# Monetary Policy and Exchange Rate: Examining the Overshooting Puzzle in a Small Open Economy

June 2024

**Abstract**

I examine the effect of an exogenous change in monetary policy and the exchange rate on a small, open economy. The empirical literature has often observed mixed results on this question. Through this paper, I provide additional evidence that the results are in line with the theoretical predictions of the seminal Dornbusch (1976) paper. I find that when structural shocks are recovered correctly, the exchange rate responds on impact and shows no signs of delay, while the price puzzle was still prevalent in the results. A comparison of the IRFs from a VAR identified using the recursiveness assumption provides additional evidence on this.

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# Contents

# 1 Introduction

This paper asks the question, *what is the effect of a monetary policy and exchange rate shock on a small, open economy? More specifically, does exchange rate overshoot following a contractionary monetary policy shock or not?*

In small open economies, the exchange rate is an important element of the transmission process of monetary policy and, in itself, is also influenced by monetary policy (Svensson, 2000; Bjørnland, 2009). Moreover, shifting from a regime of fixed exchange rate to a flexible exchange rate system can cause it to be more volatile.
The Dornbusch (1976) overshooting model predicts exchange rates to overshoot (an instantaneous appreciation) and then to gradually depreciate following a contractionary monetary policy shock. But what is often found in the empirical literature is that the results from the theoretical Dornbusch model and real data do not exactly match up – the overshooting happens only with a delay (hence the name "delayed-overshooting"). Ever since the seminal work of Eichenbaum and Evans (1995), which was the origin of this puzzling slow response of the exchange rate, this has been the subject of a large body of literature. Since the uncovered interest parity relation (UIP) is built on the assumptions of risk neutrality and no transaction costs, it is already known that the UIP is often rejected due to the presence of a time-varying risk premium. But, as many models predict, if monetary policy shocks have only small effects on the currency risk premium, then the Dornbusch overshooting should still hold in response to monetary policy shocks, even if it fails unconditionally (Faust and Rogers, 2003).

Many papers have been devoted to answering this puzzling question. Clarida and Gali (1994) built a three-equation open economy macro model in the spirit of Dornbusch (1976) and utilised the long-run properties of this model to explain the structural shocks that cause real exchange rate movements. A large literature was built on this (Weber, 1997; Chadha and Prasad, 1997; Farrant and Peersman, 2006), among others. Recent papers have focused on modelling non-linearities in their VAR models or have utilised high-frequency data. Rüth (2020) estimate a VAR model for the US economy in a high-frequency approach, focusing on the period of conventional US monetary policy. He uses surprises in the current Federal funds futures rate, as a measure of monetary policy shock, to construct the external instrument for his SVAR-IV model and finds no evidence of delayed overshooting. In order to study the effects of conventional and unconventional monetary policy on exchange rates, Inoue and Rossi (2019) propose a novel approach for identification, where shocks are defined as shifts in the entire term structure of interest rates on the day of a monetary policy announcement. They find favourable evidence for Dornbusch's overshooting hypothesis and conclude that a monetary policy easing leads to a depreciation in both conventional and unconventional periods. In general, the results from more recent literature have been that VAR models that have been successful in accurately representing real data find that Dornbusch's overshooting hypothesis is still relevant today.

In this paper, I contribute to the literature that tries to identify the effect of monetary policy on the exchange rate in a small open economy, using Canada as a case study. Following King et al. (1987) and Bjørnland (2009), I adopt an identification strategy that utilises the long-run properties of the data and also allows for contemporaneous interaction between interest rates and exchange rates when imposing short-run restrictions. In addition, I study the accuracy of the results by comparing the impulse responses generated to a VAR model identified through standard Cholesky decomposition. My main finding is that, consistent with recent literature, the exchange rate appreciates on impact following a contractionary monetary policy shock. Modelling structural VARs without taking into account the simultaneity between forward-looking variables like interest rates and exchange rates can lead to conclusions not in line with the Dornbusch model.

The rest of the paper is structured as follows: Section 2 reviews the related literature. Section 3 describes the data, while Section 4 presents the theoretical framework.

Section 5 discusses the cointegration analysis and the identification restrictions. Section 6 reports the results, followed by the discussion in Section 7. Section 8 concludes. Additional plots and results are provided in Appendix A.

# 2 An overview of past empirical work

Pioneered by Sims (1980), structural VARs have since become a key tool in studying the transmission of monetary policy. As the literature grew, the model evolved to incorporate larger systems and other non-linearities in order to better reflect the dynamics of the real world. Eichenbaum and Evans (1995) extended the baseline VAR model of Christiano et al. (1998) to an open-economy set-up by including exchange rates, in order to study the effects of a contractionary US monetary policy shock on real and nominal exchange rates as well as domestic and foreign interest rates, using the standard recursive identification scheme. They found persistent appreciation in the US nominal and real exchange rates along with significant deviations from uncovered interest parity (UIP). This was the starting point that motivated several other papers to test the robustness of these results.

Many papers that modelled exchange rates using a VAR framework also found results in support of this puzzling response (see, e.g. Gourinchas and Tornell, 1996; Faust and Rogers, 2003), while others found that exchange rates depreciated following a contractionary shock. This is also referred to as the "exchange rate puzzle." The literature that followed made attempts to study whether this empirical puzzle was prevalent by testing different identification schemes. Kim and Roubini (2000), who studied the question for non-US G7 countries, used non-recursive zero restrictions that allowed for contemporaneous interaction between monetary policy and the exchange rate, with one of the restrictions being that the monetary policymaker cannot respond contemporaneously to the foreign interest rate.[1] They found their identification scheme successful in identifying monetary policy shocks and solving the empirical puzzles (delayed overshooting and the exchange rate puzzle). In an influential paper, Bjørnland (2009) built on this idea of allowing simultaneous interaction between monetary policy and the exchange rate. However, she noted that it is not plausible to assume that the central bank of a small open economy would not respond to foreign shocks occurring within a month or a quarter. She therefore used a combination of short-run and long-run restrictions, more specifically imposing restrictions on the long-run multipliers of shocks by assuming that monetary policy shocks have no long-run effect on the level of the real exchange rate, the standard long-run neutrality assumption, while leaving the contemporaneous relationship between the interest rate and the exchange rate intact. The result was an instantaneous response of the exchange rate to a monetary policy shock.

