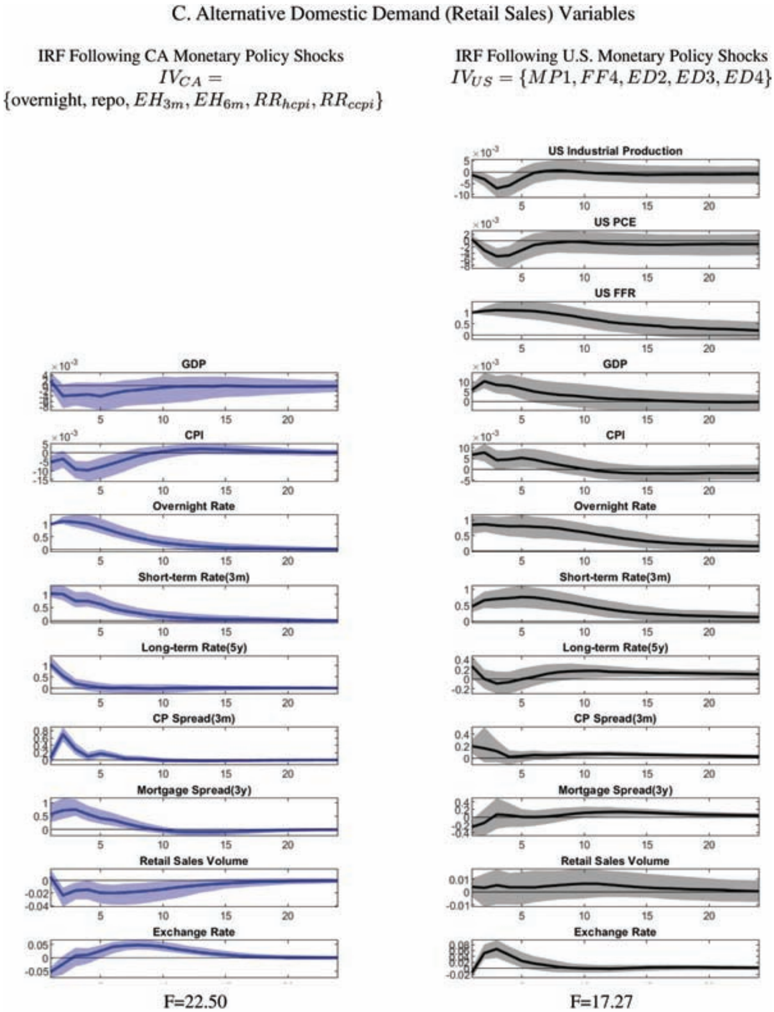
the channels with different natures—financial, aggregate demand, and trade channels—that can have somewhat opposing effects on macroeconomic variables in Canada.

On the one hand, financial transmission of U.S. monetary policy seems apparent. The effect of foreign (U.S.) interest rates on

Figure 5. (Continued)



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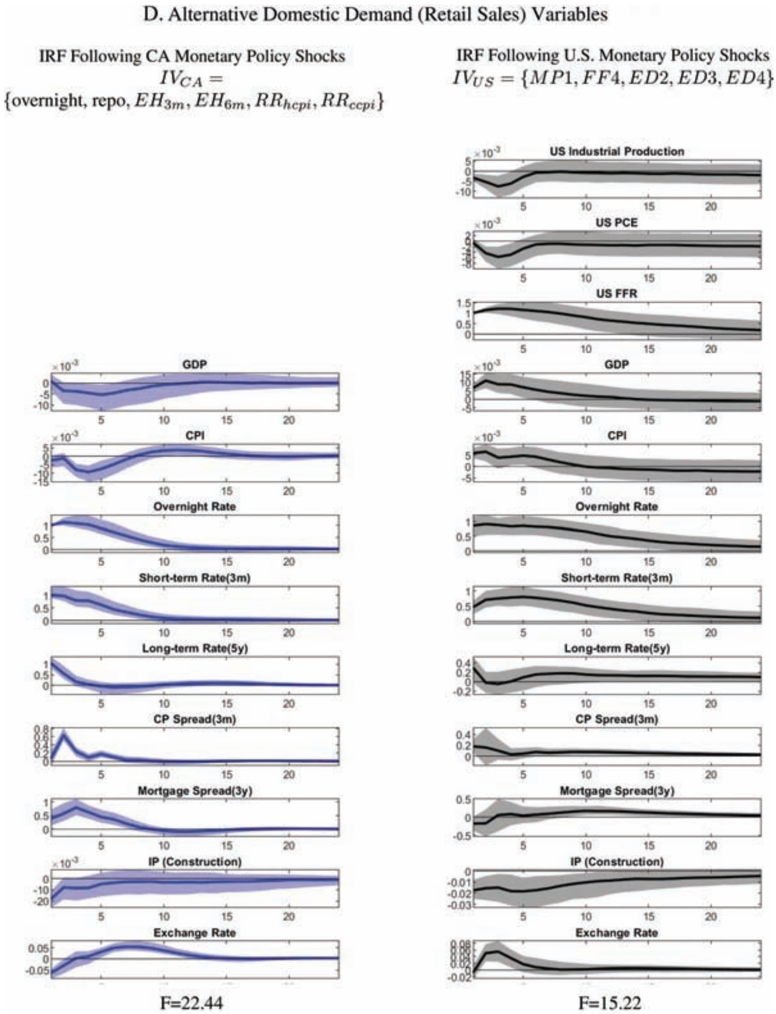
domestic interest rates is the most plausible financial channel as illustrated in Di Giovanni and Shambaugh (2008) and Rey (2015, 2016). More interestingly, Canadian interest rates of all maturities demonstrate a significant and persistent response to surprises in U.S. monetary policy. This international spillover also operates through credit conditions in Canada in both short- and long-term instruments,

Figure 5. (Continued)



Note: Y-axis indicates percent (or percentage point). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

and capital inflows to domestic financial markets (Dahlhaus and Vasishtha 2014). These results collectively indicate that financial conditions in Canada are subject to the impact of monetary policies from the center country, as Rey (2015, 2016) concludes regarding the possible dilemma that central banks in open economies may confront.

On the other hand, our results point to the predictions by Mundell-Fleming's trilemma hypothesis that depreciation of exchange rates leads to the improvement in terms of trade and an increase in net exports. More interestingly, the results suggest that despite the financial tightening and decline in domestic demand, expansion of net exports and currency depreciation boost domestic output and prices.

Admittedly, these results can be mainly specific to the Canadian economy which heavily depends on trades, in particular that of commodities. Alternatively, even within the economy, the consequences of U.S. monetary spillover could have changed over time along with the economic and financial developments.[38] Our findings suggest that more cautions should be exercised to understand the nature of transmission of foreign monetary shocks by considering the relative importance of different transmission channels.

The upshot is that, depending upon the extent to which different types of transmission channels operate in the open economy, the macroeconomic consequences of foreign monetary policy spillovers could also be quite different. This also highlights the crucial role of exchange rate in small open economies, in a financially globalized world: it can be either a shock amplifier or a shock absorber.

5. Additional Econometric Considerations and Robustness Checks

This section summarizes the results of several sensitivity and robustness checks to verify the validity of our empirical results. The exercises encompass a battery of checks: estimations with (i) pure

[38]The findings in some earlier studies suggest that the macroeconomic consequence of international spillover effects could be highly dependent upon country characteristics, as well as the sample periods that govern the degree of various channels of transmission.

monetary shocks that are orthogonal to central bank information shocks, (ii) a counterfactual closed-economy model, (iii) alternative sets of instrumental variables, (iv) the Canadian monetary policy shocks following Kearns, Schrimpf, and Xia (2020), (v) different sample periods, and (vi) alternative endogenous variables, including the one which employs the VIX as an endogenous variable instead of an external control variable. We detail each of these robustness checks below.

5.1 U.S. Pure Monetary Shocks vs. Fed Information Shocks

One important finding in the recent literature is that U.S. monetary policy surprises are driven not only by shifts in the monetary policy stance but also by central-bank-specific information on the economic outlook. For instance, Jarociński and Karadi (2020) disentangle the high-frequency-identified U.S. monetary policy shocks into pure monetary policy and the Federal Reserve (Fed) information shocks by introducing sign restrictions in addition to the exogenous instrument.

In panel A of Figure A.3, we estimate the dynamic responses of the variables in Canada to a U.S. pure monetary policy shock following Jarociński and Karadi (2020).[39] Overall, the results are consistent with the baseline results: contractionary U.S. pure monetary shocks are followed by declines of output and prices in the United States, and financial tightening, but improvement in trade balance, and expansionary effects on output and prices in Canada. This may partly reflect the greater explanatory power of the monetary policy shock for U.S. monetary policy instruments than the information shock. The responses of some variables become less statistically significant compared with the baseline results. That said, the dynamic responses of the key variables—exchange rates, short-term interest rates, and macroeconomic variables—are quite significant.

Next, we report the impulse responses to the Fed information shocks in panel B. Following the shocks, as expected, the dynamic

[39] In particular, the federal funds futures surprises which have the opposite sign to the stock price (S&P 500) surprises are used as the proxy for pure monetary policy shocks. This identification approach corresponds to the *poor man's approach* of Ca' Zorzi et al. (2020) and Jarociński and Karadi (2020).

responses of U.S. macro variables are the opposite of the pure monetary shocks: expansions in output and price levels in the United States. This is because the decision of the Fed reflects expectations on higher future economic growth (and inflation) in the U.S. economy. The effects of the shocks on financial conditions in Canada are contractionary while those on macroeconomic variables are expansionary; these effects are virtually the same as those of the pure monetary shocks.

In sum, this exercise suggests that the instrumental variables employed in the baseline estimation mainly reflect monetary policy shocks, although not wholly excluding the impacts of the central bank information shock.

