Real and nominal effects of monetary policy shocks

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Abstract. We employ the identification scheme of Kahn, Kandel and Sarig (2002) to analyze the impact of Canadian monetary policy on ex-ante real interest rates and inflationary expectations. First we decompose nominal interest rates into ex-ante real rates and inflationary expectations using the methodology of Blanchard and Quah (1989). Then we estimate a recursive VAR model with innovations in a monetary aggregate and the overnight target interest rate as alternative measures of monetary policy shocks. We find that a negative policy shock raises both nominal and ex-ante real interest rates, lowers inflationary expectations and real industrial output, and appreciates the Canadian dollar.

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1. Introduction

Early attempts to estimate the macro-economic effects of monetary policy shocks utilizing recursive VAR methodology encountered puzzling dynamic responses identified as the liquidity, price and exchange rate puzzles.[1] Through the work of Sims and Zha (2006), Cushman and Zha (1997) and Kim and Roubini (2000), among others, we now understand that these puzzles result from an inadequate identification of exogenous policy shocks. To resolve these puzzles, these authors employ a structural VAR approach with contemporaneous restrictions in order to identify the policy reaction function and thereby obtain measures of policy shocks that are orthogonal to the other variables in the model.

In a different resolution of the aforementioned puzzles, Kahn, Kandel and Sarig (2002), hereafter KKS, focus directly on the role of inflationary expectations. They argue that without a direct measure of inflationary expectations, one cannot distinguish between central bank interaction with real interest rates and its interaction with inflationary expectations. Using an Israeli data set of real interest rates and inflationary expectations calculated from the market prices of indexed and nominal bonds and employing a fully recursive VAR model, they find that a negative monetary policy shock, identified as an innovation in the overnight rate of the Bank of Israel, raises one-year real interest rates, lowers inflationary expectations and appreciates the Israeli currency, responses which are absent the aforementioned puzzles. They also find that the monetary policy impacts are mainly concentrated on short-term real rates.

We propose to apply the KSS methodology to Canadian data. Unfortunately, due to an incomplete set of maturities of indexed bonds we cannot calculate inflationary expectations from bond market prices as KKS do. Following the example of St-Amant (1995) and Gottschalk (2001) for U.S. and Euro area data, we estimate inflationary expectations and ex-ante real interest rates using the structural VAR method proposed by Blanchard and Quah (1989) with the identifying restrictions that real interest rate innovations have temporary effects while inflationary expectations innovations have permanent effects on nominal interest rates.

Using the estimated ex-ante real interest rates and inflationary expectations, we then estimate the separate reactions of ex-ante real interest rates and inflationary expectations to monetary policy shocks. To identify the policy shocks we employ a fully recursive VAR model that captures the systematic relationship between the monetary policy process and inflationary expectations. We also examine how both short-term and longer-term real interest rates react to monetary policy shocks. In addition, to provide a diagnostic check of our model, we augment our basic model to include some non-financial variables that may also impact the policy process, for the exclusion of these variables may give misleading results if they are related systematically to central bank actions. The additional variables in the augmented model are the US dollar/Canadian dollar exchange rate, industrial output and the unemployment rate.

We find that a positive monetary policy shock to M1B (currency and all chequable deposits in chartered banks) temporarily lowers the ex-ante real interest rate and raises inflationary expectations. The effect on the nominal interest rate, which nets the effect of the shock on the real interest rate and inflationary expectations, is a short-run decline that is smaller in magnitude than the decline in the ex-ante real rate. We find that the impact of a monetary policy shock is smaller on longer-term interest rates than on the one-year rate. We also find that a positive monetary shock increases real industrial output, depreciates the Canadian currency and marginally increases the unemployment rate, although only the first of these responses is statistically significant.

Using the overnight target rate as the monetary policy instrument, we find that a negative monetary policy shock temporarily lowers inflationary expectations and increases the ex-ante one-year real interest rate but does not have a statistically significant effect on the second and the third year ex-ante real forward rates. We also find that this policy shock decreases output, increases the unemployment rate and appreciates the Canadian currency. Our results using the overnight target rate as the monetary policy instrument are qualitatively superior to those generated with M1B as the policy instrument.

The remainder of the paper is organized as follows. In Section II we briefly outline the application of the Blanchard-Quah structural VAR methodology to decompose the nominal interest rate into an ex-ante real interest rate and inflationary expectations. In Section III we report on the suitability of our data for this methodology and present the estimated series of inflationary expectations and the ex-ante real interest rate. In Section IV we provide the framework for identifying monetary policy shocks and in Section V we present the estimation results. We review our conclusions in Section VI.

2. Nominal interest rate decomposition

We apply the structural VAR methodology developed by Blanchard and Quah (1989) to decompose the Canadian one-year, two-year and three-year nominal interest rates into the expected inflation and the ex-ante real interest rate components following the example of St-Amant (1996) and Gottschalk (2001). The starting point is the Fisher equation that states that the nominal interest rate is the sum of the ex-ante real interest rate and the expected inflation rate:

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

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 rate and $E_{t-1}(\pi_{t,k})$ denotes inflationary expectations for the time from t to t+k. The inflation forecast error $\varepsilon_{t,k}$ is defined as the difference between the actual inflation rate, $\pi_{t,k}$, and the expected inflation rate, $E_{t-1}(\pi_{t,k})$:

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

Substituting (2) into (1), we obtain:

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

Therefore, the ex-post real rate ($n_{t,k} - \pi_{t,k}$) is the difference between the ex-ante real 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, assumptions we test and confirm in Section III, the ex-ante real rate must be stationary.

Gottschalk emphasizes three implications that flow from these assumptions. First, if the nominal interest rate is non-stationary, this variable can be decomposed into a non-stationary component comprised of changes in the nominal interest rate with a permanent character and a stationary component comprised of the transitory fluctuations in the interest rate. Second, if the nominal interest rate and the actual inflation rate are co-integrated, it implies that both variables share the common stochastic trend, and this stochastic trend is the source of the non-stationary of both variables. Further, 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) and the inflation forecast error is integrated of order zero, this implies that changes in inflationary expectations are the source of these permanent movements in the nominal interest rate.

