

The Effects of Monetary Policy Shocks on Exchange Rates in a Small Open Economy: A Structural Vector Auto Regressive (VAR) Approach

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Abstract. Most of the previous studies found puzzling dynamic responses of the exchange rate following a monetary policy shock. In the literature, these puzzles are known as the exchange-rate puzzle, the delayed overshooting puzzle and the uncovered interest rate parity (UIP) puzzle. Empirical studies also documented the liquidity puzzle and the price puzzle. We argue that these puzzles derive from an identification of monetary policy that is inappropriate for a small open economy. We, therefore, propose to incorporate a forward-looking dimension into the monetary policy rule, by adding inflationary expectations as a contemporaneous input, to identify the policy shock in the structural VAR model. When we estimate our structural VAR model, allowing the domestic monetary policy and the exchange rate to react simultaneously to some key domestic and foreign variables, we find that the puzzles disappear.

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1. Introduction

Most of the early attempts to estimate the effects of monetary policy shocks on exchange rates and other macro-economic variables encountered puzzling dynamic responses. For example, they found that following a positive innovation in the nominal interest rate, the exchange rate either depreciates or, if it appreciates, it does so only gradually giving a hump-shaped impulse response. In the literature, the first phenomenon is known as the exchange rate puzzle, which has been documented by Grilli and Roubini (1995) and Sims (1992). The second phenomenon, labeled as the delayed overshooting puzzle, has been documented by Fama (1984), Hodrick (1987), Engel (1996), and Faust and Rogers (2003). The other closely related puzzle, identified as the uncovered interest rate parity (UIP) puzzle, is the finding that following a monetary policy shock in the home country, the interest rate differential between the home country and foreign countries is followed by a persistent opposite directional movement of the exchange rate, as predicted by the theory, reported by Eichenbaum and Evans (1995) and Faust and Rogers (2003).

Empirical studies also documented the liquidity puzzle and the price puzzle. The liquidity puzzle is the finding that an increase in the monetary aggregate is associated with an increase in nominal interest rates documented by Leeper and Gordon (1992), while the price puzzle is the finding that an increase in the nominal interest rate causes an increase in the price level documented by Sims (1980).

Cushman and Zha (1997) and Kim and Roubini (2000) criticized the use of the recursive VAR approach to identify the monetary policy shock. They argued that central banks in small open economies are likely to respond quickly to some key domestic and foreign variables, which cannot be modeled in the recursive approach, using the so called Choleski decomposition. Therefore, they proposed to use a structural VAR model with non-recursive restrictions among the contemporaneous coefficients of the domestic and the foreign vari-

ables to identify the monetary policy shock. Using the structural approach, although they found better results in terms of the exchange rate response to monetary policy shock, they still had puzzling responses of interest rates and price level.

Faust and Rogers (2003) mentioned that constructing the VAR model, assuming that the central banks of the non-US G-7 countries do not respond to the Fed policy until a month later, is inconsistent with what these central banks actually do. They also criticized the assumption made by the VAR literature that central banks ignore the within-month surprising movements of exchange rates and short-term interest rates when they make monetary policy decisions. Suspending any dubious assumptions like these and keeping all the credible assumptions, they found that the delayed overshooting result is sensitive to the dubious assumptions, while the large UIP deviations are quite robust.

On the other hand, adopting the recursive VAR approach and using a measure of inflationary expectations as the contemporaneous input to the monetary policy function, Kahn *et al.* (2002) and Bhuiyan and Lucas (2007) were able to solve the liquidity puzzle and the price puzzle. However, they were still left with the exchange rate puzzle and the delayed overshooting puzzle.

We argue that these puzzles derive from an incorrect estimation of the monetary policy shock, which follows from an incorrect identification of the monetary policy reaction function. The measurements of policy innovations in these studies are likely to be contaminated, both because they employ the *ex post* revised data of the macro-economic variables as contemporaneous inputs and because they use the recursive VAR approach, which cannot model the contemporaneous cross-directional relationships among the variables. Since the *ex post* revised data are not known with any accuracy until much later, the information or the data used by the central bank are much different from those used by the econometricians

in these studies. This divergence of the data set used by the econometricians from what the central bank actually observes certainly makes the econometricians' reaction functions incorrect, resulting in a biased estimation of the exogenous monetary policy shocks. In this regard, Clarida and Gertler (1997), Clarida, Gali and Gertler (1998) and Orphanides (1997) found that the monetary policy of the G-7 countries is driven more by the anticipated future than by the actual lagged outcomes. Empirically estimated monetary policy reaction functions also match more with the forecast-based models than with the simple Taylor-rule based models.

