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Empirical Evaluations of the U.S. and Canadian Monetary Policies and the Associated Causal Linkages

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Abstract

This study examined the effectiveness of U.S. and Canadian monetary policies. The study employed the methodology of multivariate cointegration and the estimation of Vector Error Correction Model (VECM). Granger causality tests were performed within the framework of cointegration, and trivariate VECMs. The models incorporated a monetary policy short-term interest rate, a long-term interest rate, and a proxy for nominal GDP/output. According to the empirical results, both central banks were found to succeed in affecting long-term interest rates and nominal GDP/output. U.S. monetary policy was found to affect (cause) nominal disposable personal income and to countercyclically (correctly) react to changes in it. The two central banks, however, were found to be either passive or procyclically reactive to real business cycle activity, depending on the proxy with which real economic activity was measured. Tests for cross-country effects of monetary policy from one central bank onto the other country's economy indicated that the Federal Reserve affects both economies, whereas the Central Bank of Canada affects only its domestic economy.

Key Words: unit roots, cointegration, vector error correction model, target interest rate, long-term interest rate, central bank, monetary policy
JEL Classification: C01, C32, E52, E58

Introduction

The two most important objectives of central banks are price stability and economic growth. To achieve these objectives, central banks choose to control either a monetary aggregate or to target a short-term interest rate.[1] In both cases, monetary policy is believed to affect the economy through its impact on a variety of market interest rates, which subsequently affect real and financial asset prices. The U.S. Federal Reserve System (Fed) sets the federal funds rate (r_{ff}) and intervenes through open market operations to maintain the market or effective r_{ff} close to the target rate. The central bank of Canada, known as the Bank of Canada (BOC), sets the target overnight rate (r_{ov}). The BOC also announces an operating band for r_{ov} and tries to maintain r_{ov} within the announced band through intervention in open market operations. More recently (in October 2008) the Fed adopted similar policy, restraining r_{ff} within a corridor of an upper and lower limit.[2]

This study investigated the effectiveness of monetary policy by examining the relationship between central bank target interest rates with long-term interest rates and proxies for nominal GDP or output. Increasing economic and financial integration between the two neighboring economies in the last few decades enhanced the possibility that effects of monetary policy cross into the neighboring country's economy. For this reason possible effects of U.S. monetary policy on Canadian economy, and vice versa, also were examined.

Literature Review

Few authors have investigated the existence of unique information content in the central bank target interest rate in predicting short-term interest rates and real economic activity.[3] Empirical results found by these studies, however, were inconclusive. The most prevalent economic theory that deals with the relationship between short- and long-term interest rates is the expectations theory of the term structure of interest rates.

Many empirical studies rejected the expectations theory of the term structure of interest rates. Nevertheless, a few researchers found that the spread between interest rates of different maturities predicts short-term interest rates fairly well in accordance to the expectation hypothesis.[4]

The Rational Expectations Theory of the Term Structure of interest rates (RETTS) purports that the level of long-term interest rates must be equal to the average of both present and future short-term interest rates.[5] According to the RETTS, the spread between long- and short-term interest rates is the basis for predicting short-term interest rates. Some researchers have argued that the relationship between long- and short-term interest rates, known as the yield curve, contains no useful information in predicting short-term interest rates. However, Mankiw and Miron (1986) provided evidence supporting the RETTS. Their study utilized U.S. data for 3 and 6-month interest rate spreads predating the establishment of the Fed for the period 1890-1914. They concluded that the 3 and 6-month yield spreads could be used to predict the 3-month yield. Furthermore, according to Mankiw and Miron, studies based on data postdating the establishment of the Fed, which did not find any predictive power in the yield spread, did not provide evidence for rejection of the RETTS. Their explanation was based on the fact that since the Fed stabilized interest rates, the rates are characterized by a random walk process. As a result, the Fed's monetary policy made the forecasting of U.S. short-term interest rates impossible. Further support for the RETTS was provided in studies by Mishkin (1988), Hardouvelis (1988), and Fama (1984), who employed spreads of different combinations of interest rates with different maturities.

Similarly, Cook and Hahn (1989) found that changes in the U.S. federal funds rate (r_{ff}) have strong but variable effects on short, intermediate, and long-term interest rates. Such evidence also supported the RETTS. Bernanke and Blinder (1992) found that the nominal r_{ff} was exceptionally informative in predicting real economic activity. The slope of the yield curve, the line that joins interest rate values of different maturities, was found empirically to provide forecasting information for the business cycle. The consensus among economists is that an upward sloping yield curve forecasts an expansionary period, whereas a negatively sloped, or inverted yield curve, forecasts a recession. Cuthbertson, Hayes, and Nitzsche (1998), employing cointegration and error correction models, provided some evidence supporting the expectations hypothesis.