5.2 A Counterfactual Analysis: Model without U.S. Variables

What are the implications of correlated monetary policy shocks, if any, between the two economies? What if we do not consider the impact of monetary shocks in the center country in quantifying the impact of domestic monetary policy shocks? To shed some more light on this issue, this subsection considers an alternative model that omits the impacts of U.S. variables on the Canadian economy. Put differently, we counterfactually consider only domestic (Canadian) variables in the SVAR system.

For easier comparison, IRFs based on the closed model are plotted along with our benchmark (open-economy model) results in Figure A.4. The solid lines indicate the benchmark IRFs, and broken lines are IRFs based on the alternative specification. The comparison of the IRFs suggests that the impacts of domestic monetary policy shocks on overnight and short-term interest rates in Canada are estimated to be significantly greater throughout the forecasting horizon when we choose the alternative closed-economy model. On the contrary, IRFs of capital inflows and exchange rates become quite muted when considering the alternative model. The response of Canadian output and prices on domestic monetary shocks is also weaker until around a year after the shock with the alternative model.

A careful examination of our benchmark results (as shown in Figure 3) suggests that the IRF of a variable based on the alternative model can be approximated by a linear combination of the two types of IRFs of the variable following domestic and U.S. monetary policy shocks, respectively, based on the benchmark model. That is, the IRFs based on the alternative model could be overestimated (or underestimated) partly because the model fails to control the impacts of U.S. monetary policy shocks. For instance, in Figure 3, we find that the responses of overnight and short-term interest rates are stronger and more persistent following U.S. monetary policy shocks than those following domestic monetary policy shocks. Meanwhile, the responses of exchange rates and capital inflows seem to be in opposite directions following the two types of policy shocks, a result which is quite intuitive. The responses of macroeconomic variables (output and prices) are also somewhat heterogeneous following the two monetary policy shocks. Finally, the responses of other variables (including long-term interest rates and credit spreads) are comparable to each other across the two monetary shocks.

As explained in Section 3 and Appendix A.2, we follow Mertens and Ravn (2013) and identify domestic (Canadian) monetary policy shocks that are orthogonal to the identified U.S. monetary policy shocks. More specifically, the correlated parts of domestic monetary policy shocks with U.S. monetary shocks are regarded as stemming from U.S. policy implementations. Thus, the estimated responses of the variables based on the alternative model are likely to include the (omitted) impacts of U.S. monetary policy implementations, which are correlated with domestic policy actions. This counterfactual analysis thus implies that an omission of the variable of U.S. monetary policy instrument can significantly overestimate or underestimate the impact of domestic monetary policy transmission.

5.3 Alternative Combinations of Instrumental Variables

In Section 4, we reported the impulse response of variables using each of the three types of instrumental variables proposed. We then estimated the baseline model using the three types of instrumental variables {IV1, IV2, IV3} altogether in order to maximize the explanatory power of the instrumental variables. To test the sensitivity of the results to the selection of instrumental variables, we estimate the VAR model using alternative sets of instrumental variables: {IV1 and IV2}, {IV1 and IV3}, and {IV2 and IV3}.[40]

The corresponding IRFs are given in panels A, B, and C of Figure A.5 in Appendix A.1, and can be compared with the baseline results in Figure 3. As is evident, the impulse response of variables to domestic and U.S. monetary policy shocks is overall consistent across the different sets of instrumental variables.[41]

5.4 Alternative Instrumental Variables for IV1

We test the robustness of our benchmark results by using alternative sets of instrumental variables (IV1) in the literature. Specifically, a measure of the shifts in overnight index swap (OIS) rate is tested as an alternative market-based instrument for monetary surprise in Canada. The OIS can be used to hedge the exposure to the volatility of short-term rates or to take a speculative position on the future movement of the policy rates. Due to these functions of OIS, its change surrounding the policy decisions can be regarded as the shifts of market expectations for the future path of policy rates (Jarociński and Karadi 2020; Kearns, Schrimpf, and Xia 2020). As shown in panel D in Figure A.5, our overall results do not change much despite the wider confidence intervals with the use of these instruments that mostly reflect the shorter sample periods (June 2002–December 2015).

5.5 Alternative Sample Periods

The United States has implemented unconventional monetary policies since the onset of the global financial crisis in 2008–09. In order to check the robustness of our baseline results against the policy regime changes, we compare the estimates for different sample periods with the following two approaches. First, we test the robustness of the results using the pre-crisis (January 2000–August 2008) and

[40]Moreover, empirical results based on other types of instrumental variables that are not chosen as a benchmark are all available upon request.

[41]In addition, we do find significant results for any variables when these instrumental variables are combined with other types of instrumental variables we propose.

post-crisis (January 2010–December 2017) sample period. As displayed in panels A and B of Figure A.6, the overall results, with a few exceptions, are consistent with the full sample results in Figure 3, although the results using the pre-crisis and post-crisis sample are often less significant, as reflected in the lower F-statistics of the instrumental variables.

Second, we examine the time-varying impulse response functions of the endogenous variables by estimating a rolling-sample SVAR model. Specifically, moving windows of eight years (96 months) are chosen as subsample periods, with the first window ending in January 2008. Panel B of Figure A.6 summarizes the IRFs based on the rolling-window sample periods. The results suggest that although the magnitude of responses varies across subsample periods, they are largely consistent with the results based on the full-sample period.[42]

5.6 Alternative Endogenous Variables

In Figure A.7, we test alternative data for endogenous variables to verify the robustness of our baseline results. In panel A of the figure, we test the alternative variable of monthly real GDP with 2012 as the base year (instead of chained monthly GDP). As is evident, the results are not sensitive to the type of GDP series.

We also employ U.S. shadow federal funds rates (as in Wu and Xia 2016) or U.S. government bond yields with the maturity of one year (as in Gertler and Karadi 2015) in place of effective federal funds rates considering the fact that since the global financial crisis, the variations in overnight rates are limited. The results are summarized in panels B and C of Figure A.7, respectively. Again, the overall empirical results do not change much, although the explanatory power of the instruments becomes somewhat weaker with both of the alternative policy interest rates.

Finally, we include the VIX to control external factors that can simultaneously affect both the United States and Canada. A group of recent studies, including Rey (2015, 2016), suggests that monetary policy shocks in the center country have a significant impact

[42]Notably, IRFs for some variables, including macro variables, exhibit more amplified responses after 2016. This may partly reflect the policy normalization in both economies.

on global financial market sentiments or, more generally, the global financial cycle, and the changes in the global financial markets are transmitted through financial and macroeconomic conditions in other open economies. Considering these findings, we embody the VIX as an endogenous variable here, and examine the response of the variable as well as the overall results for the other variables. Figure A.8 reports that the VIX increases within a couple of months after the contractionary U.S. monetary policy shock, consistent with the findings in earlier studies. The response of other variables in Canada does not show any notable differences.

6. Conclusion

Mundell-Fleming's trilemma has been a central building block in conventional international macroeconomics. However, as global financial markets are increasingly integrated and global factors become crucial drivers of the developments in domestic financial markets, there are extensive debates on the effectiveness of domestic monetary policy and the roles played by exchange rates in small open economies. In this context, this paper investigates the channels of monetary policy transmission in a small open economy within and across borders, by estimating an open-economy SVAR model with novel external instruments.

Our empirical findings are summarized as follows. On the one hand, the transmission of domestic monetary policy shocks operates through a variety of channels. First, both short- and long-term rates react significantly to domestic monetary policy shocks, confirming the role of the conventional interest rate channel. Second, foreign exchange rates in this process are seen to respond significantly to monetary policy shocks, as the overshooting hypothesis by Dornbusch (1976) predicts. Contrary to the findings in earlier studies that report counterevidence for the overshooting hypothesis, we find that an increase in local policy rates causes the nominal exchange rate to quickly appreciate and then depreciate gradually. Third, contractionary domestic monetary policy shocks generate an increase in credit spreads in Canada. Macroeconomic conditions (output and price levels) respond significantly to monetary policy shocks, as New Keynesian theory predicts, reflecting the pass-through of monetary policy shocks into financial and credit markets.

On the flip side, international spillovers of monetary policy shocks also play an important role in financial and credit conditions in Canada. Following a contractionary U.S. monetary policy shock, market interest rates in Canada, in both short- and long-term maturities, are significantly increased by the impact and persist for a prolonged period. More interestingly, overnight rates in Canada, which are used as a monetary policy tool, also respond to U.S. monetary policy shocks. Following a contractionary U.S. monetary policy shock, credit spreads increase substantially along with an immediate outflow of international capital investments. This is consistent with the predictions of the credit and risk-taking channels of monetary policy transmission from international perspectives (Rey 2015, 2016; Hofmann, Shim, and Shin 2016).

Finally, the response of macroeconomic variables is divergent across the two types of monetary policy shocks; U.S. monetary tightening has expansionary and inflationary consequences on the variables in Canada unlike domestic monetary shocks. This may partly reflect the expenditure-switching effects of contractionary U.S. monetary shocks, as well as pass-through of currency depreciation to domestic prices, offsetting the negative impacts of tightened financial conditions on aggregate demand in Canada.

Our empirical results indicate that as the global financial markets become more integrated, the financial and credit conditions in a small open economy can be driven not only by domestic monetary policy but also by global factors such as U.S. monetary policy. In Canada, the impacts of international monetary spillovers could be buffered by the flexible reactions of exchange rates. Admittedly, however, this result can be mainly specific to the Canadian economy. For the countries where flexible exchange rates cannot completely insulate their economies from external shocks, monetary policy decisions made by focusing only on domestic conditions can result in policy errors in achieving macroeconomic stability. The consequences of external shocks, including monetary policy shocks in the center country, should be carefully considered when implementing monetary policies as well as other policy tools.[43]

[43] From this perspective, the International Monetary Fund proposed recently the integrated policy framework which guides how a mix of additional policy tools—macroprudential measures, FX market interventions, and capital flow managements—should be deployed to achieve policy objectives.