The use of the recursive VAR approach is also a possible source of infection of the exogenous monetary policy shock because this approach does not allow the monetary policy and the exchange rate policy to react simultaneously to each other and to some key home and foreign macro-economic variables. In this era of increasingly more integrated capital and good markets, a small open economy is supposed to be vulnerable to external shocks. Therefore, not allowing the domestic monetary policy to react, within the month, to some crucial external variables, such as the exchange rate and the federal funds rate also causes a misidentification of the monetary policy rule, resulting in an erroneous measure of the policy shock.

In this paper, I propose to incorporate a forward-looking dimension into the monetary policy rule to identify the policy shock using the structural VAR approach. I assume that, as a measure of leaning today against tomorrow's wind, the central bank makes decisions on the basis of the anticipated inflation as opposed to the lagged inflation. On the other hand, as a measure of safeguarding the economy from any external shocks, the central bank also closely monitors the movements of the foreign variables such as the exchange rate and the federal funds rate. The use of the structural VAR approach enables us to capture these economically meaningful cross-directional relationships between the monetary policy variable and the other home and foreign macro-economic variables.

We estimate inflationary expectations decomposing the nominal interest rate into inflationary expectations and the *ex ante* real interest rate using the Blanchard-Quah (1989) VAR model. We use the identifying restriction that the real interest rate innovations have temporary effects, while inflationary expectations innovations have permanent effects on nominal interest rates following St. Amant (1996), Gottschalk (2001), and Bhuiyan and Lucas (2007). When we apply our model to the Canadian data, we find impulse responses of the exchange rate and other macro-economic variables that are consistent with the theory. In particular, we find that following a positive monetary policy shock, the exchange rate depreciates on impact and then gradually appreciates to the terminal values. Our findings also suggest that the impulse response of the UIP deviations is not significantly different from zero for a long period. We also find that a positive monetary policy shock increases inflationary expectations and output, and lowers the *ex ante* real interest rate.

The remainder of the paper is organized as follows. Section II gives the data source and section III briefly discusses the estimation of inflationary expectations using the Blanchard-Quah VAR model. Section IV describes the structural VAR model that identify the exogenous monetary policy shock and explains the economic rationale of the restrictions imposed on the contemporaneous coefficients of the structural VAR model. Section V presents the results and Section VI draws conclusions.

2. Data

Our data run monthly from 1975 to 2006. We first collect the monthly series of the three-month Treasury bills rate (Cansim V122529) and the CPI (Cansim V737311). Then we calculate the inflation rate as the annualized monthly rate of change of the CPI. We then use the first difference of the nominal interest rate and the *ex post* real interest rate in the bivariate Blanchard-Quah VAR model to decompose the nominal interest rate into inflation-

ary expectations (π^e) and the *ex ante* real interest rate (r), which we discuss in section III. The other variables used are: M -Canadian Monetary aggregate (M1) (Cansim, V37199), S -Nominal exchange rate in units of home currency (Cansim, B3400), Y -Canadian industrial production (Cansim, V2044332), Y^* -US industrial production (IFS, 11166..CZF.), P^* -US consumer price index (IFS, 11164..ZF.), i^* -the federal funds rate (IFS, 11164B..ZF.).

3. Estimation of Inflationary Execrations and the *Ex ante* Real Interest Rate

We start with thhe Fisher equation which states that the nominal interest rate is the sum of the *ex ante* real interest rate and inflationary expectations:

$$n_{t,k} = r_{t,k} + E_{t-1}(\pi_{t,k}), \quad (1)$$

where $n_{t,k}$ is the nominal interest at time t on a bond with k periods till maturity, $r_{t,k}$ is the corresponding *ex ante* real interest rate, and $E_{t-1}(\pi_{t,k})$ denotes inflationary expectations from time time t to $t+k$. If inflation forecast error $\varepsilon_{t,k}$ is the difference between the actual inflation rate $\pi_{t,k}$ and the expected inflation rate $E_{t-1}(\pi_{t,k})$, then:

$$\varepsilon_{t,k} = \pi_{t,k} - E_{t-1}(\pi_{t,k}). \quad (2)$$

Substituting the inflation forecast error equation (2) into the Fisher relation (1), we find:

$$n_{t,k} - \pi_{t,k} = r_{t,k} + \varepsilon_{t,k}. \quad (3)$$

Therefore, the *ex post* real interest rate is the difference between the *ex ante* real interest rate and the inflation forecast error. Under the assumptions that both the nominal interest rate and the inflation rate are integrated of order one and they are co-integrated, and that the inflation forecast error is integrated of order zero, the *ex ante* real interest rate must be stationary.