Therefore, the permanent movements of the nominal interest rate obtained by using the Blanchard-Quah methodology will be nothing other than these inflationary expectations. Since the permanent component of the nominal interest rate corresponds to inflationary expectations, the stationary component must be the ex-ante real interest rate. 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 inflationary expectations induce a permanent change in the nominal interest rate, we can estimate inflationary expectations and the ex-ante real rate of interest.[2]

3. Inflationary expectations and the ex-ante real interest rate

We use Canadian monthly data for the nominal interest rate (n_t) with one-year, two-year and three-years to maturity, and the seasonally adjusted consumer price index (CPI) from 1980:1 to 2002:12.[3] The inflation rate is calculated as the annualized monthly rate of change of the CPI. Our required assumptions are that the nominal interest rate and the inflation rate are both integrated of order one and the real rate is integrated of order zero, assumptions that imply that that the nominal interest rate and inflation rate are co-integrated (1,-1). To investigate the stationary properties of these variables, we first graph them in Figure 1 and then graph their autocorrelation functions in Figure 2.[4]

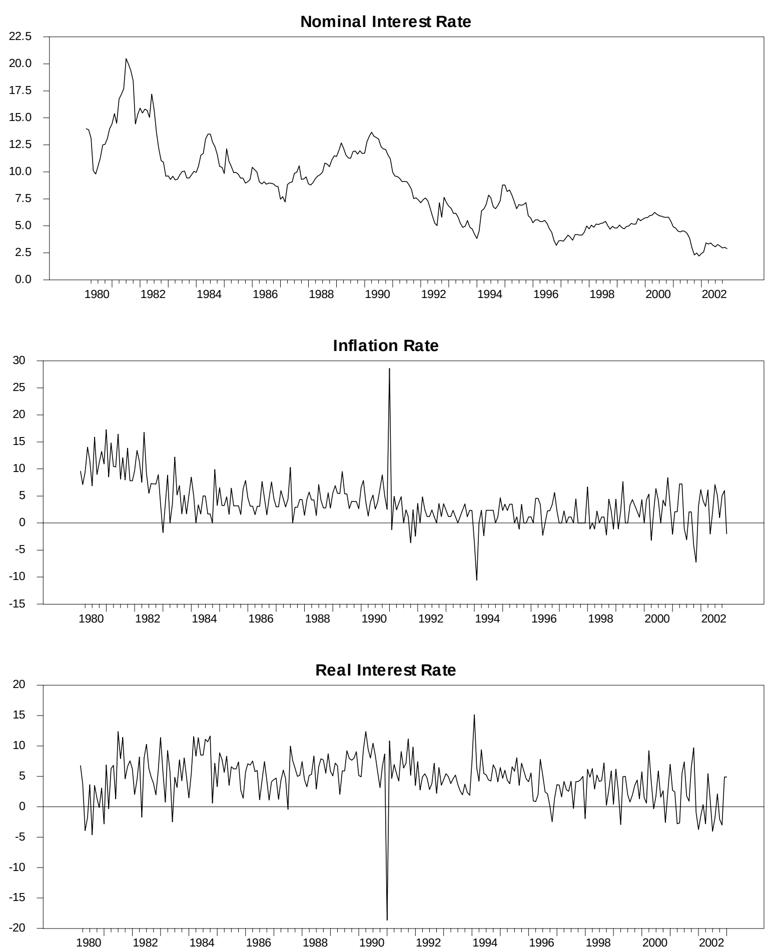

Figure 1 **Nominal Rate, Inflation Rate and One-Year Real Rate**

Figure 1 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 2 also support these hypotheses. For the nominal interest rate and the inflation rate, the autocorrelation coefficient starts with a high value and it approaches zero as the lag increases. In contrast, the autocorrelation function for the real interest rate does not exhibit decay of this magnitude.

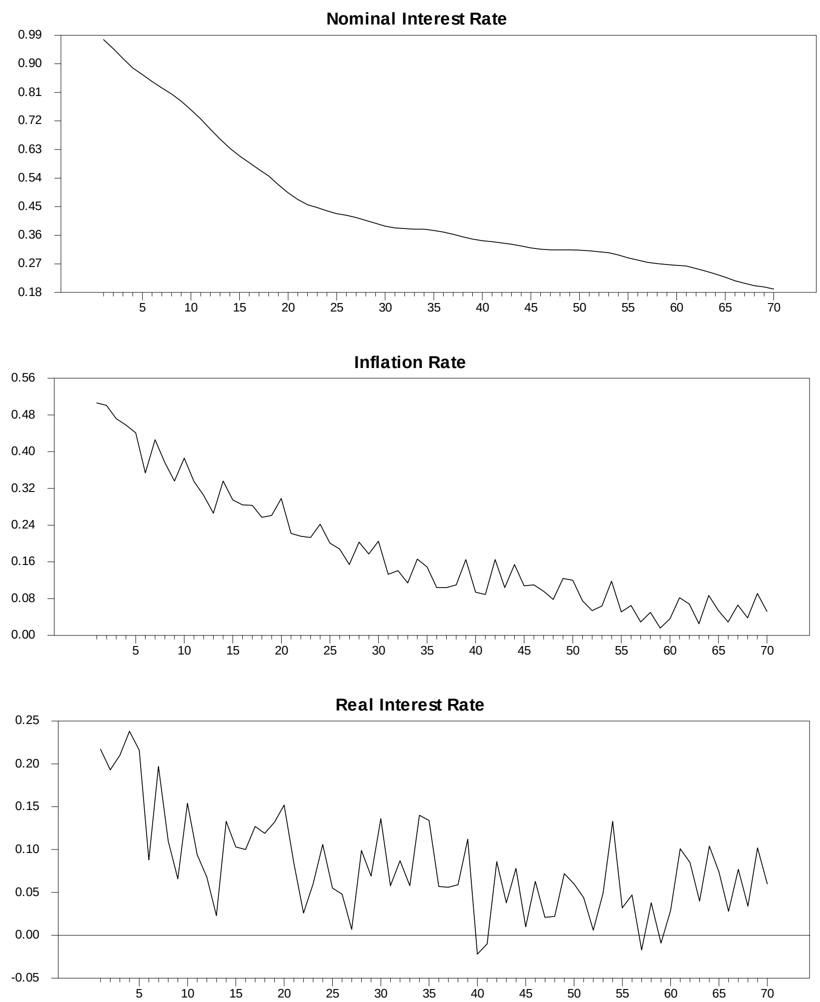

Figure 2 **Autocorrelation Functions of the Nominal Rate, the Inflation Rate and the One-Year Real Rate**

Next we use the Augmented Dickey Fuller test (ADF) test to confirm our hypothesis about the stationery properties of these variables. Table 1 which reports the results of the unit root test demonstrates that the Augmented Dickey Fuller (ADF) test cannot reject the null of unit root for the inflation rate at a ten percent level of significance and the unit root of the first difference of the inflation rate is rejected at a one percent level of significance. Therefore, we conclude that the inflation rate is integrated of order one. Table 1 also indicates that the ADF test cannot reject the null hypothesis of unit root for the nominal interest rates of all maturities at the ten percent level of significance and the hypothesis of unit root of their first differences is rejected at a one percent level of significance. These results support the hypothesis that nominal interest rates of all maturities are integrated of order one. Finally the ADF test also rejects the null hypothesis of unit root for the real interest rates of all maturities at a one percent level of significance.[5] From these finding we conclude that nominal interest rates and the inflation rate are co-integrated (1,-1)

Table 1: Unit-Root Tests[a]

Variable	**ADF Test Statistic**	**Variable**	**ADF Test Statistic**
Inflation Rate (π_t)	-1.9678 (c, 13)	2-year Nominal Rate ($n_{t,2}$)	0.8877 (c, 13)
Δ Inflation Rate	-.68357 (c, 12)	Δ Nominal Rate	4.8019 (c, 12)
Inflation Forecast Error	3.6784 (0, 3)	2-year Real Rate ($n_{t,2}$-π_t)	-4.1505 (c, 4)
1-year Nominal Rate ($n_{t,1}$)	1.4323 (c, 13)	3-year Nominal Rate ($n_{t,3}$)	0.8936 (c, 13)
Δ Nominal Rate	4.6751 (c, 12)	Δ Nominal Rate	4.9788 (c, 12)
1-year Real Rate ($n_{t,1}$-π_t)	-3.6595 (c, 6)	3-year Real Rate ($n_{t,3}$-π_t)	-4.2688 (c, 4)

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

The next step is to utilize the Blanchard-Quah (1989) methodology to estimate the time series of expectational error and real interest rate shocks that will be employed to calculate the time series of the ex-ante real interest rate and inflationary expectations. It is important to know how tightly these shocks are estimated, for if they are not, then the derived series may contain much noise. In Figure 3 we present the graph of the time series of these shocks, and the cumulative ex-ante real interest rate shocks for one-year duration along with two standard error bands.[6] It is apparent from Figure 3 that these series are tightly estimated, which supports the use of the derived series in the subsequent

Figure 3 **Expectations, Real Rate and Cumulative Real Rate Shocks with 2 S. E. Bands**

analysis.