Another strand of the literature used sign restrictions, following the work of Scholl and Uhlig (2008). Identification is achieved using static and dynamic sign restrictions on the impulse responses. Among their identifying assumptions, Scholl and Uhlig (2008) also imposed shape restrictions on the response function of the exchange rate to eliminate delayed overshooting. Other studies that used sign restrictions include Bjørnland and Halvorsen (2014) and Fisher and Huh (2016), among others.

In the context of papers that studied the same question for the Canadian economy, Cushman and Zha (1997) used non-recursive zero restrictions and found that an unanticipated decline in the domestic money supply was accompanied by an immediate and significant appreciation of the Canadian dollar. Kim (2005) and Bjørnland and Halvorsen (2014) also explored the same question. While the former found evidence of delayed overshooting and concluded that the uncovered interest parity condition assumed to hold in the rational expectations Dornbusch model is violated, the latter, who combined sign and short-run restrictions preserving the interaction between interest rates and the exchange rate, found the exchange rate to appreciate on impact.

Many papers in the literature, however, focus only on imposing contemporaneous restrictions, as they either do not find evidence of cointegration or do not test for it.

[1] To control for exogenous events, they also include world oil prices in their model to isolate exogenous monetary policy changes.

The common-trends approach discussed by King et al. (1987) is designed to handle long-run equilibrium relationships between the levels of the variables (see also Alexius, 2001). Heinlein and Krolzig (2012) developed a small econometric two-country model for the UK and the US economy and used a cointegrated VAR approach to study the response to an asymmetric monetary policy shock in the two countries. They found strong evidence for delayed overshooting and violations of UIP.

To summarise, there exists an extensive body of literature employing the structural VAR (SVAR) approach to model exchange rates, of which I have provided a non-exhaustive review in this section. As with any empirical puzzle, the general consensus is that there is no clear answer regarding how exchange rates should respond in real data, though theoretical models like Dornbusch's provide a useful baseline for comparison.

Given previous works that addressed the same question for Canada but relied only on contemporaneous restrictions, in this paper I utilise the common-trends approach discussed by King et al. (1987) and Bjørnland (2009). More specifically, I take into account the cointegration relationships suggested by the data and use a combination of long-run and short-run restrictions to identify the model. Following Bjørnland (2009), I do not impose restrictions on the contemporaneous interaction between the exchange rate and the domestic interest rate in the short run.

# 3 Data

The empirical analysis is based on monthly data for Canada spanning the period 1985–2007. The Bank of Canada pursued strong contractionary monetary policy during late 1970s attributing to oil price shocks. By early 1980s, the interest rate peaked to 20 % due to the central bank's effort to fight persistent inflation. The data ends at 2007, in order to carry out the analysis without the period of the Global Financial crisis and unconventional monetary policy in the US. All series are obtained from the Federal Reserve Economic Data (FRED) database. [2]

| Notation | Description |
|---|---|
| $p$ | Log of Consumer Price Index: All Items: Total for Canada, Index 2015=100, Not Seasonally Adjusted |
| $y$ | Log of Production: Industry: Total Industry Excluding Construction for Canada, Index 2015=100, Seasonally Adjusted |
| $i^*$ | Effective Federal Funds Rate (US) |
| $i$ | Interest Rates: 3-Month or 90-Day Interbank Rates: Total for Canada, Monthly, Not Seasonally Adjusted |
| $e$ | Log of Canadian Dollar to US Dollar Spot Exchange Rate, Monthly, Not Seasonally Adjusted |

Table 1: Variables Used in the Analysis

# 4 Theoretical Framework

In this section, I provide some insights into the seminal Dornbusch model, which serves as the basis for comparison throughout this paper. Then I postulate the theoretical cointegration vectors I expect to find, based on the Dornbusch Model and provide graphical analysis on the same.

## 4.1 The Dornbusch overshooting model

During the early to mid-1970s, when many countries were transitioning to flexible exchange rates after the breakdown of the Bretton Woods system, exchange rates were

[2]See Figure A.1 in Appendix A for a plot of the dataset.

highly volatile, often more volatile than the underlying macroeconomic fundamentals. Dornbusch's sticky-price model, which preceded the New Keynesian framework derived from microfoundations of price stickiness, provided a novel explanation for this behavior: the slow adjustment of prices played a central role in how exchange rates responded.[3]

How many cointegrating relations can we expect to find in the five-variable system considered? Two relationships form the main building blocks of the overshooting model: the uncovered interest parity condition and a money demand relation. In following sections offer a brief walkthrough of these two equations.[4]

## 4.2 Interest rates and exchange rates

The Dornbusch overshooting model assumes perfect capital mobility, such that domestic and foreign assets are regarded as perfect substitutes. This gives rise to the uncovered interest parity (UIP) condition, which links the interest rate differential between two countries to the expected change in the nominal exchange rate.[5]

Formally, the arbitrage condition can be expressed as

$$1 + i_t = (1 + i_t^*)\frac{E_{t+1}^e}{E_t}, \tag{1}$$

which in logarithmic form becomes

$$i_t = i_t^* + e_{t+1}^e - e_t, \tag{2}$$

where $e_{t+1}^e = \ln E_{t+1}^e$ and $e_t = \ln E_t$. This condition states that, under risk neutrality and in the absence of transaction costs, the expected change in the nominal exchange rate must equal the interest rate differential. Figure 1 plots the Canadian and US short-term nominal interest rates, together with their differential. The interest rate series appear potentially cointegrated, while the differential shows persistence. By contrast, the change in the spot exchange rate appears stationary.[6] If the nominal exchange rate is $I(1)$ and the risk premium is zero, implying perfect substitutability between domestic and foreign assets, the interest rate spread should also be stationary. However, the empirical literature frequently finds evidence of a time-varying risk premium, leading to systematic deviations from UIP.