Gottschalk (2001) identifies three implications that flow from the above assumptions. First, if the nominal interest rate is non-stationary, this variable can be decomposed into a non-stationary component and a stationary component. Second, if the nominal interest rate and the actual inflation rate are co-integrated, it implies that these variables share a common stochastic trend which is the source of the non-stationary of both variables. On the other hand, if the *ex ante* real interest rate is stationary, the nominal trend has no long-run effect on this variable. Third, if the nominal interest rate and the actual inflation rate are co-integrated (1,1), this implies that changes in inflationary expectations are the source of these permanent movements in the nominal interest rate. Therefore, using the identifying restrictions that shocks to the *ex ante* real rate have only a transitory effect on the nominal interest rate while shocks to inflation expectations induce a permanent change in the nominal interest rate, we can calculate inflationary expectations and the *ex ante* real rate of interest.

Having built the theoretical background to decompose the nominal interest rate into inflationary expectations and the *ex ante* real interest rate, the next step is to check whether our data satisfy the required assumptions. To investigate the stationary properties of the nominal interest rate, the inflation rate and the *ex post* real interest rate, we graph these variables and their autocorrelation functions in figure 2 and figure 3, respectively, in appendix 1. Figure 2 appears to support the hypothesis that the nominal interest rate and the inflation rate are integrated of order one and the real interest rate is integrated of order zero. The autocorrelation functions in figure 3 also support this hypothesis as the autocorrelation coefficients start with a high value and approach zero for the nominal interest rate and the inflation rate, while the autocorrelation function for the real interest rate does not exhibit much decay of its magnitude.

Next we use the ADF test to confirm our hypotheses about the stationary properties of these variables. Table 1 of Appendix 1 shows that the ADF test cannot reject the null

hypothesis of unit root for the nominal interest rate and the inflation rate at 10 percent level of significance, while the unit of the first difference of both these variables are rejected at 1 percent level of significance. On the other hand, the ADF test rejects the null hypothesis of unit for the real interest rate at 1 percent level of significance. Therefore, we conclude that the nominal interest rate and the inflation rate are co-integrated (1,-1).

Having confirmed the suitability of our data, we now estimate the bivariate Blanchard-Quah VAR model, consisting of the first difference of the nominal interest rate and the *ex post* real interest rate, to estimate inflationary expectations and the *ex ante* real interest rate series.¹ We first collect the estimated series of the the effects of *ex ante* real interest rate and inflationary expectations shocks on the nominal interest rate. According to the assumptions we made, summing the effects of these structural shocks yields the stationary and permanent components of the nominal interest rate. Therefore, an estimate of the *ex ante* real interest rate is then obtained by adding the stationary components to the mean of the difference between the observed nominal interest rate and the contemporaneous inflation rate. Then the measure of inflationary expectations is calculated by subtracting the estimated *ex ante* real interest rate from the nominal interest rate.

Recall that we assume that the inflation forecast errors are integrated of order zero. As reported in table 1 of appendix 1, the ADF test statistic of the inflation forecast errors series, as found by subtracting the calculated inflationary expectations series from the actual inflation rate series, supports this assumption at the one percent level of significance. The estimated inflationary expectation rate along with the realized *ex post* inflation rate is graphed in figure 4 of appendix 1.

Since we use the estimated *ex ante* real interest rate shocks and inflationary expect-

¹We use the RATS program to estimate the VAR model. A lag length of 14 was used, which was determined on the basis of the Likelihood Ratio criteria.

tations shocks to calculate the time series of the *ex ante* real interest rate and inflationary expectations, it is important to know how tightly these structural shocks are estimated. If they are not tightly estimated, then the derived series may contain much noise. In figure 5 of appendix 2, we present the time series of these shocks along with two standard error bands. It is apparent from the figure that these series are tightly estimated, which supports the use of the derived series in the subsequent analysis.

The two key outputs of the VAR estimation that are of interest are the variance decompositions and the impulse response functions. The variance decomposition allows us to measure the relative importance of inflationary expectations and the *ex ante* real interest rate shocks that underlie nominal interest rate fluctuations over different time horizon. It is evident from table 2 of appendix 2 that, in the long run, the proportion of the variance of the nominal interest explained by *ex ante* real interest rate shocks approaches zero while this proportion explained by inflationary expectations shocks is unity. This rapid decline of the proportion of the variance attributable to the real interest shocks supports the use of the restriction that the *ex ante* real interest rate shocks have no permanent effect on the nominal interest rate.

The impulse responses of the nominal interest rate due to *ex ante* real interest rate shocks and the inflationary expectations shocks are presented in figure 6 of appendix 2. The horizontal axis measures the number of months. We notice that the majority of the effects of the *ex ante* real interest rate disappear with two years which also supports the validity of our imposed restriction.