We estimate three different reduced-form VAR models for 3 different nominal interest rates (first differenced) and corresponding real interest rates.[7] The two key outputs of VAR estimation that are of interest are the variance decompositions and impulse response functions. The decomposition of variance presented in Table 2 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 horizons. It is evident from Table 2 that the proportion of the variance of nominal interest rates of all maturities explained by ex-ante real interest rate shocks approaches zero in the long run which is a result of the restriction that ex-ante real interest rate shocks have no permanent effect on the nominal interest rate. As in St. Amant (1996), both types of shocks have been relatively important sources of nominal interest rate fluctuations, although the relatively

Table 2: Variance Decomposition of Nominal Interest Rates (in percent)[a]

Horizon	One-Year Rate		Two-Year Rate		Three-Year Rate	
	Inflationary Expectations	**Ex-ante Real Interest Rate**	**Inflationary Expectations**	**Ex-ante Real Interest Rate**	**Inflationary Expectations**	**Ex-ante Real Interest Rate**
1	50.9	49.1	46.0	54.0	50.1	49.9
	(55.3-46.5)	(53.5-44.6)	(50.8-41.3)	(58.6-49.1)	(54.8-45.4)	(54.5-45.1)
6	63.5	36.5	56.7	43.3	58.5	41.5
	(71.7-55.4)	(44.5-28.2)	(65.2-47.9)	(52.0-34.7)	(67.4-49.6)	(50.3-32.5)
12	73.6	26.4	63.7	36.3	63.1	36.9
	(82.5-64.6)	(35.3-17.4)	(74.8-52.6)	(47.3-25.1)	(74.4-51.5)	(48.4-25.5)
24	82.05	17.95	74.5	25.5	69.9	30.1
	(90.3-73.6)	(26.3-9.6)	(85.1-63.7)	(36.2-14.8)	(82.3-57.1)	(42.8-17.6)
48	85.9	14.1	81.1	18.9	75.9	24.1
	(93.7-78.1)	(21.8-6.2)	(90.3-72.1)	(27.8-9.6)	(87.8-63.4)	(36.5-12.1)
96	87.5	12.5	84.5	15.5	78.4	21.6
	(96.1-78.7)	(21.2-3.8)	(94.0-75.1)	(24.8-5.9)	(91.9-63.8)	(36.1-8.0)
infinity	100	0	100	0	100	0

a. Two standard error bands are in parentheses.

rapid decline in the proportion of variance attributable to real interest rate shocks, we believe, supports our use of the long-run restriction.

Next we present the impulse responses of nominal interest rates to the structural shocks in Figure 4 wherein the horizontal axis measures the number of months. Recall that although the long-run responses are constrained, the short-run dynamics are not constrained. As in Gottschalk (2001) and St-Amant (1996), the majority of the effect of an ex-ante real interest rate shock disappears within two years.

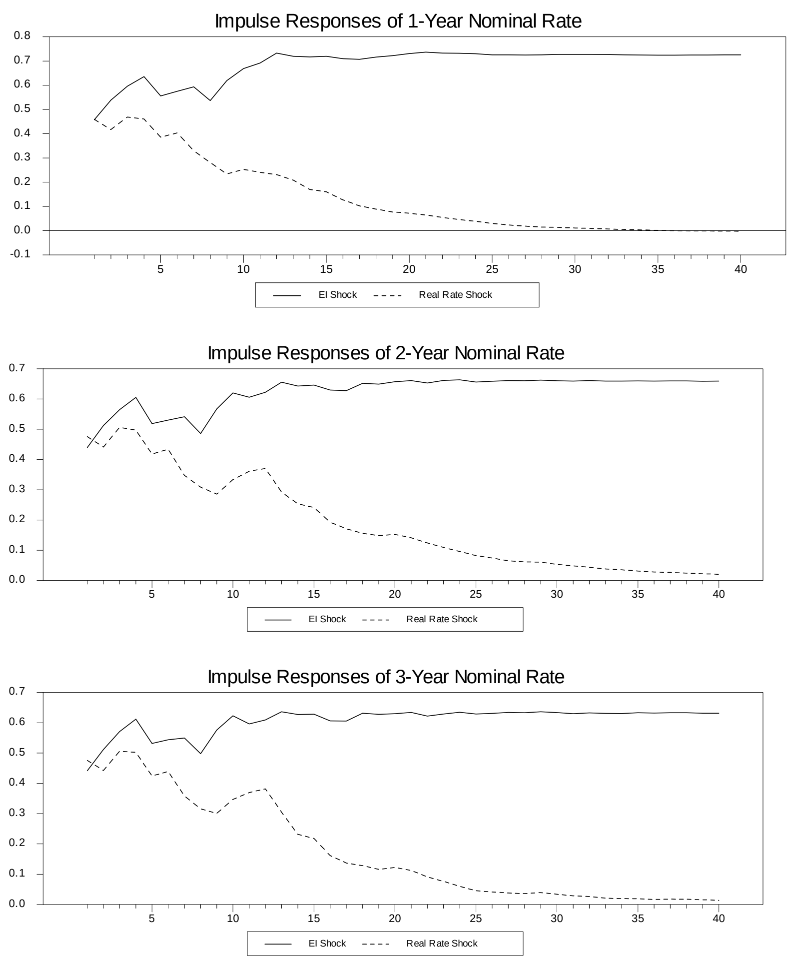

Figure 4 **Impulse Responses of Nominal Interest Rates**

To review, we first estimate the effects of ex-ante real rate and inflationary expectations shocks on nominal interest rates. Summing the effects of these structural shocks yields the stationary and permanent components of nominal interest rates. An estimate of ex-ante real interest rates is then obtained by adding the stationary components to the mean of the difference between the observed nominal interest rate and the contemporaneous rate of inflation. Then the measure of inflationary expectations is calculated by subtracting the estimated ex-ante real interest rate from the nominal interest rate. The estimated ex-ante real interest rates and inflationary expectations for one, two and three years along with the corresponding nominal interest rates are depicted in Figure 5 and the plots of actual and expected inflation rates in Figure 6. It is apparent from Figure 6 that expected inflation is less volatile than the realized inflation rate and that expectations lag the turning points of actual inflation.

Finally, recall that we assume that the inflation forecast errors are integrated of order zero. As reported in Table 1, the ADF test statistic support this hypothesis at the one percent level of significance.