Appendix

A.1 Additional Figures

Figure A.1. Policy Rate and Short-Term Spot Rates

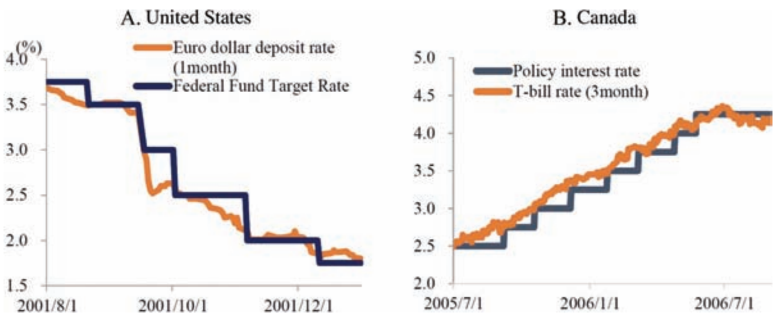
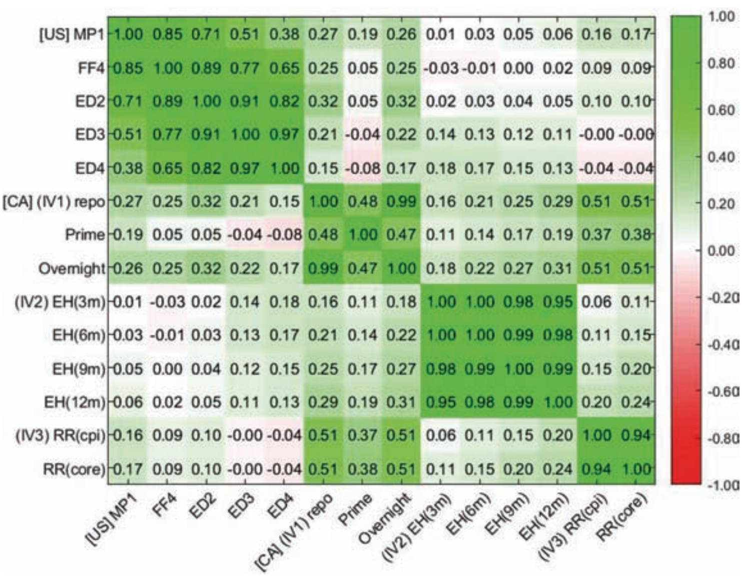


Figure A.2. Correlation Heatmap for the Instrumental Variables



Note: Numbers in cells are correlations among the instrumental variables. Thicker colors indicate higher positive (green) or negative correlation (red) than others.

Figure A.3. IRFs with Different U.S. IV Sets

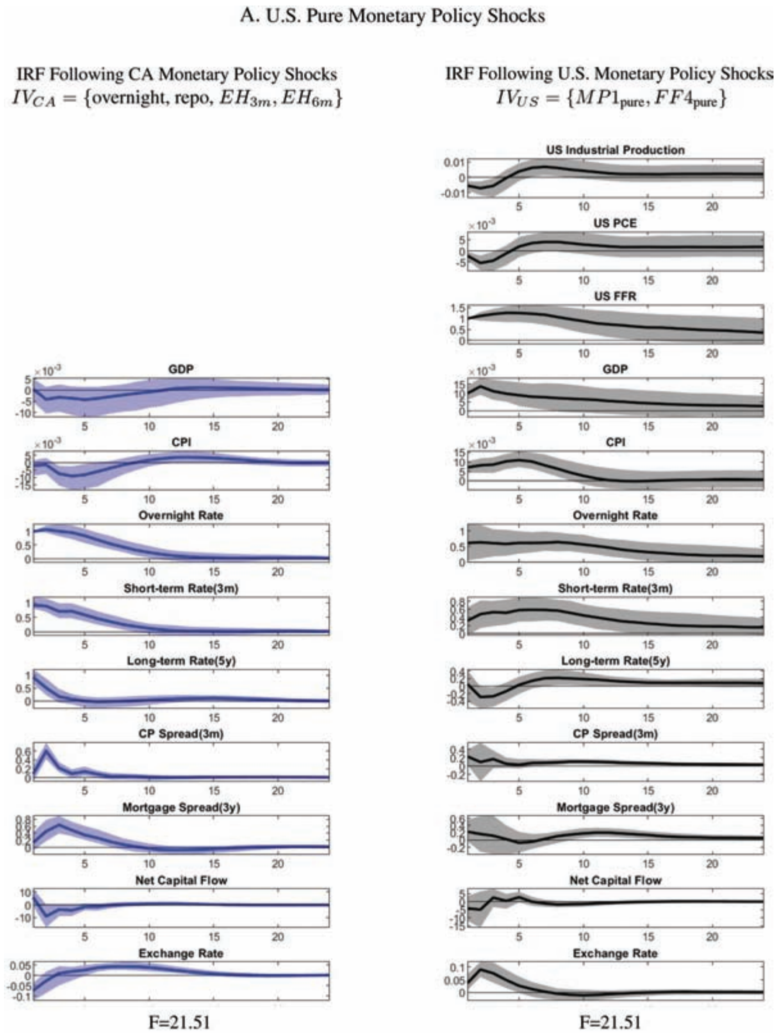


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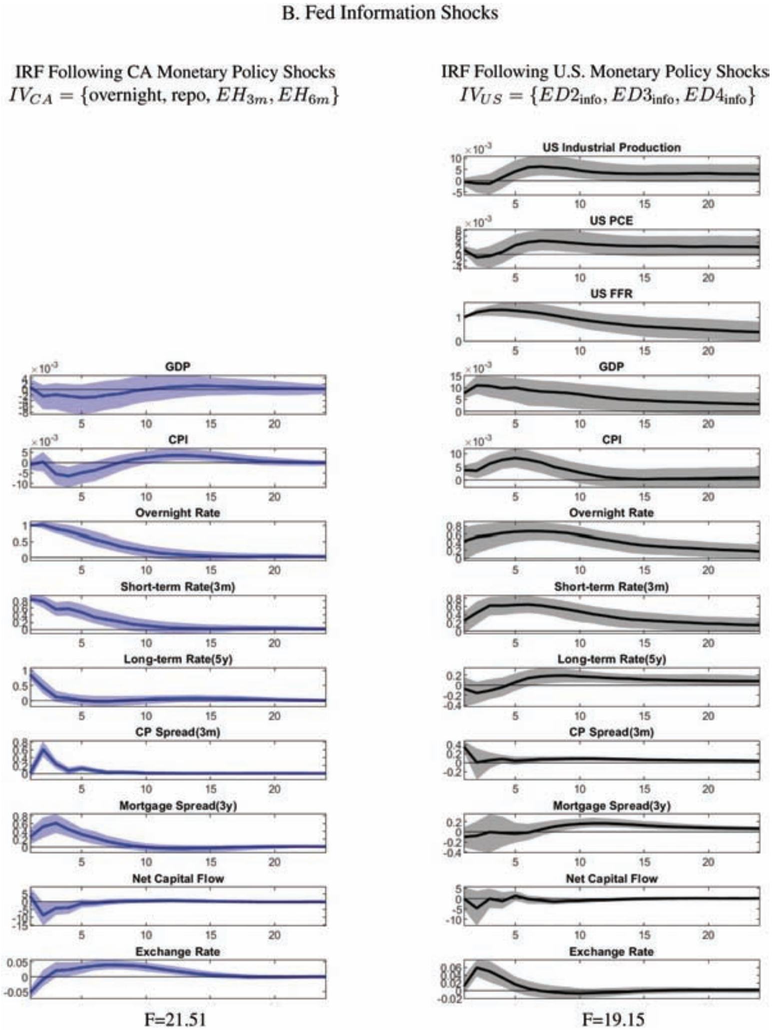
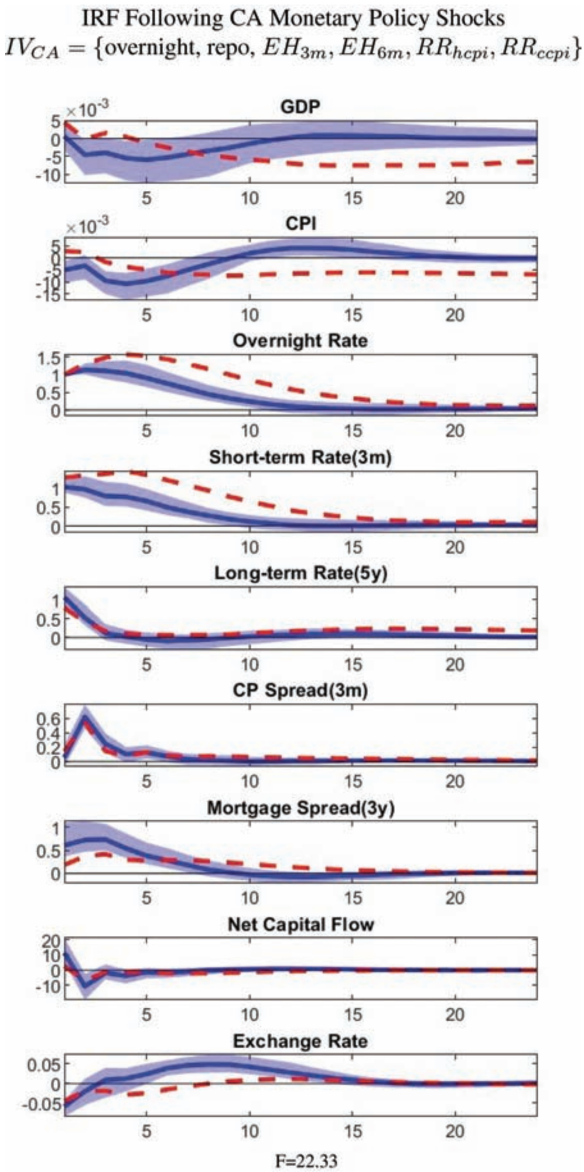
Figure A.3. (Continued)