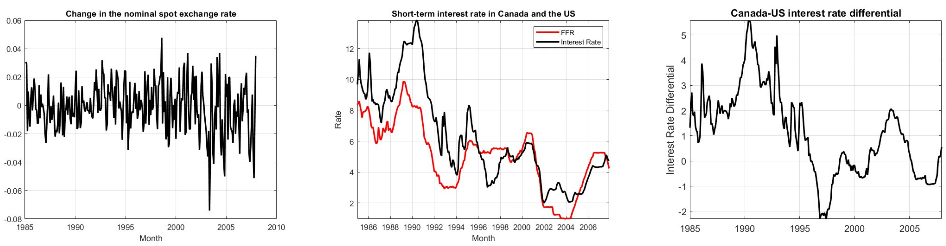



**Figure 1:** Interest rates and exchange rate series for Canada and the US.

Left panel: Change in the nominal spot exchange rate. Middle panel: Short-term nominal interest rates in both countries. Right panel: Canada–US interest rate differential.

Hence, for the vector of variables $[p_t\ y_t\ i_t^*\ i_t\ e_t]$, where $i_t^*$ denotes the foreign nominal interest rate, $p_t$, $y_t$, and $i_t$ represent the domestic consumer price index, output, and interest rate, respectively, and $e_t$ is the nominal exchange rate defined as the units of domestic currency per unit of foreign currency, I assume the existence of one cointegra-

[3] Another key novelty of the Dornbusch model was the inclusion of rational expectations, i.e. the assumption that agents form expectations about the long-run exchange rate rationally. This feature also distinguishes it from the Mundell–Fleming model.

[4] I abstract from discussing the other elements of the Dornbusch model, such as the aggregate demand and price adjustment equations, as they do not align with the main objectives of this paper.

[5] In the Dornbusch model, purchasing power parity is also assumed to hold in the long run.

[6] Stationarity of the nominal exchange rate itself is rejected by standard unit root tests.

tion relation between the domestic and foreign interest rates. This can be represented by the cointegrating vector,[7]

$$\beta_1 = [0 \quad 0 \quad -1 \quad 1 \quad 0], \tag{3}$$

which essentially tests for proportionality between the domestic and foreign interest rates.

### 4.3 A money demand relation

The second core equation in the Dornbusch model is the money demand relation:

$$m_t - p_t = -\phi i_{t+1} + \lambda y_t, \tag{4}$$

which links the real money supply to output and the interest rate, where $0 < \lambda < 1$ denotes the income elasticity of money demand, and $\phi > 0$ is the semi-elasticity of money demand with respect to the interest rate.

I consider a cointegrating vector of the form

$$\beta_2 = [1 \quad 1 \quad 0 \quad \phi \quad 0], \tag{5}$$

where, following Crowder and Wohar (2004), I assume a unitary income elasticity (i.e., $\lambda = 1$), while allowing $\phi$ to be freely estimated.[8]

I interpret this vector as a goods market equilibrium relation, representing a long-run relationship among domestic variables, namely, prices, output, and interest rates. [9]

## 5 Econometric Framework

This section briefly outlines the underlying econometric theory. I begin by presenting the cointegrated SVAR representation, which provides the structural basis of the model, before turning to the cointegration analysis and the identification restrictions imposed on the structural model.

### 5.1 The Cointegrated SVAR

We start by considering the VEC representation of a VAR($p$) model:

$$\Delta x_t = \mu + \Pi x_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + u_t,$$

where the vector of endogenous variables is $x_t = [p_t \; y_t \; i_t^* \; i_t \; e_t]$.

If there are $r$ cointegrating relations, then $\Pi$ has reduced rank and can be written as $\Pi = \alpha\beta'$. The model can then be rewritten in the common trends representation:

$$x_t = \Xi \sum_{i=1}^{t} u_i + \Xi^*(L)u_t + x_0^*,$$

where

$$\Xi = \beta_\perp \left[ \alpha'_\perp \left( I_k - \sum_{i=1}^{p-1} \Gamma_i \right) \beta_\perp \right]^{-1} \alpha'_\perp$$

[7] Ideally, the change in the exchange rate should enter this relation. Since UIP is often rejected empirically, a modified version of the form $\Delta s_t - (i_t - i_t^*) = \rho_t$, where the expected change is replaced by $\Delta s_t$ and $\rho_t$ denotes a risk premium, is typically tested in the literature.

[8] Crowder and Wohar (2004) estimate four long-run relations—a consumption–income relation, a consumption–wealth relation, a money demand equation, and a Fisher equation—using a cointegrated structural VAR model for Canada over the period 1964–1994.

[9] While a more standard money demand relation of the form $m_t - p_t = \lambda y_t - \phi i_t$ would require including a money supply variable in the VAR, this is not done here. As such, the interpretation of this vector is more consistent with a goods market equilibrium condition.

By replacing $u_t$ with $B_0^{-1}w_t$, we obtain the structural common trends model:

$$x_t = \Upsilon\Xi\sum_{i=1}^{t} w_i + \Xi^*(L)B_0^{-1}w_t,$$

where

$$\Upsilon = \Xi B_0^{-1}$$

Here, $\Upsilon$ is the matrix of long-run multipliers. To identify the permanent structural shocks, restrictions must be imposed on the long-run impact matrix. For a $K$-variable system with rank $r$, we require $(K-r)(K-r-1)/2$ long-run restrictions and $r(r-1)/2$ short-run restrictions on the $B_0^{-1}$ matrix for exact identification.