4. The identification of monetary policy shocks

We employ a fully recursive VAR model to estimate the effects of monetary policy shocks on various macroeconomic variables. The first step is to identify policy shocks that are orthogonal to the other shocks in the model. To do this, we follow the approach of KKS to categorize all the variables in our model into three broad types.

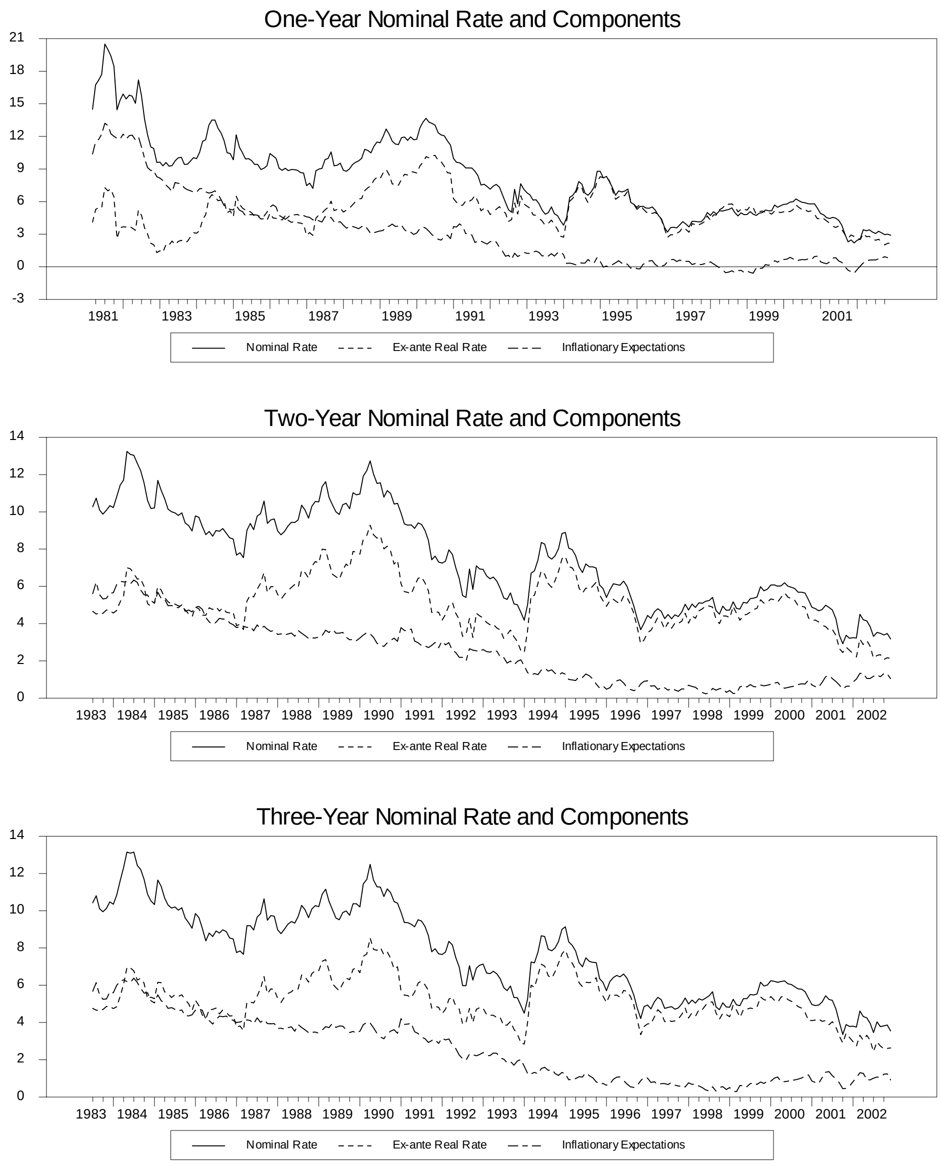

Figure 5 Nominal Interest Rates and Their Components

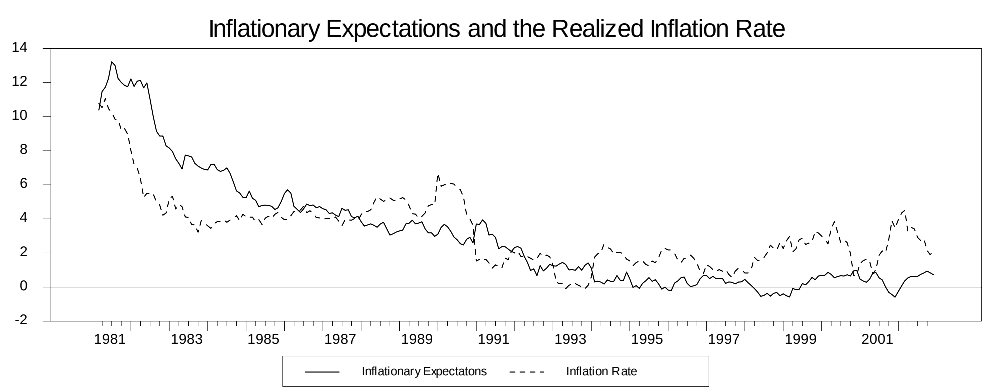

Figure 6 **Inflationary Expectations and the Realized Inflation Rate**

The first type of variable (Type I variable) is the monetary policy instrument. We use the monetary aggregate, M1B, and the overnight target rate, OT, as alternative monetary policy instruments. The second type of variable (Type II variable) is a contemporaneous input to the monetary policy rule, that is, a variables the central bank observes when setting its policy. To facilitate a comparison with KKS, in the basic model we include only one variable, the measure of inflationary expectations, EI, as the contemporaneous input to the policy process. The third type of variable (Type III variable) in the basic model is a variable that responds to the change in policy. Since conventional theory treats the ex-ante real interest rate as the channel through which changes in policy are transmitted to policy targets, we use three alternative interest rates, R_1 , the one-year ex-ante real interest rate, F_2 , the two-year forward ex-ante real interest rate and F_3 , the three-year forward ex-ante real interest as our Type III variables. The use of the forward rates in years two and three is motivated by a concern for double counting that is inherent in the use of yields to maturity. In the augmented model, however, we include three other variables, the exchange rate, EXR, output, Y, and the unemployment rate, UNPR, as either Type III or Type II variables.

Therefore our basic model includes three different variables: [EI, (M1B or OT), and R]. We assume that the central bank's feedback rule is a linear function of contemporaneous values of Type II variables (inflationary expectations) and lagged values of all types of variables in the economy. That means that time t's change of monetary policy of the Bank of Canada is the sum of the following three things:

- the response of the Bank of Canada's policy to changes up to time t-1 in all variables in the model (i.e., lagged values of Type I, Type II and Type III variables),
- the response of the Bank of Canada's policy to time t changes in the non-policy Type II variable (inflationary expectations in the basic model), and
- the monetary policy shock.