Based on the asset-pricing theory, Harvey (1997) found that the term structure of interest rates in Canada accurately predicted changes in economic growth. More specifically, this study found that the Canadian term structure of interest rates predicted the part of the Canadian economic growth that is unrelated to US economic growth.

In the U.S., when the Fed sets the target interest rate, it also stabilizes the market or effective rate at the target rate via open market operations by buying and selling short-term government securities. This Fed action affects all short-term interest rates and through term structure, it also affects the long-term interest rates. Long-term interest rates affect investments and consumption of durable goods, and purchases of homes. Long-term interest rates consequently constitute the vehicle for the transmission of monetary policy that influences economic growth. An abundance of studies exists in the literature on the term structure of interest rates, examining the relation between short-term and long-term interest rates. Most of this work was based on a partial equilibrium analysis focusing on a single equation describing a structural relationship between long-term and short-term interest rates. A few exceptions exist, such as Clarida and Friedman (1983), who incorporated both interest rates in a simple IS-LM model, allowing short-term interest rates to enter the LM curve and the long-term interest rates to enter the IS curve. According to Turnovsky (1989), almost all studies of the term structure of interest rates employed a partial equilibrium model. As a result, this model was the main reason that many studies rejected the RETTS. Instead, Turnovsky suggested a stochastic macroeconomic model including both short- and long-term interest rates along with additional macroeconomic variables. In such a model short- and long-term interest rates and other included macroeconomic variables are simultaneously determined, and the term structure of interest rates is sensitive to the presence and type of macroeconomic policy shocks in the economy. Particularly, Turnovsky demonstrated that it is important to know not only if these policy shocks are monetary or fiscal, but also whether the shocks are temporary or permanent.

A relation between short- and long-term interest rates will be specified correctly if both interest rates are jointly determined in a macroeconomic model. Since both short- and long-term interest rates depend on the performance of the economy, as a first approximation the two interest rates and a proxy for the performance of the economy should be included in the model. Such a relation between the three variables is plausible. This study examined whether central banks' targeting short-term interest rates r_{ff} and r_{ov} affected long-term interest rates, and nominal GDP/output in the U.S. and Canada. The reaction of the two central banks to changes in economic activity was studied as well.

Data Description

This study employed four data sets, two for the U.S., one for Canada, and a joint U.S.-Canadian data set.

U.S. Monthly Data Set: 1959:02-2005:01 (552 observations)

This data set consisted of a short-term interest rate, a long-term interest rate ,and two proxy variables capturing the performance of the U.S. economy (one nominal and two real proxies). The source of the U.S. data was the International Financial Statistics (IFS) database. The variables of in this data set were the following: (a) federal funds rate (r_{ff}), (b) 10-year treasury bond yield (r_{tb10}), (c) the natural logarithm of the nominal disposable personal income (ln*dpi*), and (d) the natural logarithm of industrial production (ln*ip*).

U.S. Quarterly Data Set: 1957Q$_1$-2005Q$_2$ (197 observations)

This data set consisted of the variables r_{ff}, r_{tb10}, and natural logarithm of the real gross domestic product (ln*rgdp*).

Canadian Monthly Data Set: 1975:01-2005:02 (362 observations)

This data set consisted of three variables: a short-term and a long-term interest rate, and a proxy variable capturing the performance of the Canadian economy.[6] These variables were (a) overnight rate (r_{ov})[7], (b) 10-year government bond yield (r_{gb10}), and (c) the natural logarithm of the index of industrial production (ln*ip*).

Combined U.S. and Canadian Monthly Data Set: 1975:01-2005:02 (362 observations)

Lastly, a combined data set of monthly Canadian and U.S. data was constructed. This data set included the U.S. interest rates, r_{ff}, and r_{tb10}, and two Canadian interest rates, r_{ov}, and r_{gb10}. The data set included the U.S. and Canadian natural logarithms of the respective indices of industrial production (ln*ip*).

Methodology

The study employed the econometric techniques of cointegration, and the VECM. Such methodology permits the simultaneous estimation of a model that includes a central bank short-term policy interest rate, a long-term interest rate, and a proxy for nominal GDP or output in each country. Within the framework of VEC model, Granger causality tests were performed to reveal evidence, strength, and direction of causality between these variables.