## 5.2 Model Specification

### 5.2.1 Cointegration Analysis

Using the information criteria (Akaike, Schwarz, and Hannan-Quinn) to choose the lag length, I select a lag length of 2 for Canada, as suggested by all three criteria. This corresponds to one lag in the Vector Error Correction Model (VECM). The model was estimated with a constant term but no trend.[10] Table - presents the results of the Johansen test for the cointegration rank. Starting with the hypothesis that $r = 0$, the null hypothesis is rejected at the 1 percent level. Increasing the rank to 2, we find that this hypothesis cannot be rejected. The data therefore suggest the presence of two cointegration vectors.[11] This implies that two of the innovations in the data will have only transitory effects, while the remaining shocks must be interpreted as permanent.

| rank | h | stat | pValue | eigVal |
|---|---|---|---|---|
| 0 | 1 | 134.7760 | 0.0010 | 0.1495 |
| 1 | 1 | 71.4481 | 0.0010 | 0.1230 |
| 2 | 0 | 20.1443 | 0.4488 | 0.0302 |
| 3 | 0 | 8.1529 | 0.4985 | 0.002 |

Table 2: Cointegration Test Results

I report the estimated normalised cointegration vectors below, assuming a rank of 2 and only a constant term in the cointegration vectors: [12]

$$\hat{\beta_1} = [0.0807 \quad 0.3125 \quad -0.5426 \quad 1.000 \quad -0.0826]$$
$$\hat{\beta_2} = [-0.1675 \quad -0.2344 \quad -0.1782 \quad 1.000 \quad 0.1424]$$

Comparing these estimates with the hypothesised theoretical cointegration vectors, we observe that the first estimated vector bears some resemblance to the first theoretical vector. The coefficients for the first, fifth (though with the opposite sign), and possibly the second parameters are close to zero, while the remaining parameters are close to one but with opposite signs. By contrast, the second estimated vector does not appear to align with the theoretical arguments presented in Section 3. As is evident, the estimates and the signs are quite far off, which makes it difficult to provide any economically meaningful interpretation.

For testing the UIP, I start by examining the interest rate relationships among the variables individually, while leaving the second vector unrestricted. Initially, I test the hypothesis of a unitary relationship between domestic and foreign interest rates, which is rejected with a p-value of 0.023. I next relax the assumption of a unit coefficient for

[10] The LM test for autocorrelation suggested no autocorrelation in the residuals for the model with 2 lags, while there were still ARCH effects, and the test for normality was rejected.

[11] The test for the null that the linear trend can be excluded from the cointegration space was also not rejected.

[12] For the second vector, I normalised the fourth term since the estimates otherwise were extremely large.

the foreign interest rate. This relaxed version of UIP is not rejected, with a p-value of 0.0634. Hence, for a value smaller than the theoretical point estimate of 1, i.e., when the estimate on the foreign short-term interest rate takes a value of -1.7, the two variables appear to be cointegrated. However, the second vector remains theoretically unidentified.[13]

## 5.3 Identification Restrictions

For the five-variable system considered, the Johansen test for cointegration indicated the presence of two long-run equilibrium relations. Since there are five structural shocks in the model, this implies that, for exact identification, three restrictions must be imposed on the long-run effects and one restriction on the contemporaneous effects.

I consider the two transitory shocks to be an exchange rate shock and a domestic interest rate shock. As mentioned earlier, the identification restriction I impose follows Bjørnland (2009), allowing for contemporaneous interaction between the domestic interest rate and exchange rate in the short run.[14] The one short-run restriction I impose prevents US monetary policy from responding to the domestic interest rate shock, a plausible small open economy restriction. Both the domestic interest rate and the exchange rate are allowed to react immediately to all shocks. With the vector defined as $x_t = [p_t\ y_t\ i_t^*\ i_t\ e_t]$, this implies the following structure for the $B_0^{-1}$ matrix:

$$\begin{bmatrix} * & * & * & * & * \\ * & * & * & * & * \\ * & * & * & 0 & * \\ * & * & * & * & * \\ * & * & * & * & * \end{bmatrix}$$

Turning to the long-run restrictions: with two cointegration vectors in a system of five variables, there are three common trends. To identify the model, we therefore require three restrictions to disentangle the permanent shocks. In the long-run multiplier matrix $\Upsilon$, the last two columns, corresponding to the two transitory shocks, are set to zero since these shocks cannot have any long-run effect on the variables in the model. To interpret the three permanent shocks, I assume that the structural shock to output represents a permanent supply shock, which has lasting effects on both prices and output in the small open economy. The structural shock to the price variable is interpreted as a demand shock, with no permanent effect on output. This allows me to impose one long-run restriction by setting the first element in the second row equal to zero. The third permanent shock is labelled as a foreign monetary policy shock, which affects all variables in the system. To fully identify the model, two additional restrictions are imposed: both the domestic supply and domestic demand shocks are assumed to have no effect on foreign monetary policy. Since my main interest lies in the impulse responses to the two transitory shocks, the restrictions on the permanent shocks are not given much weight.

Hence, the long-run multiplier matrix $\Upsilon$ takes the form:

$$\begin{bmatrix} * & * & * & 0 & 0 \\ 0 & * & * & 0 & 0 \\ 0 & 0 & * & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & 0 & 0 \end{bmatrix}$$

# 6 Results

In this section, I present the impulse response functions (IRFs) obtained from the two transitory shocks. The IRFs generated for the three permanent shocks are reported

[13] In this case, I used the estimates of the second cointegration vector for computing the impulse responses.