Therefore, a monetary policy shock at time t is orthogonal to: changes in all variables in the model observed up to time t-1, and contemporaneous changes in the Type II non-policy variable (inflationary expectations). So, by construction, a time t monetary policy shock of the Bank of Canada affects contemporaneous values of Type III variables (i.e., the real ex-ante interest rates of different maturities in the basic model) as well as all variables in the later periods.[8]

5. Estimation

All data is monthly from 1980 to 2002. The nominal interest rates used in the decomposition described in Section II are the one-year Government of Canada Treasury bill rate and the two-year and three-year Government of Canada bond rates. From the latter we calculate the two and three year forward rates.

5.1. The impulse responses of the basic model

First we report the impulse response of MIB, and the overnight rate, O, to a positive one standard deviation shock to inflationary expectations in Figure 7.[9] Under the current inflation targeting regime, we anticipate that the central bank's response to a rise in inflationary expectations is to tighten the money supply and we observe this response in Figure 7, although it is not statistically significant. In contrast, the overnight rate response is more immediate and statistically significant and this qualitative difference is similar to that of KSS. We interpret these responses as support for our view that our measure of inflationary expectations is an input to the policy process.

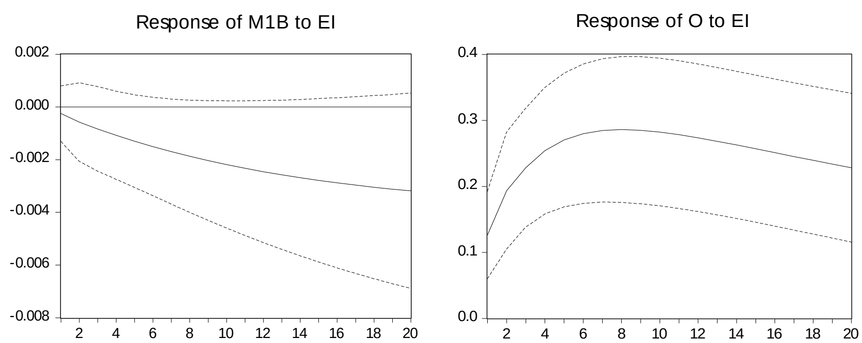

Figure 7 **Impulse Responses of M1B and O with 2 S.E. Bands**

We begin with M1B as the policy instrument to facilitate comparisons with previous research. In the first column of Figure 8 we report the response of inflationary expectations and the one-year ex-ante real interest rates to a one standard deviation policy shock to M1B.[10] We expect innovations in the money supply will increase inflationary expectations and reduce ex-ante real interest rates, although the degree of impact on a particular interest rate should vary depending on the maturity of the rate. Observe from Figure 8 that inflationary expectations increase by 7 basis points (statistically significant for eight months) and the one-year ex-ante real interest rate decreases by 14 basis points (statistically significant from the eighth to the twenty-eight month) following a money supply innovation.

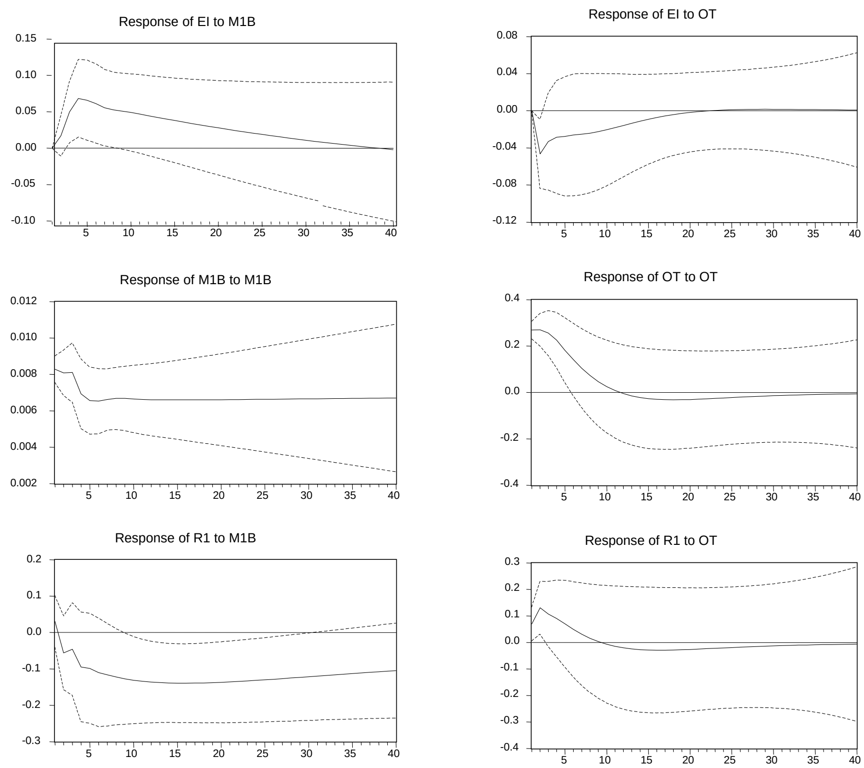

Figure 8 **Impulse Responses of EI and R1 with 2 S.E. Bands**

It is instructive to compare these results with previous research. Using M1 as the policy instrument, KKS find for Israeli data that the effect on inflationary expectations is statistically insignificant while the effect on the one-year ex-ante real interest rate is statistically significant for about eight months. In contrast, using a structural VAR model with contemporaneous restrictions and M1 as the monetary policy instrument, Cushman and Zha (1997) find for Canadian data that a negative monetary policy shock raises the real interest rate but the effect is small and statistically significant for two months only.

In 1994 the Bank of Canada adopted a target band and target rate for the overnight rate on loans among banks and other financial intermediaries as its principal policy instrument. The target band of 50 basis points is designed to allow for small and presumably temporary adjustments of the overnight rate to market developments while adjustments in the target rate are reserved for implementation of changes in the stance of policy. Only if the overnight rate threatens to break through the upper or lower band will the Bank intervene in the overnight market.[11]

Since the target rate is under the sole control of the Bank of Canada, it follows that innovations in this rate should be a more precise measure of monetary policy shocks than innovations in a monetary aggregate. We, therefore, re-estimate our basic VAR model using the overnight target rate as the monetary policy instrument from 1994-2002 and the impulse responses are reported in the second column of Figure 8. A negative monetary policy shock introduced by increasing the overnight target rate by 25 basis points (a one standard deviation shock) lowers inflationary expectations by 5 basis points and raises the ex-ante one-year real interest rate by 15 basis points and these effects are statistically significant for three and four months, respectively. A comparison with the results using M1B suggests that a shock to the overnight target rate has a much more immediate impact on the real interest rate than a shock to a monetary aggregate and this difference is likely because the interest rate shock does not require a response of chartered bank deposits for its impact.

Although the Bank of Canada's policy impacts real interest rates at the short end of the maturity spectrum, we expect it may also impact real interest rates at longer horizons. Following KKS we use the forward ex-ante real interest rates of two- and three-years to estimate the longer-term impact of monetary shocks and we report the estimated impulse responses using M1B as the policy instrument in the first column of Figure 9. We find that the effect of money supply innovations on interest rates declines with an increase in maturity (but is still significant), a result similar to that found by Edelberg and Marshall (1996) and KKS. In contrast, the second column of Figure 9, which presents the impulse responses using the overnight target rate as the policy instrument, indicates that the impacts on the forward interest rates are insignificant. This difference likely follows from the fact that, as Figure 8 indicates, the impact on interest rates is more immediate using the overnight target rate and so the duration of the impact is reduced.