4. Identification of a Forward-Looking Monetary Policy in a Structural VAR Model

We assume that the economy can be described by the following structural system of equations:

$$G(L)X_t = \varepsilon_t, \quad (4)$$

where $G(L)$ is a matrix of polynomials in the lag operator L , X_t is an $n \times 1$ data vector, and ε_t is an $n \times 1$ vector of structural disturbances or shocks. We assume that the ε_t 's are both serially and mutually uncorrelated. Let $\text{var}(\varepsilon_t) = \Sigma_\varepsilon$, which is a diagonal matrix. Let G_0 be the matrix of contemporaneous coefficients and $G^0(L)$ be the matrix without contemporaneous coefficients, that is,

$$G(L) = G_0 + G^0(L). \quad (5)$$

In our model, X is comprised of two blocks of variables—the Canadian block, $X_1:[m, r, s, \pi^e, y]$ and the US block, $X_2:[y^*, p^*, i^*]$. All the variables are in logarithms except for interest rates. Since we assume that the US block is exogenous to the Canadian block, both contemporaneously and in lag, the assumption which follows from the identification of a small open economy, the structural system can be re-written as follows:

$$\begin{pmatrix} G_{11}^0 & G_{12}^0 \\ 0 & G_{22}^0 \end{pmatrix} \begin{pmatrix} X_{1t} \\ X_{2t} \end{pmatrix} + \begin{pmatrix} G_{11}^0(L) & G_{12}^0(L) \\ 0 & G_{22}^0(L) \end{pmatrix} \begin{pmatrix} X_{1t} \\ X_{2t} \end{pmatrix} = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}. \quad (6)$$

The restrictions that $G_{21}^0 = 0$ and $G_{21}^0(L) = 0$ follows from the assumption that the US block of variables does not enter into the Canadian block of variables either contemporaneously or in lag. We keep the US block in the lower-triangularized fashion of the order y^* , p^* and i^* .

We can estimate the following reduced-from VAR:

$$X_t = B(L)X_t + e_t, \quad (7)$$

where $B(L)$ is a matrix of polynomials in the lag operator L . Let $\text{var}(e_t) = \Sigma$. It can be shown that the structural disturbances and the reduced-form residuals are related by $\varepsilon_t = G_0 e_t$, which implies that:

$$\Sigma = (G_0^{-1})\Sigma_\varepsilon(G_0^{-1})' \quad (8)$$

The right-hand side of equation (8) has $n \times (n + 1)$ free parameters to be estimated, while Σ contains $n \times (n + 1)/2$ estimated parameters. Normalizing n diagonal elements of G_0 to 1's, we still need at least $n \times (n - 1)/2$ more restrictions on G_0 to achieve an exact identification.

The restrictions that we impose on G_0 to achieve identification are shown in the system of equations (9). In fact, it is system of equations (9) where we make economically meaningful restrictions on the contemporaneous values of the home and foreign variables in a small open economy context, which makes us able to identify a better monetary policy shock. The structure is:

$$\begin{pmatrix} \varepsilon_m \\ \varepsilon_r \\ \varepsilon_s \\ \varepsilon_{\pi^e} \\ \varepsilon_y \\ \varepsilon_{y^*} \\ \varepsilon_{p^*} \\ \varepsilon_{i^*} \end{pmatrix} = \begin{pmatrix} 1 & g_{12} & g_{13} & g_{14} & g_{15} & 0 & 0 & g_{18} \\ g_{21} & 1 & 0 & g_{24} & g_{25} & 0 & 0 & 0 \\ g_{31} & g_{32} & 1 & g_{34} & g_{35} & g_{36} & g_{37} & g_{38} \\ g_{41} & g_{42} & g_{43} & 1 & 0 & 0 & 0 & g_{48} \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & g_{76} & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & g_{86} & g_{87} & 1 \end{pmatrix} \begin{pmatrix} e_m \\ e_r \\ e_s \\ e_{\pi^e} \\ e_y \\ e_{y^*} \\ e_{p^*} \\ e_{i^*} \end{pmatrix}. \quad (9)$$

We assume a forward-looking money supply function as shown by the first equation

of the system of equations (9). As a measure of leaning today against tomorrow's wind, we assume that the central bank takes into account the contemporaneous values of inflationary expectations, output and the *ex ante* real interest rate, in addition to the exchange rate and the federal funds rate, while setting the monetary policy.