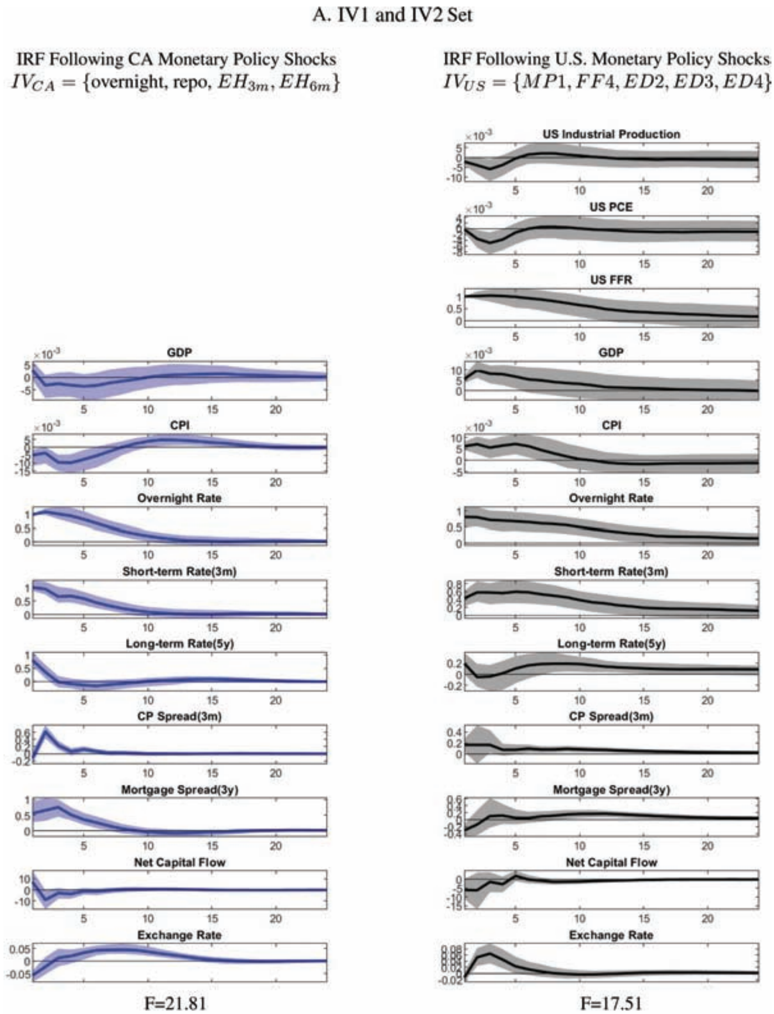
Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for capital flow). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

Figure A.4. IRFs with Alternative Specification: Model without U.S. Variable



Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for capital flow). X-axis indicates months after shock. Based on contractionary (+100 bps) Canadian monetary policy shocks. Solid lines (confidence intervals in shaded areas) are based on benchmark model (with U.S. monetary policy instruments) and broken lines are based on alternative model without U.S. monetary policy instruments. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set (altenative model).

Figure A.5. IRFs with Different Canadian IV Sets



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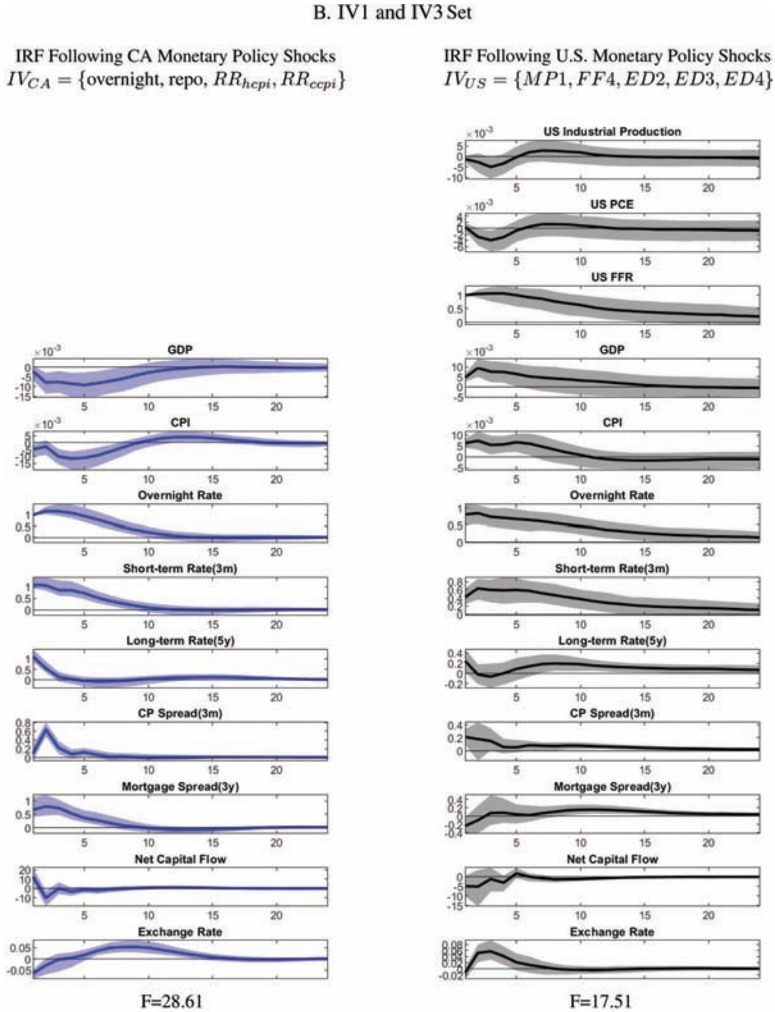

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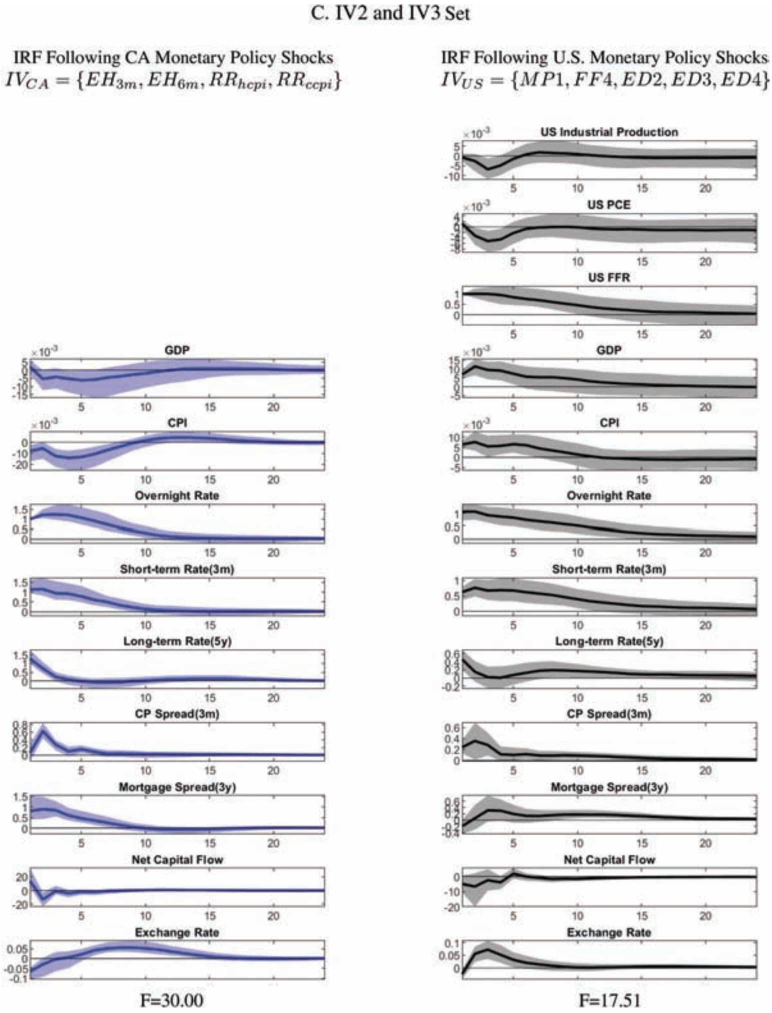

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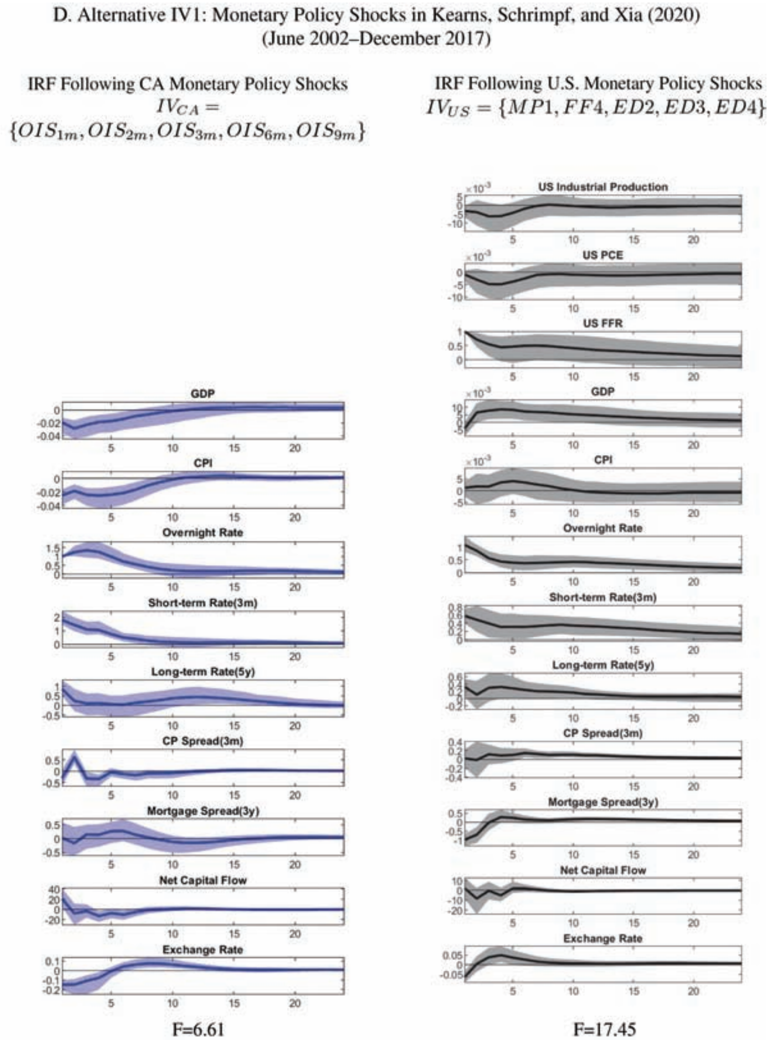

Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for capital flow). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

Figure A.6. IRFs with Alternative Sample Periods

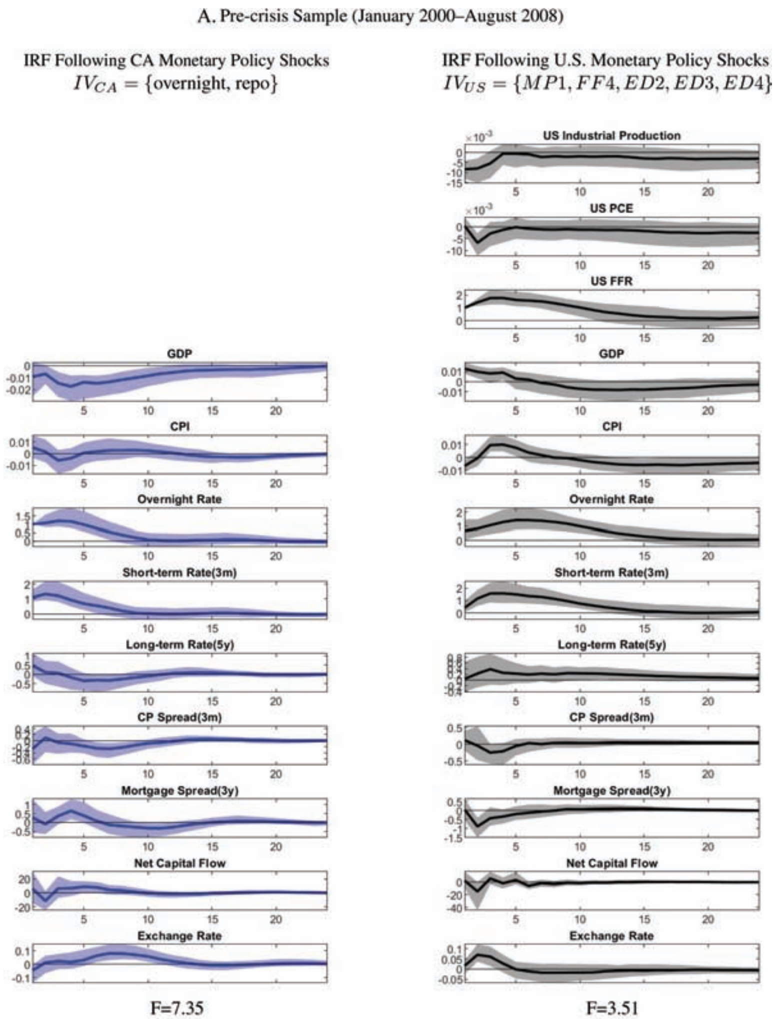

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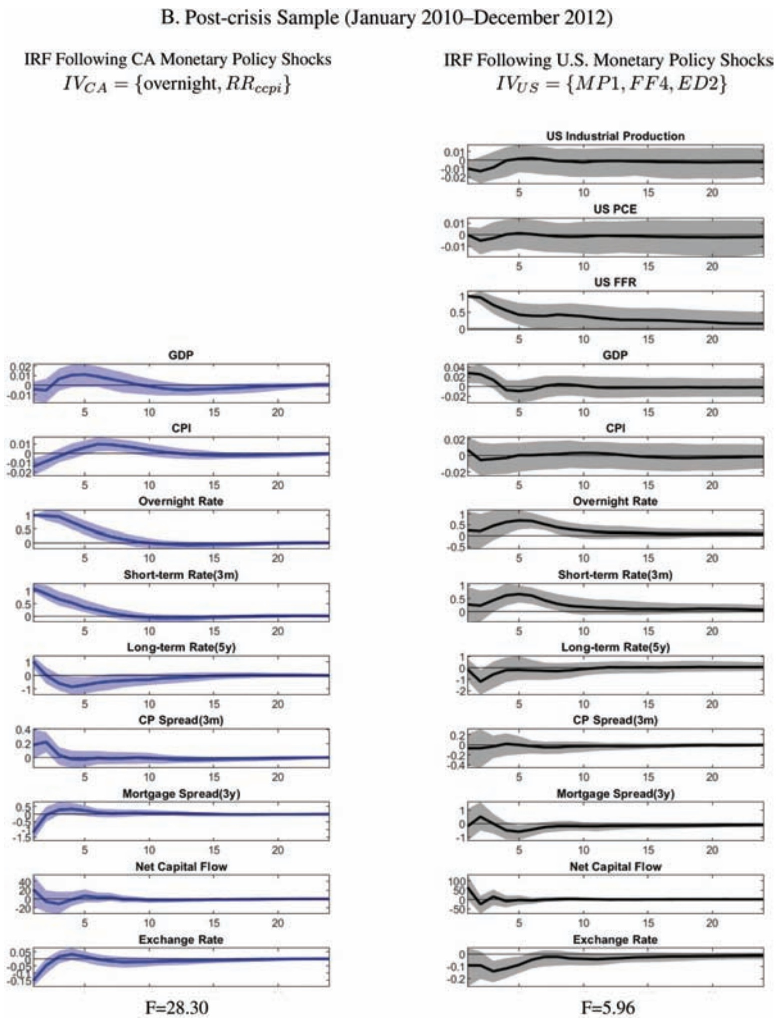
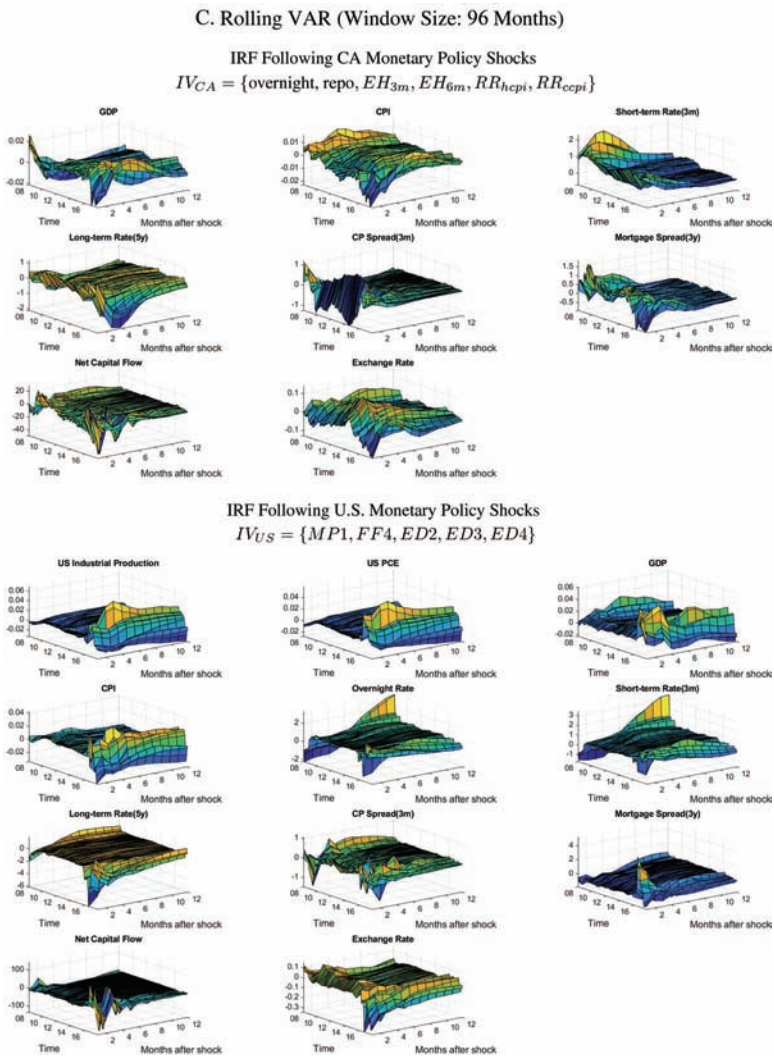
Figure A.6. (Continued)