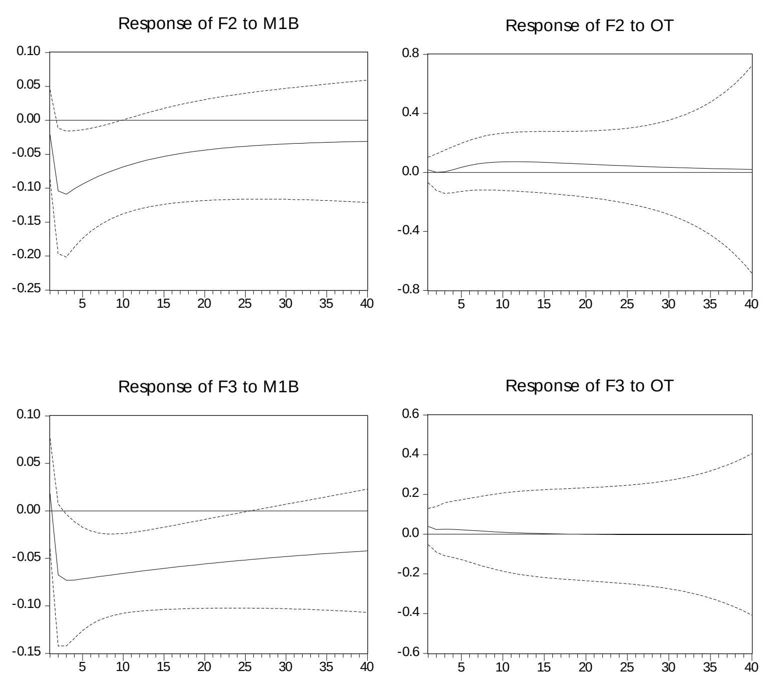

Figure 9 **Impulse Responses of F2 and F3 with 2 S.E. Bands**

Most previous studies report the response of nominal interest rates rather than ex-ante real interest rates to monetary policy shocks. For comparison purposes we estimated the

VAR model with nominal rates in place of real rates. It is important to note that the impact of monetary policy shocks on nominal interest rates nets two opposite directional impacts--the impact on ex-ante real interest rates and the impact on inflationary expectations. The shape and magnitude of the impact on nominal interest rates should, therefore, depend on the combined shape and magnitude of the impacts on the real interest rate and on inflationary expectations. We report the impact of a positive shock to M1B on inflationary expectations and the nominal interest rate in the first column of Figure 10. As expected, this shock lowers the one-year nominal interest rate, and the impact is smaller (10 basis points) than the impact on the one-year ex-ante real interest rate (14 basis points). In contrast, Cushman and Zha (1997) find that a monetary policy shock has a minor and only briefly significant effect on the nominal interest rate.

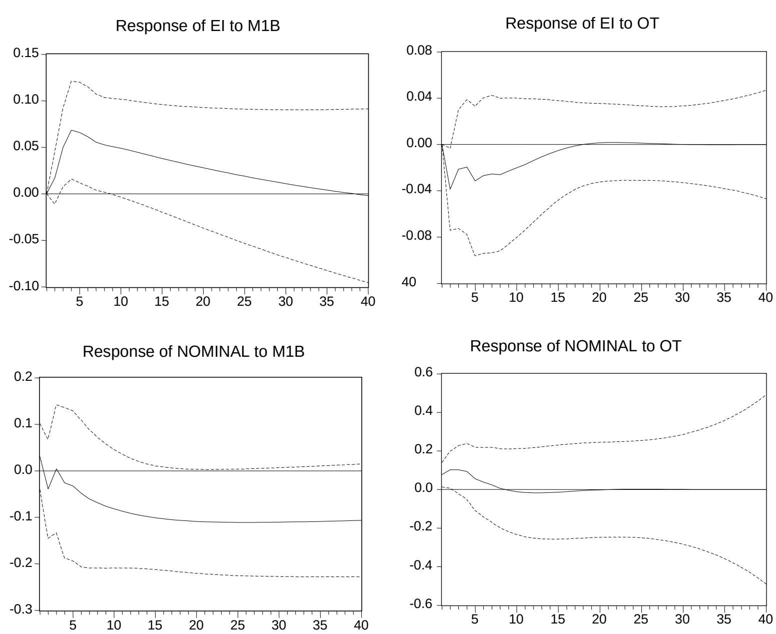

Figure 10 **Impulse Responses of EI and the Nominal Interest Rate with 2 S.E. Error Bands**

In column two of Figure 10, we report the impulse response functions of the one-year nominal interest rate to an innovation in the target rate. Consistent with the previous results, the impact of the negative monetary policy shock is smaller (10 basis points) than its impact on the one-year ex-ante real interest rate (15 basis points).

A criticism of the recursive VAR model is that its results crucially depend on the order in which the variables are estimated. We examine whether the change in the order of the variables impacts the estimates of the impulse response functions by re-estimating the model in the following order: [M1B or OT, EI and R]. The estimated results are reported in Figure 11. For this ordering we find a statistically insignificant impulse response for inflationary expectations and we interpret this result as support for our identification scheme that uses inflationary expectations as a contemporaneous input to the monetary

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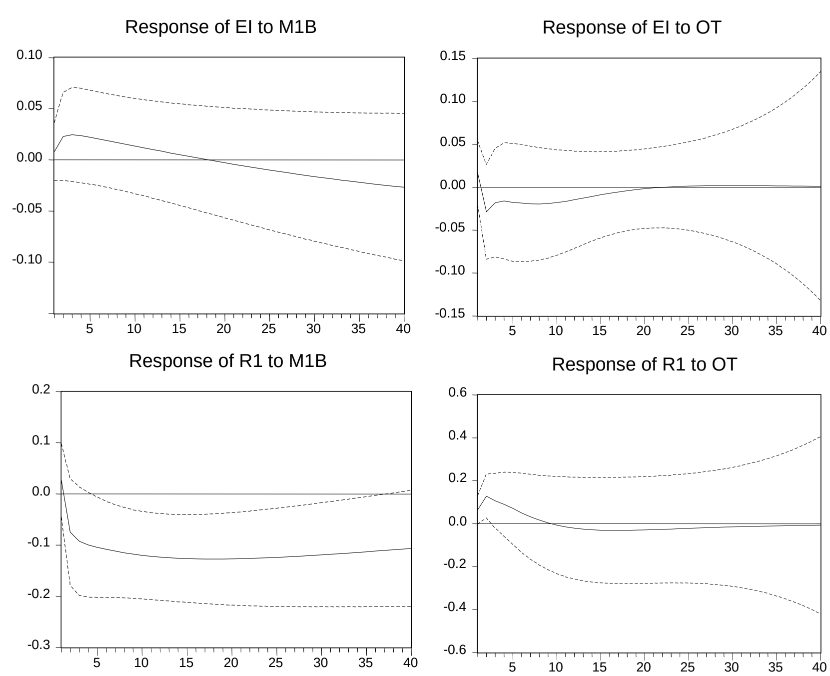

Figure 11 **Impulse Responses of EI and R1 for an Alternative Ordering of Variables**

policy reaction function.