The choice of inflationary expectations as a contemporaneous input is crucial because the inflation-targeting countries, including Canada, make their monetary policy decisions based on the explicit inflation forecast. In this regard, Haldane and Batini (1998) found that the inflation forecast-based monetary policy rule is within the reach of the fully-optimal monetary policy rule. Clarida, Gali and Gertler (1998) found that the central banks in G3 countries (Germany, Japan and the US) respond to the anticipated inflation as opposed to the lagged inflation. They reported that, in response to a rise in expected rate of inflation relative to the target rate, these central banks raise nominal rates sufficiently enough to push the real rates up. They found that this behavior of the central banks is statistically significant and quantitatively important for each country. Finally, they showed that the forward-looking specification of the monetary policy performs much better against all other alternative specifications, including the backward-looking specification of the monetary policy. Clarida and Gertler (1997) also argued for a modified version of the Taylor rule, where the central bank adjusts the short-term interest rate in response to the gaps between inflation and output and their respective targets. They found that the estimated forward-looking monetary policy reaction function does a good job of characterizing the path of the German short rate over the post-Bretton Woods era.

Orphanides (1997) showed that the monetary policy reaction function based on the *ex post* real data yields misleading descriptions of the historical policy. He demonstrated that the real-time policy recommendations for the central bank differ considerably from those obtained using the *ex post* data by the econometricians. He found that, for the U.S. economy,

the forward-looking specification of the monetary policy rule, using the Federal Reserve staff forecasts, describes the monetary policy better than comparable Taylor-type specifications.

In this regard, it would be worthy to note the summary of the Alan Greenspan's Humphrey-Hawkins Testimony in 1994 about the monetary policy problem, which is: "The challenge of monetary policy is to interpret current data on the economy and financial markets with an eye to anticipating future inflationary forces and to countering them by taking action in advance." Keynes (1924), in the *Tract on Monetary Reform*, stated "If we wait until a price movement is actually afoot before applying remedial measures, we may be too late."

The rationale of the incorporation of the exchange rate as contemporaneous input to the monetary policy was discussed by Cushman and Zha (1997), Kim and Roubini (2000), and Faust and Rogers (2003). Having the exchange rate as a contemporaneous input is important for a small economy like Canada, as it is likely to be affected by the exchange rate shocks. In addition, information about this variable is available to the bank of Canada within the month.

We also have the federal funds rate as a contemporaneous input to the monetary policy of the Bank of Canada. Eichenbaum and Evans (1995) and Kim and Roubini (2000) assume that the foreign monetary policies do not to the Fed policy until a month later. Faust and Rogers (2003) argued that this assumption is inconsistent with the striking movements in foreign rates that regularly follow within minutes of the Fed policy announcements.

We also assume that the money demand function, the second equation in the system of equations (9), is a function of the contemporaneous values of the *ex ante* real interest rate, inflationary expectations and income level. Our third equation in the system of equations is the foreign exchange market equation, in which we assume that an efficient foreign exchange market is able to respond to all variables in the model within the month. Since the exchange rate is a forward-looking asset price, we assume that all variables in the model have con-

temporaneous effects on the exchange rate. One important thing to notice in our structural identification is the simultaneous interaction between the monetary policy and the exchange rate policy. Our structural identification scheme made it possible for the monetary policy and the exchange rate policy to contemporaneously react to each other, which would not be possible in a recursive identification scheme. We also assume that people form inflationary expectations looking at the contemporaneous monetary policy decision (which is the money supply), the real interest rate, the exchange rate and the federal funds rate, which can be seen from the fourth equation of the system of equations. As seen from the system of equations (9), we leave the foreign block in the lower-triangularized order of y^* , p^* and i^* .

It is obvious from the system of equations (9) that total of thirty four zero restrictions on G_0 makes our model over-identified, as only twenty eight such restrictions would make it exactly-identified. We do not any restrictions on the coefficients of the lagged variables so that each variables in the model can react to all other variables as well as can affects other variables in the model.

5. Empirical Evidence of the Effects of Monetary Policy Shocks

We first perform the likelihood ratio (LR) test of the over-identifying restrictions. We found that our identifying restrictions are not rejected at the conventional significance level (the significance level was 0.596). We use a lag length of ten to estimate the model, which was determined on the basis of the Akaike information criterion and the LR test. The impulse responses of the exchange rate and other macro-economic variables following an expansionary monetary policy shock are presented in figure 1. The response horizon in months is given on the horizontal axis. The dashed-lines indicate the 95 percent confidence interval. We see that a sharp increase in the money stock is accompanied by an immediate depreciation of the Canadian dollar which gradually appreciates towards the terminal value. We also notice that

this expansionary monetary policy shock temporarily reduces the *ex ante* real interest rate and increases inflationary expectations and output. Therefore, our results are consistent with the theory.