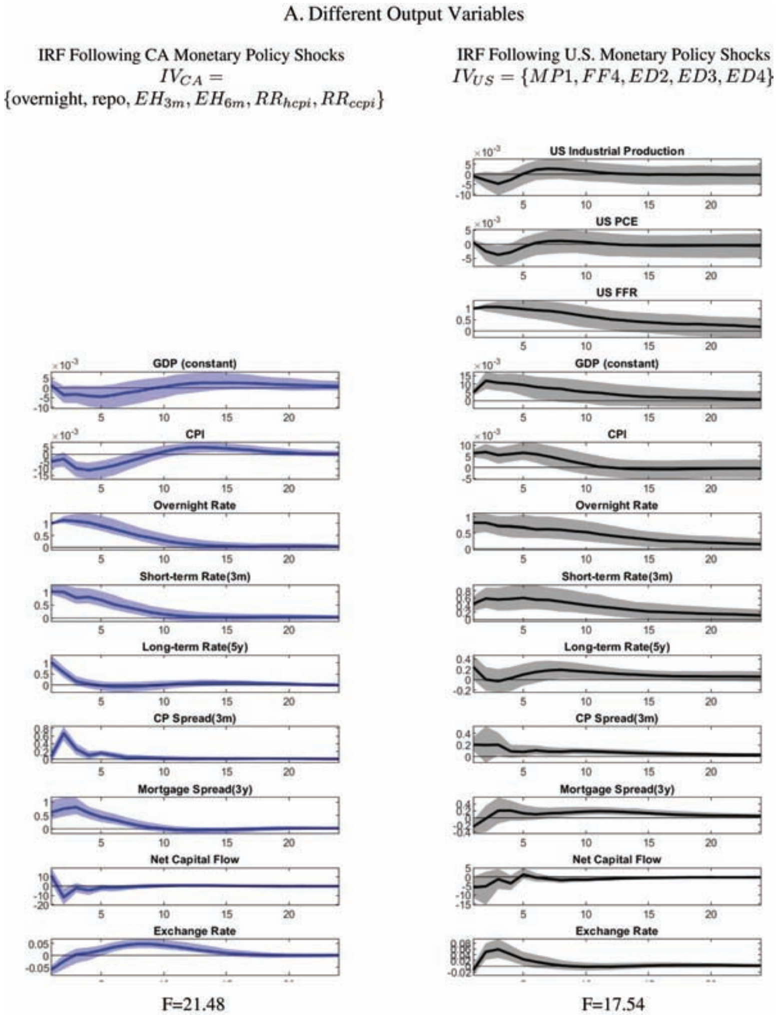
(continued)

Figure A.6. (Continued)



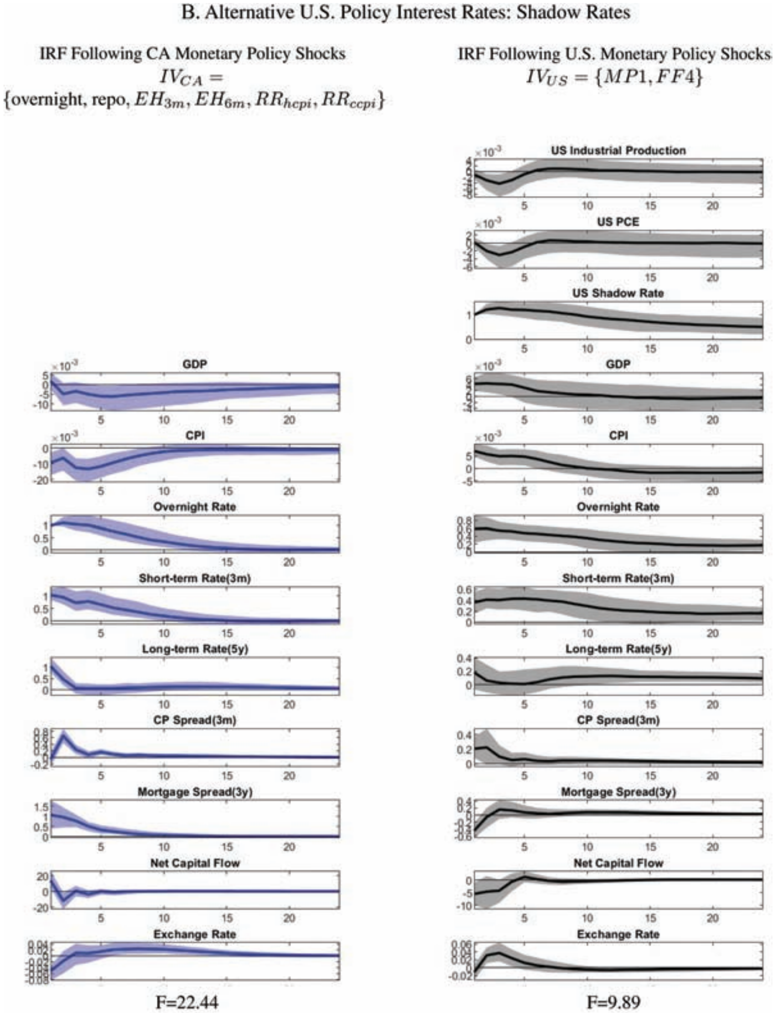
Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for capital flow). "Time" indicates the sample periods, while "Months after shock" indicates the forecasting horizons after monetary policy shocks. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively.

Figure A.7. IRFs with Alternative Endogenous Variables



(*continued*)

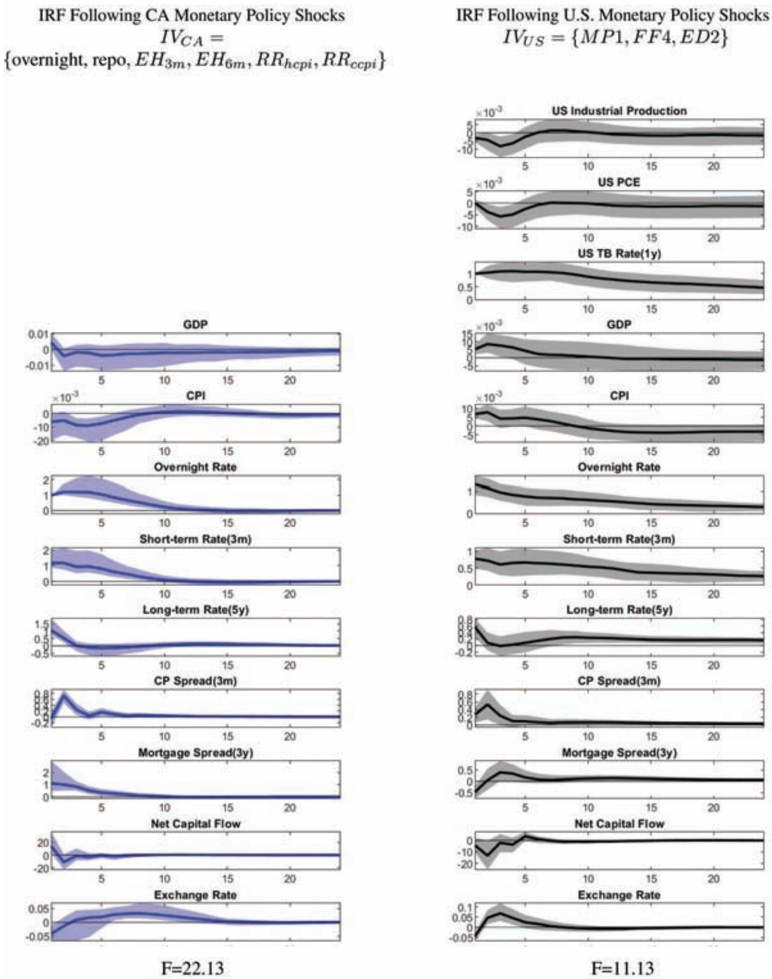
Figure A.7. (Continued)



(continued)

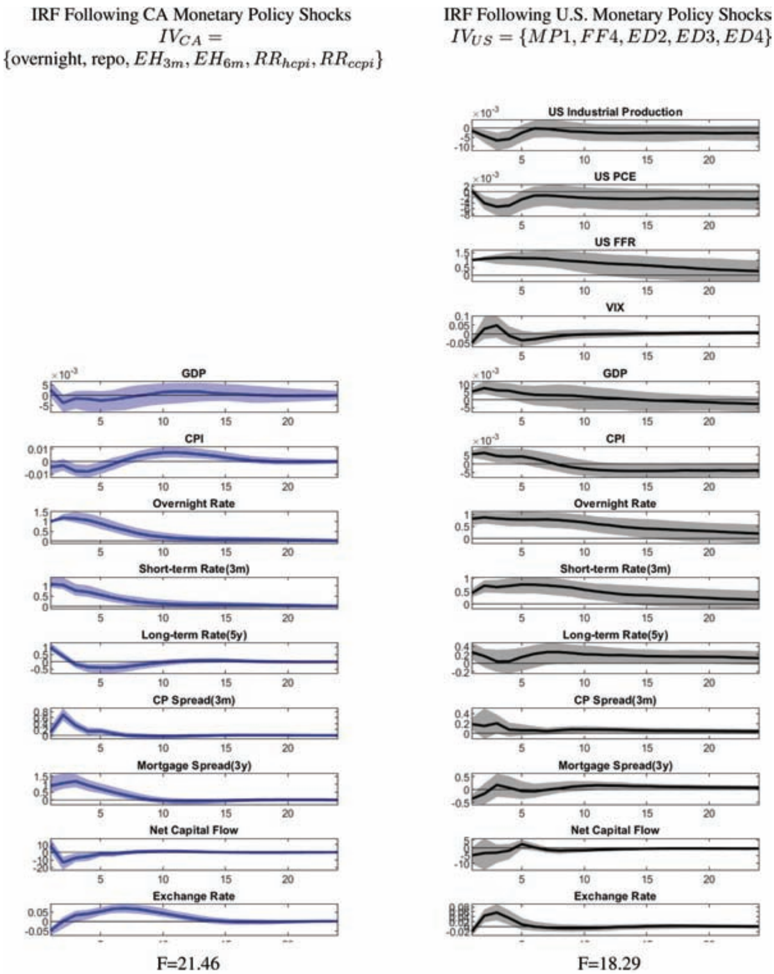
Figure A.7. (Continued)

C. Alternative U.S. Policy Interest Rates: U.S. Treasury Bond Yield (One Year)



Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for capital flow). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

Figure A.8. VIX Included as an Endogenous Variable



Note: Y-axis indicates percent (or percentage point for interest rates, or mil. CAD for capital flow). X-axis indicates months after shock. Based on contractionary (+100 bps) U.S. and Canadian monetary policy shocks, respectively. Shaded areas are the 16 and 84 percentiles of the empirical distribution based on wild-bootstrapped samples. "F" denotes F-statistics for the first-stage regression of residuals of policy indicators on each IV set.