[14] These identifications are not exactly the same as those used in Bjørnland (2009). The incorporation of the foreign interest rate facilitated imposing this short-run restriction necessary to identify the short-run structure of the model.

in Appendix A. For comparison, I also include the results obtained under standard Cholesky decomposition. In addition, impulse responses generated from both the VAR model and the Local Linear Projections (LPs) introduced by Jordà (2005) are presented in the case of Cholesky identification.

## 6.1 Impulse Responses

Figures 2 and 3 display the impulse response functions (IRFs) of all variables to a one-standard-deviation monetary policy shock and to an exchange rate shock.[15] In both cases, the effects revert to zero since the shocks are assumed to be transitory.

The monetary policy shock generates an immediate appreciation of the exchange rate, that is, it overshoots,without any evidence of an exchange rate puzzle. Output declines, while prices exhibit a price puzzle, as is often found in the literature. The confidence bands around the Federal Funds Rate (FFR), however, appear relatively wide. For the exchange rate shock, a depreciation leads to a temporary rise in output as domestic goods become cheaper abroad, while the interest rate falls. This response is consistent with economic theory: a weaker domestic currency improves trade competitiveness, and lower interest rates stimulate domestic demand. However, prices move in the opposite direction,they decline,rather than increase as one would expect following a currency depreciation.

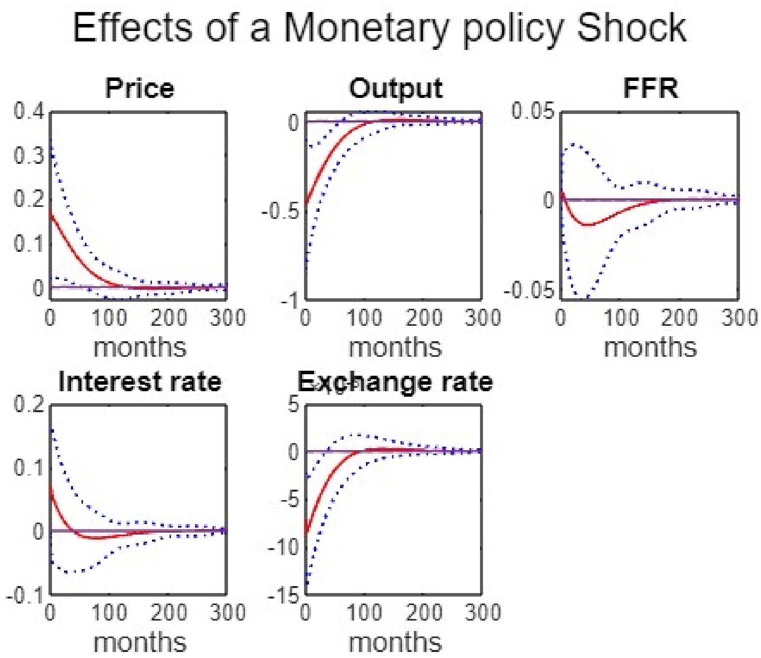



**Figure 2:** Impulse responses to a monetary policy shock.

## 6.2 Comparison with Cholensky identification

For comparison, I also report the results from the standard recursive order-based identification introduced by Christiano et al. (1998), where the identification is essentially based on timing. With the monthly data I use, one could argue that the assumption of monetary policy not affecting the variables ordered before it is reasonable, given that monetary policy affects variables like prices and output with a lag (the outside lag of monetary policy). This assumption may be less convincing, however, when including a highly responsive variable like the exchange rate in the VAR.

[15]The impulse responses are generated using the standard residual-based recursive design bootstrap with standard bootstrap error estimates.

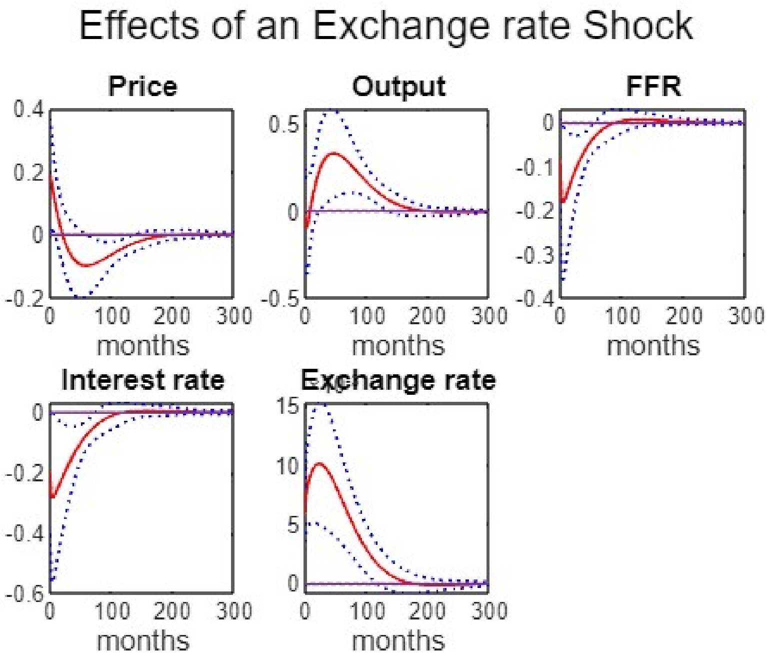



**Figure 3:** Impulse responses to an exchange rate shock.

Figure 4 shows the response to an interest rate shock when the time-series vector is ordered as $[\epsilon^{i^*} \quad \epsilon^p \quad \epsilon^y \quad \epsilon^e \quad \epsilon^i]$. In Figure 5, which shows the impulse response to an exchange rate shock, the exchange rate is ordered last.[16]

We see that the exchange rate does not respond on impact but instead shows a slow response to an interest rate shock. This can be interpreted as a clear indication of the delayed overshooting response often found in the literature when using implausible identification schemes. Prices again show a puzzling response. The response to an exchange rate shock is also rather different from the one generated in Figure 3. Prices rise and the interest rate falls (although it initially rises), while output falls, which is against convention. In both cases, I place the foreign interest rate ($i^*$) first, since foreign monetary policy can be considered exogenous and shocks from the small open economy should have no effect on it in the short run.