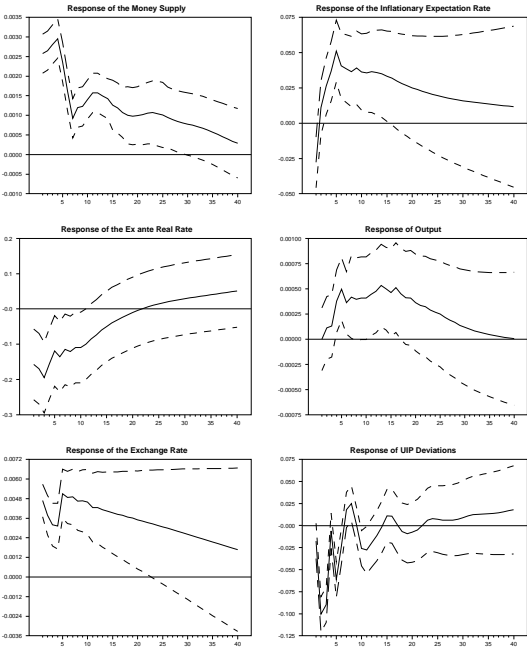


Figure 1: Impulse Responses of Macro-economic Variables Due to Monetary Policy Shocks

It would be interesting to compare our findings with other findings in the literature. Using a structural identification in the small open economy context, both Cushman and Zha (1997) and Kim and Roubini (2000) found that, following a contractionary monetary policy shock, the exchange rate appreciates on impact and then gradually depreciates. However, their estimated impulse responses for nominal interest rates and the price level were not satisfactory. Cushman and Zha (1997) did not find any significant effect on the nominal interest rate, while they found that the effect on the price level started to be significant after about two years, which remained significant up to the end of the third year. The contractionary monetary policy shock in Kim and Roubini (2000) produced the liquidity puzzle for Canada and a few other G-7 countries, and this shock had a statistically significant effect on the Canadian

price level for more than four years. It is important to note in this regard that Cushman and Zha (1997) and Kim and Roubini (2000) did not use any forecast or expectation variables as contemporaneous inputs to the monetary policy. They used CPI in their model which was not observed by the central bank until a period later. While Cushman and Zha (1997) used the world total export commodity price index and Kim and Roubini (2000) used the world oil price, which might be proxies for inflationary pressure, as contemporaneous inputs to the monetary policy rule, the use of our directly measured inflationary expectations, as contemporaneous inputs, makes our identification more appropriate.

On the other hand, employing a recursive VAR method and using inflationary expectations as a contemporaneous input to the monetary policy rule, Bhuiyan and Lucas (2007) found consistent impulse responses for the real interest rate and inflationary expectations. However, the impulse response of the exchange rate was puzzling and there was no significant effect on output. As has been argued in the literature, the recursive approach of identification, using the Choleski decomposition, cannot incorporate the contemporaneous interrelationships among variables. The recursive approach, therefore, could lead to a serious misidentification of the monetary policy function and hence to an erroneous estimation of the monetary policy shock. In this regard, Kim (2005) found ample contemporaneous interaction between the monetary policy and the exchange rate policy for Canada. Since the recursive approach, with any ordering of the variables, cannot capture this simultaneity between the monetary policy and the exchange rate policy, it produces a flawed monetary policy shock.

In a different approach to the same problem, Bernanke *et al.* (2005) conditioned the VAR model of monetary policy on a richer information sets using the dynamic factor model, which suggests that the information from a large number of time series can be summarized by a small set of estimated indexes or factors. The idea behind the use of these factors as contemporaneous inputs to the monetary policy was that if econometricians cannot model

all the variables in their VAR analysis, which the central actually observes before setting monetary policy, then they would obtain biased estimates of the policy shock and impulse responses. Using this approach, however, they also found the delayed overshooting puzzle of the exchange rate response.

We also investigate the response path of the deviations from the UIP defined as the *ex post* difference in one-period Canadian assets and one-period US assets, that is, the impulse response of $\psi_t = i_t - i_t^* + 12(s_{t+1} - s_t)$. For direct comparison with interest rates, which is already in annual terms, we multiply the exchange rate by twelve. If the UIP condition holds and expectations are rational, this excess return should be zero. Figure 1 shows that the impulse response of the UIP deviations does not seem to be significantly different from zero for a prolonged period, as found by Eichenbaum and Evans (1995). This result of ours might indicate the importance of identifying a forward-looking monetary policy function with contemporaneous restrictions in the structural VAR model. In this regard, McCallum (1994) showed that regressions ignoring endogenous monetary policy reactions to interest rates and exchange rates may exhibit deviations from UIP, even when UIP holds.