The study also tested for presence of cross-country monetary policy effects, triggered by central bank changes in their respective policy interest rate, onto the economy of the other country.

Econometric Causality

Granger econometric causality theory allows the study of relations among variables, since it can reveal statistical evidence for the degree and direction of causality. Econometric causality has been attributed to Engle and Granger (1987), who introduced causality within the framework of the Error Correction Model.

The Vector Error Correction Model (VECM)

Tests for Granger econometric causality are performed within the framework of estimated VECMs.[8] A VECM is a set of simultaneous equations, which include equal number of cointegrated variables. Each left-hand side variable, expressed in first differences, is a function of an optimum number of lagged differences of all the right-hand side variables and the one-period lagged error correction term θ_{t-1} of the cointegrating equation. The error term, ε_t, in each equation is assumed to be a random white noise variable with a zero mean and constant variance.

$$\Delta X_t = \alpha_1 + \alpha_x \theta_{t-1} + \sum_{i=1}^{r_1} \alpha_{1i} \Delta X_{t-i} + \sum_{i=1}^{s_1} \beta_{1i} \Delta Y_{t-i} + \sum_{i=1}^{k_1} \gamma_{1i} \Delta Z_{t-i} + \varepsilon_{1t} \tag{1}$$

$$\Delta Y_t = \beta_2 + \beta_Y \theta_{t-1} + \sum_{i=1}^{r_2} \alpha_{2i} \Delta X_{t-i} + \sum_{i=1}^{s_2} \beta_{2i} \Delta Y_{t-i} + \sum_{i=1}^{k_2} \gamma_{2i} \Delta Z_{t-i} + \varepsilon_{2t} \tag{2}$$

$$\Delta Z_t = \gamma_3 + \gamma_z \theta_{t-1} + \sum_{i=1}^{r_3} \alpha_{3i} \Delta X_{t-i} + \sum_{i=1}^{s_3} \beta_{3i} \Delta Y_{t-i} + \sum_{i=1}^{k_3} \gamma_{3i} \Delta Z_{t-i} + \varepsilon_{3t} \quad (3)$$

The variables *X*, *Y*, and *Z* above represent the various U.S. and Canadian interest rates and business cycle activity proxy variables. Since only cointegrated variables are employed in a VECM, the stability properties of all candidate variables for the VECM first were tested. Variables found nonstationary in levels, but stationary in first differences, subsequently were tested for cointegration; hence, only cointegrated variables were employed in the estimation of a VECM.

Three Granger Causality Tests

The one-period lagged error term, θ_{t-1}, is one of the right-hand side variables in all three equations of the VECM model. The variable, θ_{t-1}, was constructed as a vector of values, based on the estimated cointergrating equation by plugging the data values of the variables X, Y, and Z for the entire sample period into the estimated cointegration equation. [9]

Three different Granger causality tests were performed for each equation[10]. The first test was a *t*-test on the significance of the coefficient of θ_{t-1}, for long-run causality. A statistically significant coefficient of θ_{t-1} indicated that, if the variables deviated from their long-run equilibrium values, then existing forces in the system (captured by θ_{t-1}) would restore the variables to their long-run equilibrium values.

The second Granger causality test was a joint test on the coefficients of all the lagged differences in the equation for each of the right-hand side variable. This test was for short-run causality, since the coefficients of the included lagged differences of each right-hand side variable captured the short-run dynamic adjustments of the system. A Wald (*F*-test) was used to determine whether the included lagged differences for each right-hand side variable belonged in the equation.

The third test was a test for overall causality. It was a test on the joint significance of the coefficient of θ_{t-1} and the coefficients of all the lagged differences of each relevant right-hand side variable grouped with the coefficient of θ_{t-1}. All three tests were illustrated by considering equation (1). A test for long-run non-causality was carried out by testing H_0: $\alpha_X = 0$. A rejection of the null hypothesis constituted evidence of long-run causality, meaning that the right-hand side variables, *Y* and *Z*, jointly caused the left-hand side variable, *X*[11]. A test for short-run non-causality from *Y* to *X* was stated by testing whether the coefficients of the lagged differences of *Y* were jointly equal to zero.

$$H_0: \quad \beta_{11} = \beta_{12} = \beta_{13} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = \beta_{1S_1} = 0$$

(4)

Rejection of the null hypothesis constituted evidence of short-run causality from *Y* to *X*. Similarly, a test for short-run non-causality from *Z* to *X* was performed by setting all the coefficients of the lagged differences of *Z* equal to zero.