Since structural identification using VAR and Local Projections (LPs) can be based on the same recursive assumption, I also include the impulse responses generated from LP for comparison. As can be clearly seen, the LP-based IRFs appear much more jagged compared to the VAR-based IRFs. This reflects the commonly observed bias-variance trade-off: the biased but low-variance IRFs of the VAR produce much smoother results.[17]

# 7 Discussion

In the results presented in Section 5.2, I concluded from the Johansen cointegration test that there exist two long-run relationships in the data for the period considered. However, it is well known that cointegration test results may not be stable across subsamples, and that structural breaks in the time series can bias the cointegration tests. Since Canada experienced regime shifts in monetary policy during the sample period, most notably the adoption of inflation targeting by the Bank of Canada in the early 1990s, it is worth considering whether the cointegration rank of 2 remains stable over a shorter sample.

[16]The time horizon in Figures 4 and 5 is shorter than in Figures 2 and 3 as I used a different code package. The plots looked rather strange when increasing the horizon, so I only report 68 months here.

[17]Individual IRFs obtained from the VAR and LP under Cholesky identification are presented in Figures A.5 and A.6 in Appendix A.

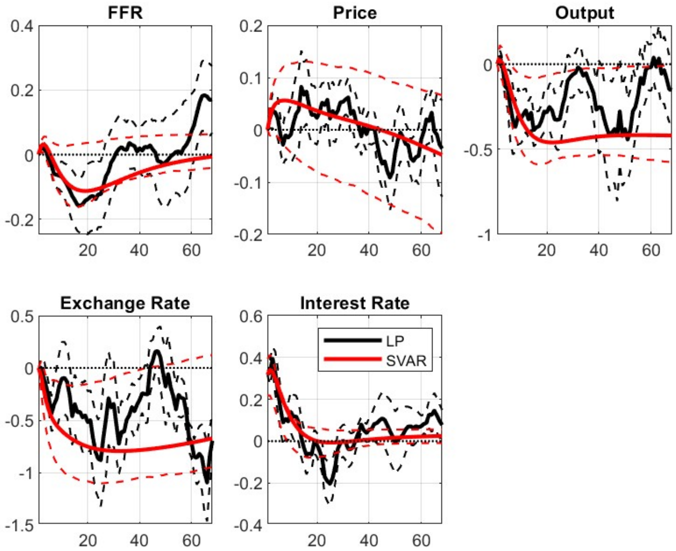



**Figure 4:** Impulse responses to a contractionary monetary policy shock. Both SVAR and LP-based responses under Cholesky identification are shown.

Another potential drawback that needs to be acknowledged is that the conventional money demand function in the Dornbusch model explicitly includes money in the system. In my analysis, I did not include a measure of money in the variable set, which may partly explain why the second estimated cointegration vector deviated so significantly from the proposed theoretical vector of a money demand function, making it difficult to assign any economically meaningful interpretation to it.

# 8 Conclusion

In this paper I answer the question, *what is the effect of a monetary policy and exchange rate shock on a small, open economy?*

To address this question, I first discussed an empirical puzzle commonly observed in studies that posed a problem - that the results predicted in the theoretical Dornbusch (1976) model and what is often found in empirical literature do not always match up - there was an "overshooting puzzle." As opposed to an instantaneous appreciation followed by a persistent depreciation, many papers found a delayed exchange rate response to a contractionary monetary policy shock. Many papers that used structural VAR largely relied on short-run restrictions when modelling exchange rates and interest rates. But as Bjørnland (2009) pointed out in her influential paper, not allowing for simultaneous interaction between the exchange rate and interest rates when imposing these short-run restrictions can be one cause of this bias in the results.

I follow King et al. (1987) and Bjørnland (2009), and identify the exogenous shocks by taking into account the cointegration relations and thereby "letting the data speak". In other words, I use a combination of short-run and long-run restrictions to identify the model. By using this approach, I find that the exchange rate responds on impact and shows no signs of delay, consistent with the Dornbusch (1976) overshooting hypothesis, while the price puzzle was still prevalent in the results. A temporary exchange rate shock caused a temporary rise in output and a fall in interest rates. Overall, the response of all the variables to the two shocks, monetary policy and exchange rate, was in line with what economic theory predicts, except for the response of prices.

In addition, I compare the results with a VAR model identified through Cholesky decomposition and find evidence of a delayed response of the exchange rate when using the same dataset. In this case, the impulse responses from the VAR model are also compared to those generated from Local Projections, where the bias–variance trade-off is

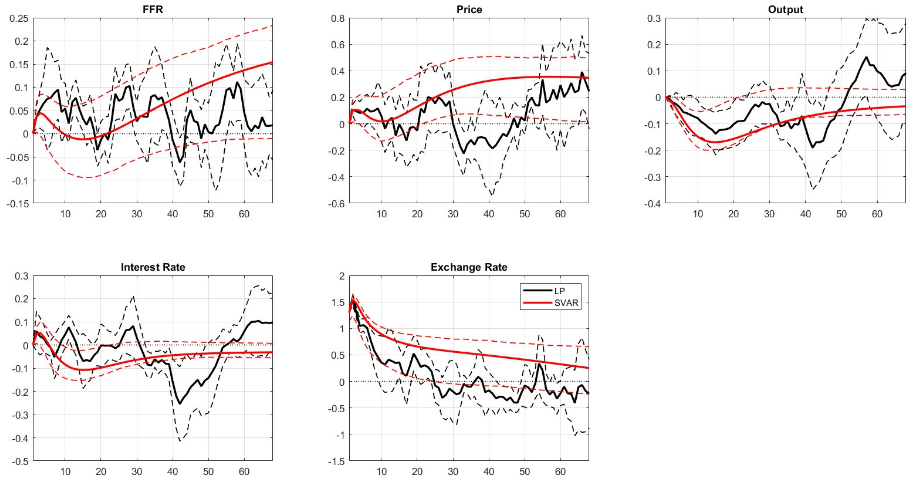



**Figure 5:** Impulse responses to an exchange rate shock, estimated using SVAR and LP under Cholesky identification.

clearly evident. This comparison highlights the importance of identification assumptions in empirical macroeconomic work.