We believe that the superiority of our results over Bhuiyan and Lucas (2007), in terms of the exchange rate response and output response, is due to our structural identification scheme, which appropriately incorporates the features of a small open economy. In a small open economy like Canada, it is important to capture the simultaneous interrelationships among the domestic and the foreign variables using economic theory, which is not possible in the recursive approach. On the other hand, the reason that our findings dominate Cushman and Zha (1997) and Kim and Roubini (2000), in terms of interest rates and price responses, is due to having a forward-looking dimension into our monetary policy rule by adding inflationary expectations as a contemporaneous input.

6. Conclusion

The effects of monetary policy shocks on various macro-economic variables generated puzzling dynamic responses in the literature. We claim that these puzzles arise from an inappropriate identification of the monetary policy. We believe that, for the proper identification of the exogenous monetary policy shock, it is important first, to use a structural VAR approach that explicitly accounts for the appropriate home and foreign variables, and second, to identify a monetary policy reaction function that has inflationary expectations as a contemporaneous input. By incorporating a forward-looking dimension, that is, adding inflationary expectations into the feedback rule of the monetary policy, our structural identification approach in the context of a small open economy produces impulse responses that are consistent with the theory.

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Appendix 1

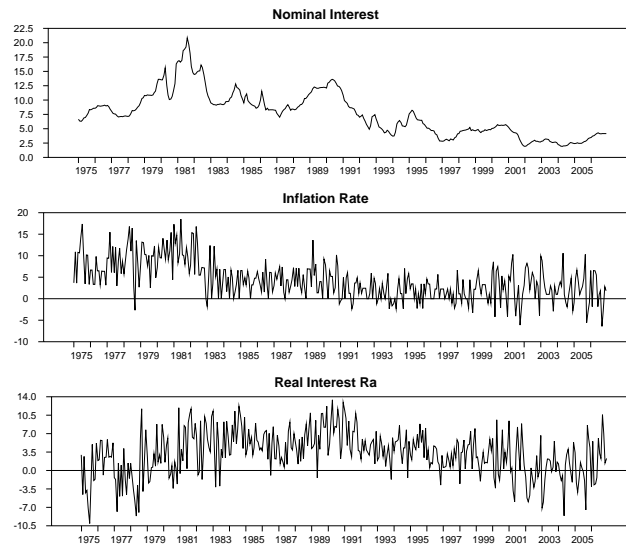


Figure 2: Nominal Interest Rate, Inflation Rate, and *Ex post* Real Interest Rate

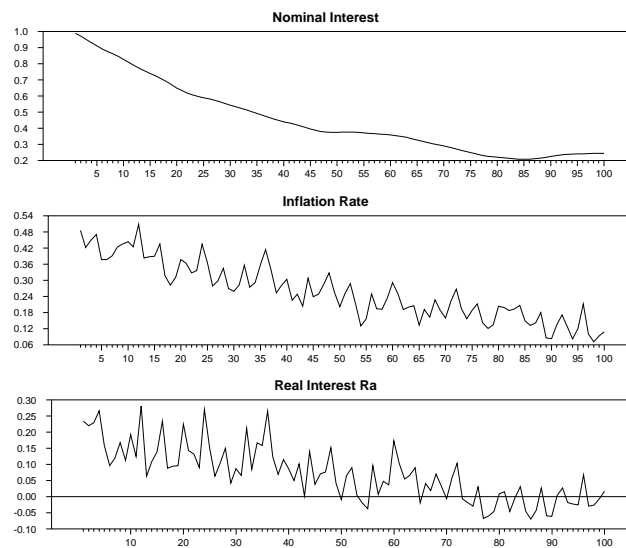


Figure 3: ACFs of Nominal Interest Rate, Inflation Rate and *Ex Post* Real Rate

Table 1: Unit-root tests

Variable	ADF test statistic
Nominal rate	-1.456 (c,14)
Δ Nominal rate	-5.678 (c,13)
Inflation rate	-1.896(c,14)
Δ Inflation rate	-5.458 (c,13)
Real rate	-3.489 (c,6)
Inflation forecast error	-4.368 (0,4)

The brackets indicates the inclusion of the constant and the lag length. Lag lengths are chosen by the Ng-Perron (1995) recursive procedure. Δ is the first difference operator.