5.2. The augmented model

We now augment the basic VAR model by incorporating some additional variables that may impact real interest rates and inflationary expectations. If these variables are correlated with the monetary policy of the Bank of Canada, their omission may lead us to erroneously attribute the impact of these variables to Bank policy. Cushman and Zha (1997), for example, identify the US /Canadian exchange rate as an important channel of the monetary transmission mechanism. Additionally, in the semiannual Monetary Policy Report, the Bank places significant emphasis on its estimates of the real output gap. Therefore, in the augmented model we include EXR, the log of the US/Canadian exchange rate; Y, the log of industrial production, and UNPR, the unemployment rate.[12]

5.2.1. Impulse responses using M1B

In the first version of the augmented model we continue to use inflationary expectations as the only Type II variable and specify the ex-ante real interest rate, the exchange rate, industrial output and the unemployment rate as Type III variables with the following order: [EI, M1B, R1, EXR, Y, UNPR]. The estimated impulse responses of this augmented model are reported in Figure 12. In the augmented model inflationary expectations increase by 5 basis points following a positive shock and this response remains statistically significant for five months. The ex-ante real interest rate also decreases by 18 basis points and the decrease remains significant for fifteen months. In addition, the shock temporarily depreciates the Canadian dollar (although it appreciates

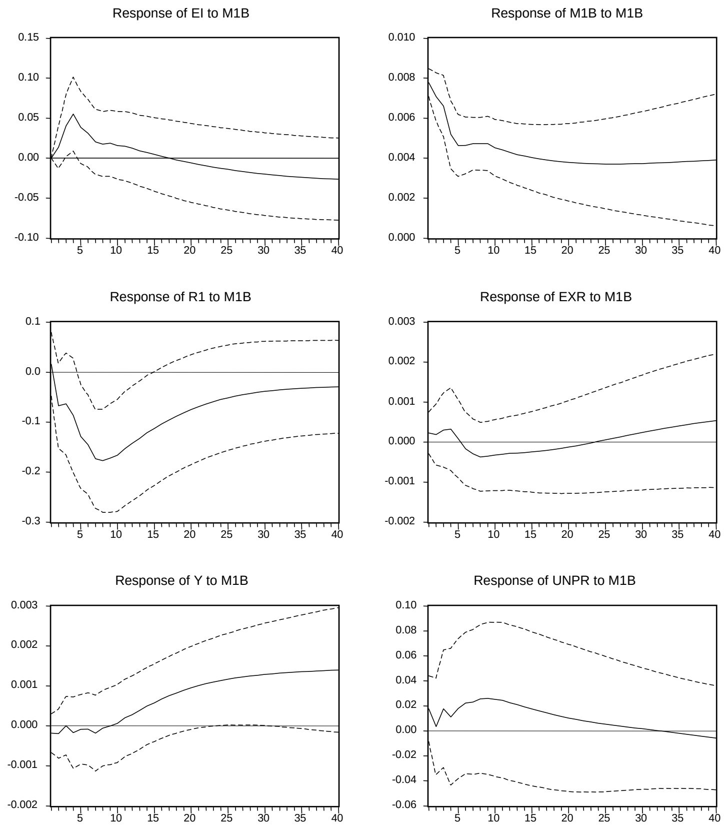

Figure 12 **Impulse Responses of the Augmented Model with 2 S. E. Bands**

for the first four months), increases industrial output (which is statistically significant after eighteen months) and has an insignificant effect on the unemployment rate. KKS also found an insignificant effect for the unemployment rate although they obtained a significant effect on the exchange rate. In contrast, Cushman and Zha (1997) reported an increase in output and a depreciation of the Canadian currency and these are statistically significant for seven and thirteen months, respectively. They conclude that the monetary policy transmission mechanism works primarily through the exchange rate because of a very short-run effect on the nominal and real interest rate.

To test the robustness of these results to a change in the order of variables in a six variable model, we require a strategy to limit the number of orderings to test. For this purpose we present the correlation matrix of residuals in Table 3. Using Enders (2003) guide of 0.20 as significant, we find only two significant correlations, (M1B, UNPR) and (R1, EXR). We estimated the augmented model with UNPR as a contemporaneous input to the monetary policy reaction function (Type II variable), and with the order of R1 and EXR reversed, but the results appear to be robust to these change of ordering.[13]

Table 3: Correlation Matrix of Residuals

Variable	EI	M1B	R1	EXR	Y	UNPR
EI	1.00					
M1B	-0.02	1.00				
R1	-0.09	0.06	1.00			
EXR	0.12	-0.07	0.29	1.00		
Y	0.06	-0.10	0.10	-0.05	1.00	
UNPR	0.09	-0.29	-0.09	0.05	-0.08	1.00

The impulse responses for the exchange rate, real output and the unemployment rate are not very satisfactory. This may reflect the fact that a monetary aggregate is likely to be influenced by sources other than the central bank and this will reduce the precision of estimates of monetary policy shocks in a recursive setting. Accordingly, we also investigate the overnight target rate as an alternative measure of the monetary policy instrument in the augmented model.

5.2.2. Impulse responses using the overnight target rate

The impulse responses of the augmented model with the overnight target rate are reported in Figure 13.[14] We find that a 22 basis point increase in the overnight target rate lowers inflationary expectations by 5 basis points and raises the ex-ante real interest rate by 18 basis points and these responses are significant for three and four months respectively. In addition, the exchange rate appreciates (statistically insignificant) industrial output decreases (statistically significant from month six to month sixteen) and the unemployment rate increases (statistically significant).[15]

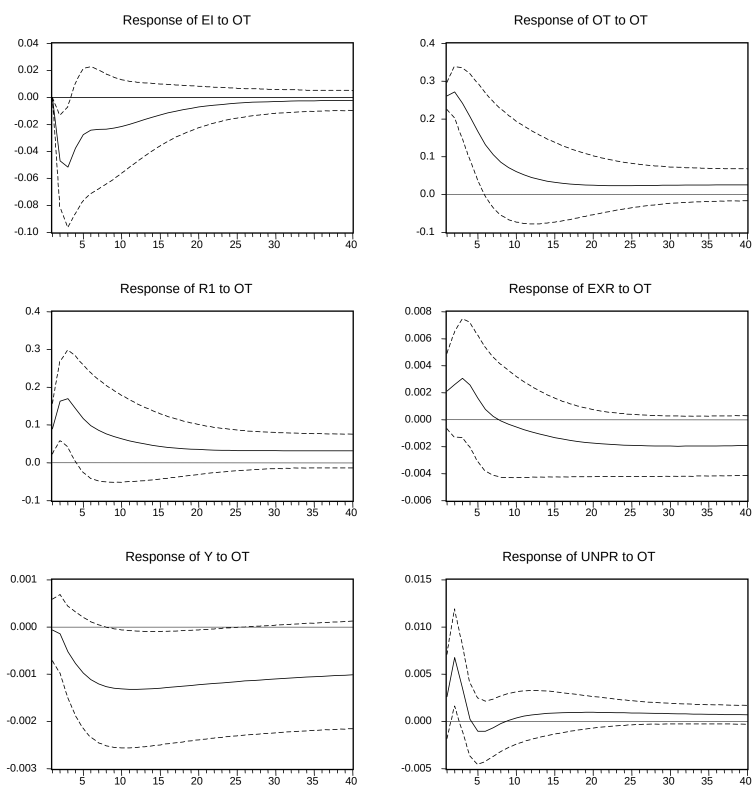

Figure 13 Impulse Responses of the Augmented Model with 2 S. E. Bands

Comparing the responses of the augmented model with those from the model with M1B as the policy instrument, we find no reversal in the movement of the exchange rate and a more immediate response of industrial output. Furthermore, the response of the unemployment rate is significant, although it reaches its peak in the second month which is prior to the trough in real output. [16]

We present the correlations of residuals in Table 4. We observe three marginally significant correlations, (EI, Y), (OT, R1) and (R1, EXR). Again we estimated the model with changes in the ordering of these three pairs of variables and, as with the model employing a monetary aggregate, the responses are robust to a change in the order of variables.