In conclusion, this paper confirms that when modelling fast-moving variables like interest rates and exchange rates, it is crucial to take into account the response rate of these variables, as placing zero short-run restrictions on any of them can lead to puzzling results.

# APPENDIX

# A Additional Figures

**Figure A.1:** Descriptive time series. All series except interest rates are log-transformed.

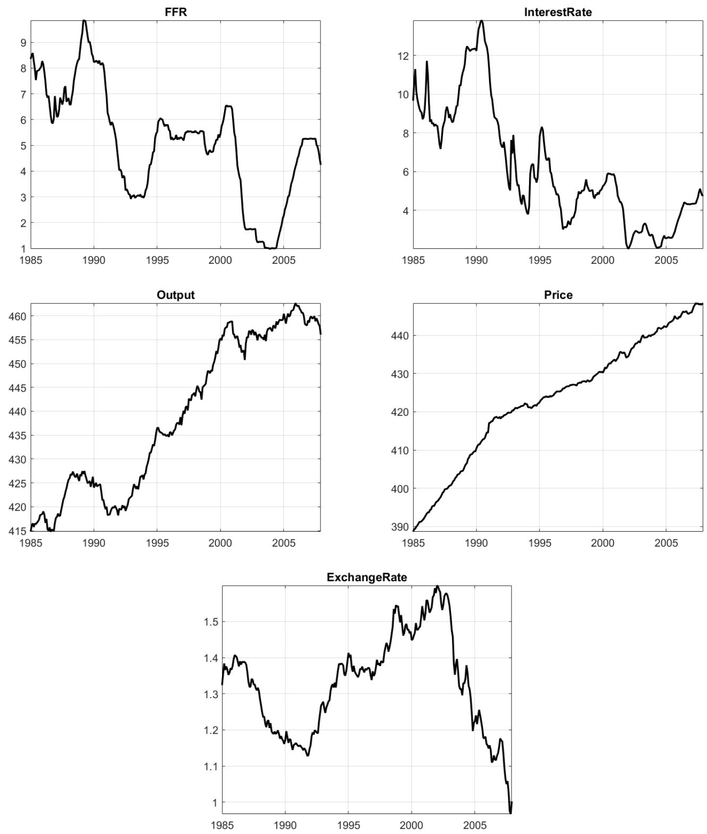


**Figure A.2:** Impulse responses to a demand shock.

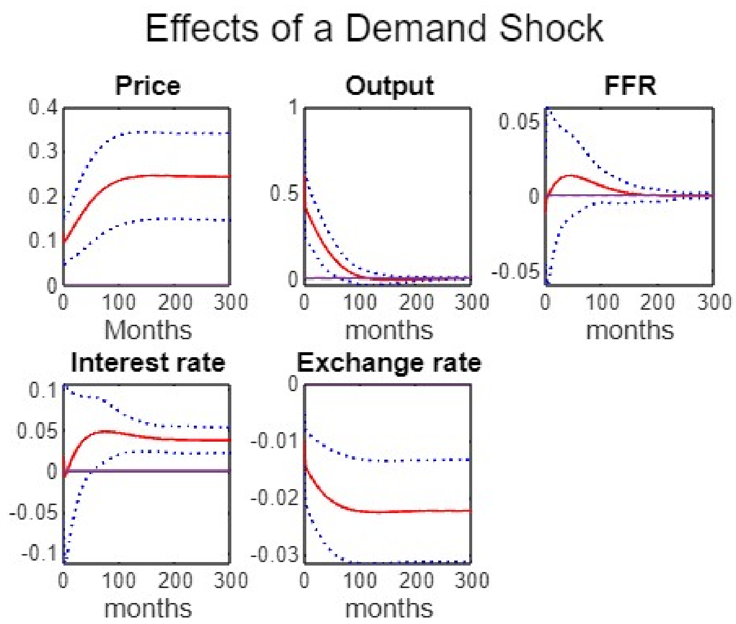



**Figure A.3:** Impulse responses to a supply shock.

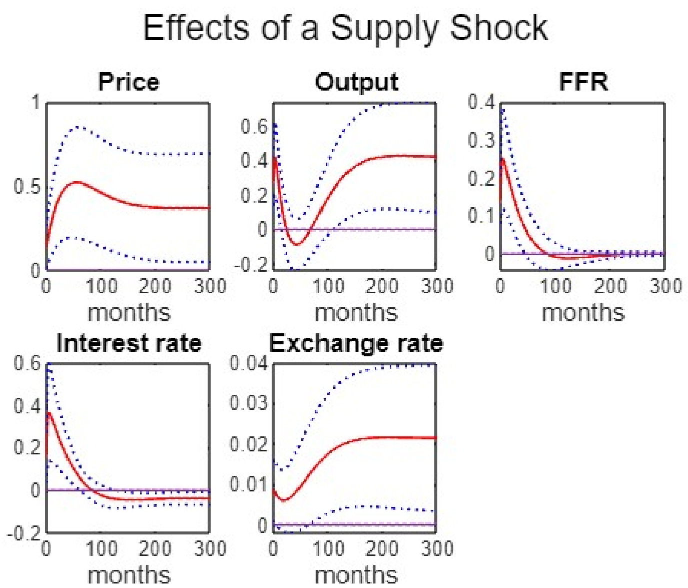
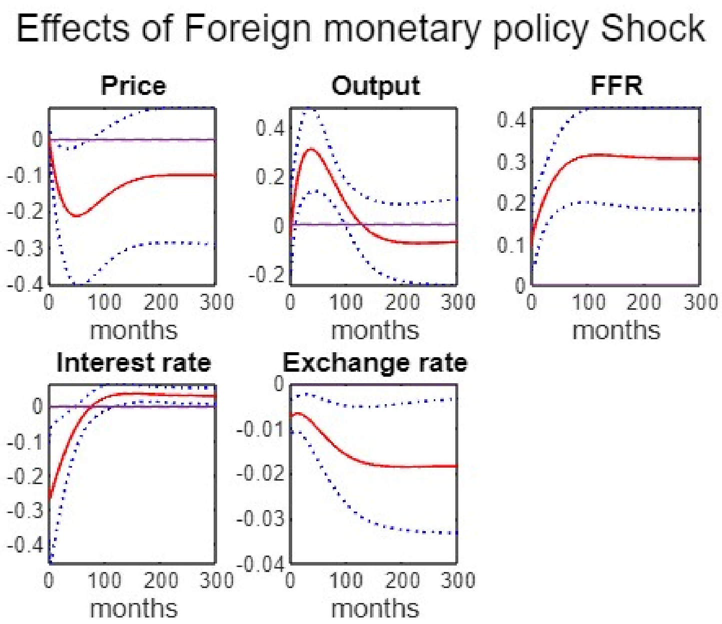