A.2 Technical Details on External Instrument Identification Scheme

The relationship between residuals of reduced-form VAR (e_t) and structural shocks (ε_t) in Equation (7) can be rearranged as (A.1):

$$\begin{bmatrix} e_t^p \\ e_t^q \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^q \end{bmatrix} = \begin{bmatrix} s_{11}\varepsilon_t^p + s_{12}\varepsilon_t^q \\ s_{21}\varepsilon_t^p + s_{22}\varepsilon_t^q \end{bmatrix}, \tag{A.1}$$

where s_{11} represents the response of the residuals of the monetary policy instrument to its own shock and s_{21} represents the responses of residual series of the other variables to the structural monetary policy shock. Since we are interested in how variables respond to monetary policy shocks, s_{11} and s_{21} are the only two parts of the impact matrix (S) to be identified.

Next, VAR residuals e_t^p and e_t^q can be expressed by the other reduced-form residuals and structural shocks ε_t^p or ε_t^q because those are composites of structural shocks as in (A.2) and (A.3):

$$e_t^p = \eta e_t^q + C_1 \varepsilon_t^p \tag{A.2}$$

$$e_t^q = \theta e_t^p + C_2 \varepsilon_t^q, \tag{A.3}$$

where $\eta = s_{12}s_{22}^{-1}$, $\theta = s_{21}s_{11}^{-1}$, $C_1 = s_{11} - s_{12}s_{22}^{-1}s_{21}$, and $C_2 = s_{22} - s_{21}s_{11}^{-1}s_{12}$. In particular, the 2×2 matrix C_1 represents variance–covariance between two structural monetary policy shocks.[44] It has the following relationship with s_{11} and s_{21}:

$$\begin{bmatrix} s_{11} \\ s_{21} \end{bmatrix} = \begin{bmatrix} \left(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}\right)^{-1} \\ s_{21}s_{11}^{-1}\left(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}\right)^{-1} \end{bmatrix} C_1 \tag{A.4}$$

$$C_1C_1' = \left(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}\right) s_{11}s_{11}' \left(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}\right)'. \tag{A.5}$$

Thus, obtaining s_{11} and s_{21} requires identification of two parts: One is $s_{21}s_{11}^{-1}(= \theta)$, which can be estimated by two-stage least

[44] C_1 can be rearranged as $C_1 = s_{11} - s_{12}s_{22}^{-1}s_{21} = \left(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}\right) s_{11}$ and thus $s_{11}C_1^{-1} = \left(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}\right)^{-1}$. Similarly, C_2 can be expressed in terms of partitions of S matrix as the following form: $s_{21}C_1^{-1} = s_{21}s_{11}^{-1}s_{11}C_1^{-1} = s_{21}s_{11}^{-1}\left(I - s_{12}s_{22}^{-1}s_{21}s_{11}^{-1}\right)^{-1}$.

squares (2SLS) estimation, and the others are $s_{11}s_{11}'$ and $s_{12}s_{22}^{-1}$, which can be calculated by restrictions from the covariance matrix.[45]

Restriction from 2SLS Estimation: $\boldsymbol{s_{21}s_{11}^{-1}(=\theta)}$. Consider first the regression of Equation (A.2). Since the reduced-form residual for monetary policy instrument $(e_t^p(=s_{11}\varepsilon_t^p+s_{12}\varepsilon_t^q))$ is correlated with $C_2\varepsilon_t^q$, denoting it as u_t hereafter, we can obtain consistent estimates of θ of regression e^q on e^p from 2SLS, employing appropriate instrumental variables that satisfy the following moment conditions, as in (A.6) and (A.7):

$$E\left[Z_t u_t\right]=0 \qquad \text{or} \qquad E\left[Z_t \varepsilon_t^q\right]=0 \tag{A.6}$$

$$E\left[Z_t e_t^p\right]=\pi(\pi\neq 0) \qquad \text{or} \qquad E\left[Z_t \varepsilon_t^p\right]=\phi(\phi\neq 0). \tag{A.7}$$

Restriction from Covariance Matrix: $\boldsymbol{s_{11}s_{11}'}$ and $\boldsymbol{s_{12}s_{22}^{-1}}$. In addition to the restrictions derived from IV estimation, identification of s_{11} and s_{21} requires the additional restrictions from the covariance matrix. Consider the following reduced-form variance–covariance and its partitioning in (A.8):

$$\Sigma=E[SS']\Rightarrow\begin{bmatrix}\Sigma_{11} & \Sigma_{12}\\ \Sigma_{21} & \Sigma_{22}\end{bmatrix}=\begin{bmatrix}s_{11}s_{11}'+s_{12}s_{12}' & s_{11}s_{21}'+s_{12}s_{22}'\\ s_{21}s_{11}'+s_{22}s_{12}' & s_{21}s_{21}'+s_{22}s_{22}'\end{bmatrix}. \tag{A.8}$$

Then, $s_{11}s_{11}'$, $s_{12}s_{22}^{-1}$ is obtained by the following closed-form solution in (A.9) and (A.10):

$$s_{11}s_{11}'=\Sigma_{11}-s_{12}s_{12}' \tag{A.9}$$

$$s_{12}s_{22}^{-1}=\left(s_{12}s_{12}'\theta'+(\Sigma_{21}-\theta\Sigma_{11})'\right)\left(s_{22}s_{22}'\right)^{-1}, \tag{A.10}$$

where $s_{12}s_{12}'=(\Sigma_{21}-\theta\Sigma_{11})'Q^{-1}(\Sigma_{21}-\theta\Sigma_{11})$, $s_{22}s_{22}'=\Sigma_{22}+s_{21}s_{11}^{-1}(s_{12}s_{12}'-\Sigma_{11})\left(s_{21}s_{11}^{-1}\right)'$, and $Q=\Sigma_{22}-(\Sigma_{21}\theta'+\theta\Sigma_{21})+\theta\Sigma_{11}\theta'$.[46]

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[45] The different types of instruments may deliver quite distinct information as discussed in Section 3. Taking this into account, we identify each shock using multiple proxy variables in the 2SLS estimation.

[46] Consider first the fact that $\Sigma_{21}-\theta\Sigma_{11}=C_2s_{12}'$ because $\Sigma_{21}-\theta\Sigma_{11}=s_{21}s_{11}'+s_{22}s_{12}'-s_{21}s_{11}^{-1}(s_{11}s_{11}'+s_{12}s_{12}')=s_{22}s_{12}'-s_{21}s_{11}^{-1}s_{12}s_{12}'=\left(s_{22}-s_{11}^{-1}s_{12}\right)s_{12}'$. The derivation of $s_{12}s_{22}^{-1}$ is straightforward, noticing that

These restrictions from 2SLS and VAR residual covariance allow for the identification of C_1C_1' and the covariance of $C_1\varepsilon_t^p$. If structural shocks to domestic monetary policy are uncorrelated with foreign monetary policy shocks and vice versa, C_1 is a diagonal and can be directly identified up to a sign convention from Equation (A.6).[47] However, if we cannot impose zero cross-correlations between structural shocks, we must make an arbitrary assumption regarding how domestic monetary policy shocks respond contemporaneously to unanticipated movements in foreign monetary policy instruments and vice versa in order to disentangle the causal effects of shocks on both monetary policy shocks. To the extent that the model considers two countries, the United States and a small open economy, Cholesky decomposition of C_1C_1', supposing that the foreign monetary policy shock is ordered before the domestic monetary policy shock, permits economically meaningful results in this analysis. Finally, by plugging the identified C_1 back into (A.5), s_{11} and s_{21} are uniquely pinned down.

A.3 Technical Details on Instrumental Variable II: Monetary Policy Shock Implied in Term Structure Model

The affine model we consider is described below. The prices of zero-coupon bonds are derived from the pricing kernel as in (A.11):

$$P_t{}^\tau = E_t\left[m_{t+1}P_{t+1}{}^{\tau-1}\right], \tag{A.11}$$

where $P_t{}^\tau$ is the zero-coupon bond price with a maturity τ, m_{t+1} is a stochastic discount factor. E_t is a conditional expectation on

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$s_{12}s_{22}' = s_{12}s_{12}'\theta' + (\Sigma_{21} - \theta\Sigma_{11})'$. $Q = Q'$ because Q is symmetric, and it is same as u_tu_t' or C_2C_2'. Using this fact, $s_{12}s_{12}'$ can be obtained by the following form: $s_{12}s_{12}' = s_{12}C_2'C_2'^{-1}C_2^{-1}C_2s_{12}' = s_{12}C_2'Q^{-1}C_2s_{12}' = (\Sigma_{21} - \theta\Sigma_{11})' Q^{-1} (\Sigma_{21} - \theta\Sigma_{11})$. And from the covariance matrix, $s_{22}s_{22}' = \Sigma_{22} - s_{21}s_{21}'$, and it can be expressed as the above because $s_{21}s_{21}' = s_{21}\left(s_{11}^{-1}s_{11}s_{11}'s_{11}^{-1\prime}\right)s_{21}' = \left(s_{21}s_{11}^{-1}\right)(\Sigma_{11} - s_{12}s_{12}')\left(s_{11}^{-1\prime}s_{21}'\right)$.

[47]If so, a simpler identification approach, such as Gertler and Karadi (2015) employ, can be directly applied to identify s_{11} and $s_{21}C_1$.

the information set up to time t. We specify the discount factor as (A.12):

$$m_{t+1} = exp\left(-r_t - \frac{1}{2}\Lambda_t'\Omega\Lambda_t - \Lambda_t'\nu_{t+1}\right) \tag{A.12}$$

with the assumption that the risk-free short-term rate (r_t) and time-varying market prices of risk (Λ_t) are linear functions of factors as in (A.13):

$$r_t = \delta_0 + \delta_1' X_t \qquad \text{and} \qquad \Lambda_t = \lambda_0 + \lambda_1 X_t, \tag{A.13}$$

where δ_0 is a constant term; δ_1 and λ_0 are $N \times 1$ vectors; and λ_1 is a $N \times N$ matrix, respectively. We assume that the transition equation for state variable X_t follows the first-order vector-autoregressive process as in (A.14):

$$X_t = \mu + \Phi X_{t-1} + \nu_t, \tag{A.14}$$

where factor shocks ν_t follows *iid* normal distribution $N(0, \Omega)$.