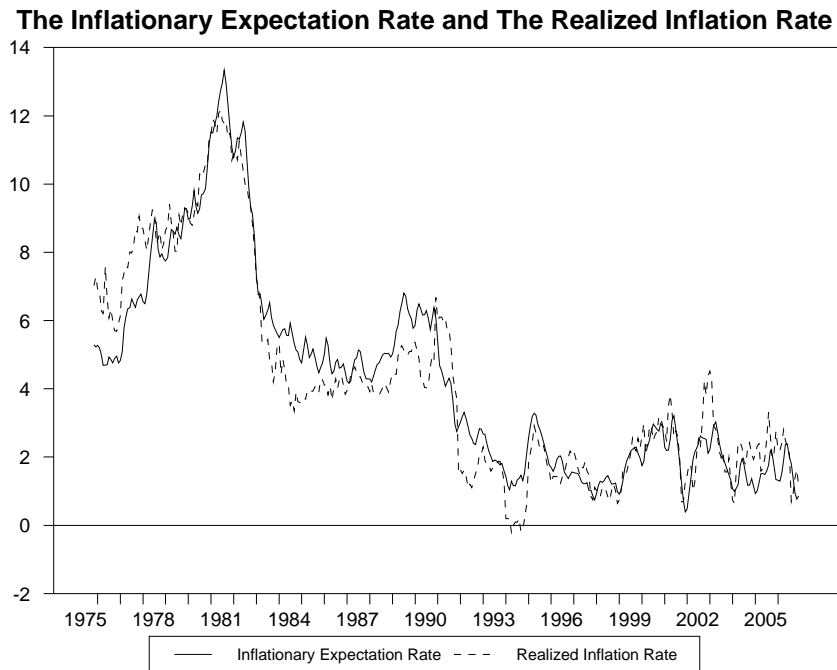


Figure 4: Inflationary Expectation Rate and Realized Inflation Rate

Appendix 2

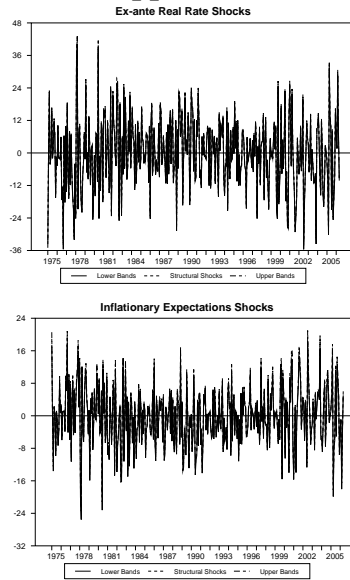


Figure 5: Inflationary Expectations shocks and *Ex ante* Real Rate Shocks with 2 S.E.Bands

Table 2: Variance Decomposition of the Nominal Interest Rate (in percent)

Horizon (Month)	Inflationary Expectations	<i>Ex ante</i> Real Interest Rate
1	48.1 (53.3-44.5)	51.9 (55.5-46.6)
6	61.5 (69.7-53.4)	38.5 (46.5-30.2)
12	71.4 (80.5-62.6)	28.6 (37.3-19)
24	80.5 (88.3-71.6)	19.5 (28.3-11.6)
48	83.3 (91.7-76.6)	16.7 (23.8-8.2)
96	85.5 (94.1-76.7)	14.5 (21.4-5.6)
Infinity	100	0

Two standard error bands are in parentheses.

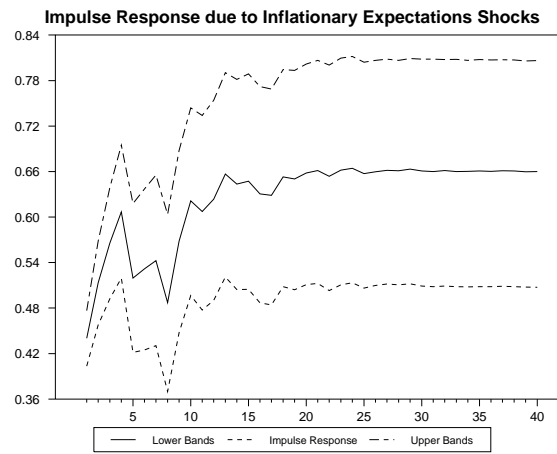
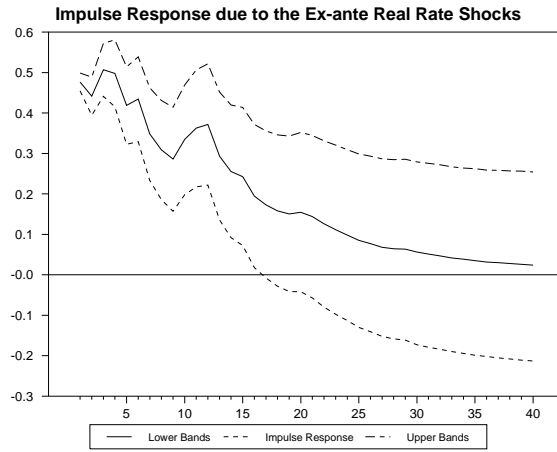


Figure 6: Impulse Responses of the Nominal Interest Rate