**Figure A.4:** Impulse responses to a foreign monetary policy shock.




*Note:* Under the imposed restrictions, prices increase permanently in response to a permanent demand shock, with output eventually returning to its steady state. Prices and output increase permanently in response to a supply shock. The response of the federal funds rate is muted.

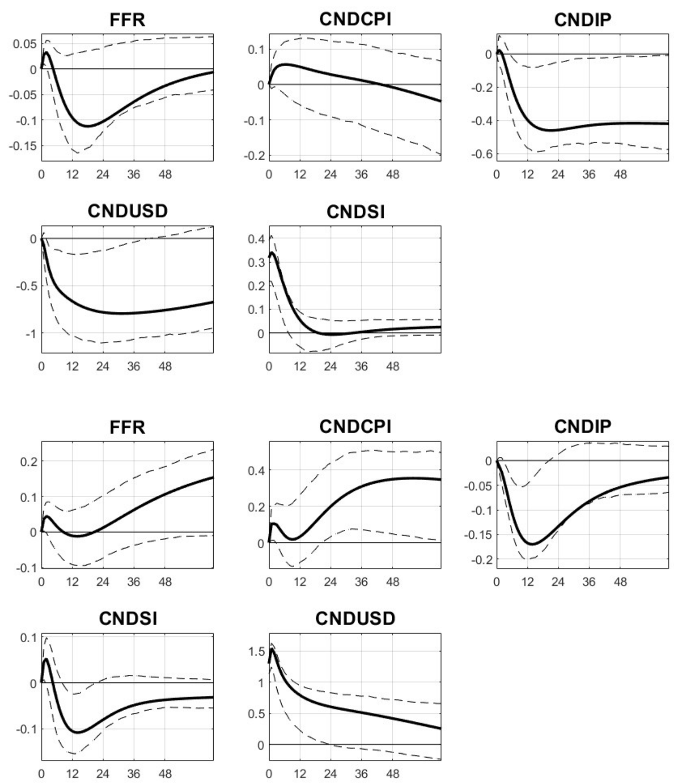



**Figure A.5:** The bias-variance tradeoff: impulse responses to an interest rate shock (top panel) and exchange rate shock (bottom panel) under SVAR.

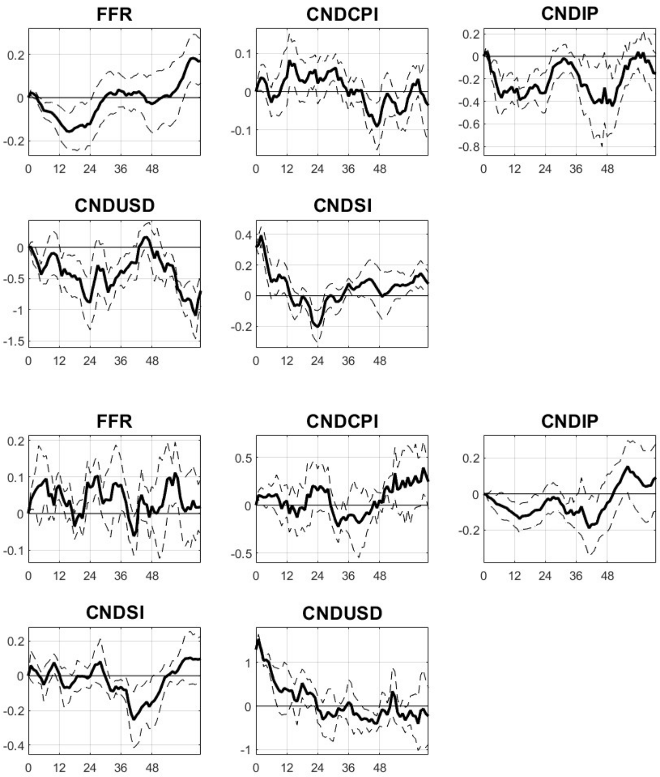



**Figure A.6:** The bias-variance tradeoff (continued): impulse responses to an interest rate shock (top panel) and exchange rate shock (bottom panel) under LP estimates.

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