Table 4: Correlation Matrix of Residuals

Variable	EI	OT	R1	EXR	Y	UNPR
EI	1.00					
OT	0.10	1.00				
R1	-0.16	0.22	1.00			
EXR	0.02	0.15	0.23	1.00		
Y	0.22	0.01	0.12	-0.02	1.00	
UNPR	0.09	0.13	-0.07	-0.02	-0.12	1.00

6. Conclusions

We estimated the impact of monetary policy on various real and nominal macroeconomic variables. Our approach of decomposing the nominal interest rate into the ex-ante real interest rate and inflationary expectations using the Blanchard-Quah identification make it possible to separately examine the reactions of these variables to monetary policy shocks. Whether we use only inflationary expectations or inflationary expectations and other macroeconomic variables (the exchange rate and industrial output) as contemporaneous inputs to the policy reaction function of the Bank of Canada, we do not encounter anomalies such as the liquidity or exchange rate puzzles that plagued early VAR studies of monetary policy shocks in small open economies. Thus we are able to validate the identification scheme of KKS using an alternative data set.

In addition, we obtain qualitatively better results in a recursive VAR model using the overnight target rate rather than a monetary aggregate. We suggest this result likely follows because, unlike money, the overnight target rate cannot be influenced by private sector behavior except through the channel of an endogenous policy response of the central bank to changing economic conditions. Since our approach identifies this reaction function explicitly, we are able to estimate innovations in the overnight target rate that are orthogonal to other variables in the model. Therefore, we conclude it is better to model monetary policy shocks in a recursive VAR model with the overnight target rate.

We believe these results complement the work of Cushman and Zha (1997) in estimating monetary policy effects in a small open economy with the use of a monetary aggregate as the policy instrument. They demonstrate that to avoid the anomalies that characterized previous studies, it is necessary to impose identifying restrictions in a structural VAR model in order to separate the money demand function from the money supply (policy reaction) function. Only in this manner is it possible to correctly identify policy shocks that are exogenous. Since we find that a monetary aggregate performs relatively poorly in a recursive setting compared to their results, notwithstanding the use of the KSS identification scheme, our analysis supports their central message.

Our results differ from Cushman and Zha (1997) in one important respect. They find that the transmission mechanism from monetary policy shocks to real output is through the exchange rate. While we obtain this effect as well, we also find a significant role for the real interest rate channel. That is, we estimate that a 22 basis point increase in the overnight target rate raises the one-year ex-ante real interest rate by 18 basis points and this response is significant for four months.

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Appendix: Data sources

Money supply-M1B: Cansim, Series Level-V37199

Overnight Rate: Cansim, Series Level-V122514

One-year nominal interest rate- Government of Canada One-year Treasury Bills Rate: Cansim, Series Level-V122533

Two-year nominal interest rate-Selected Government of Canada Benchmark Bond Yields: Cansim, Series Level-V122538

Three-year nominal interest rate- Selected Government of Canada Benchmark Bond Yields: Cansim, Series Level-V122539

Consumer Price Index: Cansim, Series Level-V737311

Exchange Rate-US dollar/Canadian dollar: Cansim, Series Level-V37426

Industrial Production: Cansim, Series Level-V2044332

Unemployment Rate: Cansim, Series Level-V2062815

Overnight Target Rate: (1994-1996) Cansim Series Level-B114039; (1996-2002) Bank of Canada, Summary of Key Monetary Policy Variables

Footnotes

Lead footnote: We acknowledge the helpful comments of David Cushman and two anonymous referees although the standard caveat applies. An earlier version of this paper was presented at the Canadian Economics Association Annual Meeting, Ryerson University, Toronto, June, 2004.

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[1] For an extensive review of these puzzles and early attempts to resolve them, see Kim and Roubini (2000).

[2] A formal representation of the structural VAR model is available from the authors upon request.

[3] Definitions and sources for all data are provided in the Appendix.

[4] For the sake of brevity, we present results only for the one-year real interest rate, but the results for the two- and three-year rates are similar.

[5] The stationarity tests are applied to $i_{t,k} - \pi_t$ which is equivalent to the tests that $i_{t,k} - \pi_{t,k}$ are stationary.

[6] For the sake of brevity we do not report the results for two and three year duration as the error band widths are similar.

[7] We used the RATS program (Doan, 2000) to estimate the VAR models. In all the models we use a lag-length of 12 which was determined on the basis of Likelihood Ratio criteria.

[8] This framework assumes that the central concern of the Bank of Canada in the setting of policy is inflationary expectations because of the lag between changes in its instrument and the impact on its objective. That is, unless the Bank targets inflationary expectations directly, it cannot hope to control inflation efficiently.

[9] As with all response functions to be reported, the solid line is the impulse response and the dashed lines contain the 95% confidence interval, calculated with 10,000 Monte Carlo repetitions.

[10] For all interest rates response functions reported from the basic model, we use a lag-length of three that was determined on the basis of the Akaike Information criterion.

[11] Prior to 1999, the target rate could be anywhere within the band, but since 1999 it has been set at the midpoint of the band. Prior to 2001 the target rate could be changed on any day, but in 2001 the Bank implemented a system of eight fixed dates in the year on which the target rate can be adjusted.

[12] We use a lag-length of six in the augmented model on the basis of the Akaike Information criterion. The impulse responses are not sensitive to variations in the lag length.

[13] The impulse responses for alternative orderings of this and other models are available from the authors upon request.

[14] We used a lag-length of four in the augmented model that was determined on the basis of the Akaike Information criterion. The impulse response functions are invariant to the choice of lag length.

[15] A referee questioned the inverse correlation between the real interest rate and real output, since in a benchmark intertemporal model of optimization with price flexibility, these variables are positively correlated. However, the addition of nominal rigidites to intertemporal models of optimization generates a 'liquidity effect' from a monetary policy shock that implies impulse responses consistent with Figure 13. See, for example, Woodford (2003, Chapter 3) for an intertemporal model with nominal price rigidity and

Christiano, Eichenbaum and Evans (2005) for an intertemporal model that emphasizes nominal wage rigidity.

[16] This latter result appears to be sensitive to the lag length. For longer lag lengths, the response of the unemployment rate lags the response of output, reaching its peak in the twelfth month following a shock.