Combining Equations (A.11)–(A.14) yields the bond price and yield for maturity τ as the following affine functions of the state variables:

$$P_t{}^\tau = exp[A_\tau + B_\tau X_t] \tag{A.15}$$

$$R_t{}^\tau \approx -\frac{1}{\tau} log P_t{}^\tau = -\frac{1}{\tau}\left(A_\tau + B_\tau X_t\right), \tag{A.16}$$

where A_τ and B_τ are obtained in the recursive equations as in (A.17) and (A.18).

$$A_{\tau+1} = A_\tau + B_\tau'\left(\mu - \Omega\lambda_0\right) + \frac{1}{2}B_\tau'\Omega B_\tau - \delta_0 \tag{A.17}$$

$$B_{\tau+1}' = B_\tau'\left(\Phi - \Omega\lambda_1\right) - \delta_1' \tag{A.18}$$

In estimating coefficients and pricing factors, we follow the approach of Adrian, Crump, and Moench (2013), which comprises three-step regressions. First, a VAR of order one in Equation (A.14) is estimated via ordinary least squares (OLS). This step decomposes pricing factors X_t into a predictable component and estimated factor innovations v_t. Second, we regress excess bond returns on a constant, lagged pricing factors and the pricing factor innovations. By doing so, we have predictive coefficients and factor risk exposures. Third, the market price of risk parameters λ_0 and λ_1 are estimated by cross-sectionally regressing predictive coefficients on factor risk exposures.

By estimating the term structure model with this approach, we can decompose daily bond yields with a variety of maturities into the sum of expected short-term rates and term premiums. Other things being equal, monetary shocks around policy decisions directly cause changes in the future path of the short-term interest rate. Thus, we consider the daily change of short-term expectations around monetary policy announcements as monetary surprises.

A.4 Technical Details on Instrumental Variable III: Residuals from Policy Reaction Functions

We follow Champagne and Sekkel (2018) and take two steps in estimating the Taylor-rule equation. First, using the minutes of monetary policy reports (source: Bank of Canada Monetary Policy Reports), we collect real-time forecasts for output and inflation in Canada. We use both headline and core CPI inflation for the CPI inflation forecast. Second, we regress changes in monetary policy target rates from the previous monetary policy decision meeting to the current meeting (Δr_m) on a set of explanatory variables that purge the intended policy rate. The explanatory variables include (i) levels of policy rates (two weeks prior to the monetary policy meeting, r_{t-14}), (ii) forecasts of real GDP growth ($y^f_{m,j}$) and inflation ($\pi^f_{m,j}$); we here include the one- and two-month-ahead forecasts as well as the forecasts for the contemporaneous period and the forecast made one month before the meeting, (iii) changes of the variables selected in (ii) from the previous period, and (iv) other variables that could potentially reflect economic developments between meetings. The terms in (iii) reflect revisions to the forecasts relative to the previous round of forecasts. The last variable (iv) includes real-time rates of unemployment for the previous three months and the levels and changes of U.S. federal fund rates and the logs of the USD/CAD nominal exchange rate two weeks before the meeting. The estimated regression is summarized as (A.19).

$$\Delta r_m = \alpha + \underbrace{\beta_1 r_{t-14}}_{(i)} + \underbrace{\sum_{j=-1}^{2} \beta_{2,j} y^f_{m,j} + \sum_{j=-1}^{2} \beta_{3,j} \pi^f_{m,j}}_{(ii)}$$

$$+ \underbrace{\sum_{j=-1}^{2} \beta_{4,j} \left(y^f_{m,j} - y^f_{m-1,j}\right) + \sum_{j=-1}^{2} \beta_{5,j} \left(\pi^f_{m,j} - \pi^f_{m-1,j}\right)}_{(iii)}$$

$$+ \underbrace{\gamma Z}_{(iv)} + \varepsilon_m, \qquad \text{(A.19)}$$

where Δr_m, changes in policy rates, is measured at the frequency of monetary policy meetings, as indicated by the subscript m. The subscript j denotes the quarter of the real-time data or forecast relative to the meeting date. Z includes other control variables.

The regression coefficients for Equation (A.19) are summarized in Table A.1 (using headline CPI inflation forecast in panel A and the core CPI inflation forecast in panel B). Consistent with the findings in Champagne and Sekkel (2018), the results indicate that changes in policy rate are significantly and positively associated with levels or changes in the forecast of inflation and/or output growth. The results also provide evidence that monetary policy decisions in Canada reflect both levels and changes in monetary policy target rates in the United States. A higher real-time unemployment level is associated with a decrease in policy rates with less statistical significance after controlling for GDP growth and inflation forecasts. R^2 of the regressions is over 0.8. This suggests that explanatory variables in the regressions which proxy the intended component of policy changes in Canada explain around 80 percent of variations in monetary policy target rates in Canada over the sample period.

Table A.1. Regression of Monetary Policy Rates on Explanatory Variables

Variable	Coefficient	Std. Error	t-statistic	Prob.
A. Regression with Headline CPI Inflation Forecast				
Initial Policy Rates in Canada	–0.1926	0.0259	–7.4286	0.0000
Policy Rates in United States (FFR)				
Level	0.1306	0.0182	7.1896	0.0000
Changes	0.0807	0.0273	2.9603	0.0040
CAD/USD Rates				
Level	–0.3594	0.2242	–1.6036	0.1126
Changes	–0.0062	0.0071	–0.8668	0.3886
Unemployment in Canada				
One Month Before	–0.0368	0.0726	–0.5065	0.6139
Two Months Before	–0.0177	0.0881	–0.2012	0.8410
Three Months Before	0.0557	0.0682	0.8177	0.4159
Forecasted Output Growth				
One Quarter Before	0.0268	0.0240	1.1175	0.2671
Contemporaneous	0.0455	0.0371	1.2253	0.2240
One Quarter Ahead	–0.0787	0.0378	–2.0824	0.0404
Two Quarters Ahead	0.0533	0.0327	1.6314	0.1066
Changes in Forecasted Output Growth				
One Quarter Before	–0.1498	0.0552	–2.7145	0.0081
Contemporaneous	0.1383	0.0685	2.0182	0.0468
One Quarter Ahead	0.0931	0.0629	1.4802	0.1427
Two Quarters Ahead	–0.1185	0.0498	–2.3820	0.0195
Forecasted Headline CPI Inflation				
One Quarter Before	–0.0371	0.0219	–1.6929	0.0943
Contemporaneous	0.0640	0.0369	1.7332	0.0868
One Quarter Ahead	–0.0260	0.0466	–0.5584	0.5781
Two Quarters Ahead	0.0129	0.0486	0.2664	0.7906
Changes in Forecasted Headline CPI Inflation				
One Quarter Before	0.0097	0.0479	0.2030	0.8397
Contemporaneous	0.0213	0.0591	0.3597	0.7200
One Quarter Ahead	0.1018	0.0569	1.7892	0.0773
Two Quarters Ahead	–0.1115	0.0603	–1.8485	0.0681
Constant	0.0827	0.1878	0.4404	0.6608
R^2: 0.83				

(*continued*)

Table A.1. (Continued)

Variable	Coefficient	Std. Error	*t*-statistic	Prob.
B. Regression with Core CPI Inflation Forecast				
Initial Policy Rates in Canada	–0.2169	0.0282	–7.6814	0.0000
Policy Rates in United States (FFR)				
Level	0.1434	0.0189	7.5926	0.0000
Changes	0.0748	0.0296	2.5297	0.0134
CAD/USD Rates				
Level	–0.3728	0.2549	–1.4628	0.1474
Changes	–0.0136	0.0077	–1.7637	0.0816
Unemployment in Canada				
One Month Before	–0.0458	0.0793	–0.5778	0.5650
Two Months Before	–0.0217	0.0991	–0.2187	0.8275
Three Months Before	0.0459	0.0745	0.6157	0.5398
Forecasted Output Growth				
One Quarter Before	0.0337	0.0243	1.3846	0.1700
Contemporaneous	0.0248	0.0457	0.5424	0.5890
One Quarter Ahead	–0.0533	0.0455	–1.1719	0.2447
Two Quarters Ahead	0.0375	0.0376	0.9985	0.3210
Changes in Forecasted Output Growth				
One Quarter Before	–0.1188	0.0534	–2.2232	0.0290
Contemporaneous	0.0487	0.0689	0.7062	0.4821
One Quarter Ahead	0.1431	0.0726	1.9721	0.0521
Two Quarters Ahead	–0.1156	0.0556	–2.0801	0.0407
Forecasted Headline CPI Inflation				
One Quarter Before	–0.0203	0.0729	–0.2786	0.7813
Contemporaneous	–0.1870	0.1034	–1.8078	0.0744
One Quarter Ahead	0.1376	0.1627	0.8458	0.4002
Two Quarters Ahead	–0.0523	0.1289	–0.4057	0.6861
Changes in Forecasted Headline CPI Inflation				
One Quarter Before	–0.0447	0.1201	–0.3724	0.7106
Contemporaneous	0.3166	0.1984	1.5959	0.1145
One Quarter Ahead	–0.2862	0.2274	–1.2585	0.2119
Two Quarters Ahead	0.2309	0.1557	1.4832	0.1420
Constant	0.5186	0.3299	1.5719	0.1199
R^2: 0.81				

Note: This table reports regression coefficients of changes in Canada policy rates from previous MPC meeting on various independent variables.

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