$$H_0: \quad \gamma_{11} = \gamma_{12} = \gamma_{13} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots = \gamma_{1k_1} = 0$$

(5)

A test for overall non-causality also was performed. This test was carried out by testing the null hypothesis that the coefficient of θ_{t-1} and the coefficients of the lagged differences of each relevant right-hand side variable were jointly equal to zero. For example, based on equation (1), the following null hypothesis was tested for overall non-causality from *Y* to *X*.

$$H_0: \quad \alpha_X = \beta_{11} = \beta_{12} = \beta_{13} = \dots\dots\dots = \beta_{1S_1} = 0 \tag{6}$$

Lastly, the following null hypothesis below tested for statistical evidence of overall non-causality from *Z* to *X*.

$$H_0: \quad \alpha_X = \gamma_{11} = \gamma_{12} = \gamma_{13} = \dots\dots\dots = \gamma_{1k_1} = 0 \tag{7}$$

Analogous tests for long-run, short-run, and overall non-causality were performed in equations (2) and (3).

Unit Root Tests

Unit root tests were performed by employing both the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests. The two tests were carried out with a constant, and with a constant and a trend. To assure that the error term was a white noise, an optimum number of lagged differences were included in the test equation for the ADF test.[12] The regression equation for the ADF unit root test for a variable, X_t, is given below

$$\Delta X_t = \beta_0 + \beta_1 t + \beta_2 X_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta X_{t-i} + \varepsilon_t \tag{8}$$

where, β_0, β_1, β_2, φ_1, $\varphi_2 \dots \varphi_k$ are parameters to be estimated and ε_t is the error of the regression.[13]

According to the unit root results based on the U.S. data sets, all variables possessed the required stability properties, that is, they are non-stationary in levels, but stationary in first differences. In a small number of cases, however, there were ambiguities. In these few cases the *p*-value of the test falls in the *inconclusive* range between 0 and .1. Unit root test results for the first differences indicated that all variables were stationary. The Canadian unit root results were similar to those of the U.S. These results allowed the researchers to proceed with the cointegration test. The unit root results can be requested from the corresponding author.

Estimated Trivariate VECMs for U.S.: 1959:02-2005:01

The Johansen (1991; 1995) cointegration test was performed among the U.S. variables, ln*dpi*, r_{tb10}, and r_{ff}. According to both λ_{trace} and λ_{max} statistics in Table 1, evidence exists of at least one cointegrating vector at any plausible value of significance level, α.

Table 1. *Johansen Cointegration Test Between U.S. Monthly Variables*

H_0	Eigenvalue	λ_{max}	Critical Value at 5%	*p*-value	λ_{trace}	Critical Value at 5%	*p*-value
$r = 0$	0.08	46.31	25.82	0.00	76.28	42.92	0.00
$r \leq 1$	0.05	27.41	19.39	0.00	29.96	25.87	0.01
$r \leq 2$	0.00	2.56	12.52	0.92	2.56	12.52	0.92

A trivariate VECM was estimated utilizing the three variables r_{ff}, r_{tb10}, and ln*dpi*. Equation (9), below, is the estimated cointegration equation of the U.S. variables.[14]

$$\ln dpi = .083908r_{tb10} - .011030r_{ff} + .006026\text{Trend} + 5.385420 + \theta_t \text{(Model 4, 6 lags)} \quad (9)$$

The estimated cointegrating equation (9) was plausible since the proxy variable for nominal national income, ln*dpi*, was negatively related to the r_{ff} and positively related to the r_{tb10}. The negative relationship between r_{ff} and ln*dpi* showed that the Fed can increase (decrease) national income by decreasing (increasing) r_{ff}. Nonetheless, nominal national income was positively related to r_{tb10}. When income rose during expansions, long-term nominal interest rates increased. Three explanations are provided for this relation. First, the long-term nominal bond yield increased during expansionary periods because higher expected inflation raises the inflation premium. Second, the increase in money demand during expansionary periods raises all interest rates. The opposite occurs during recessionary periods. Lastly, an increase in the supply of bonds to finance projects during expansionary periods reduces the price of bonds and automatically increases bond yields, that is, the long-term interest rate. It is theoretically possible, however, for the interest rate to remain unchanged or even to decline.

Table 2. Estimated VECM for U.S. Monthly Data 1959:02 – 2005:01 With One Cointegrating Vector

Dependent Variable	C	θ_{t-1}	$\sum_{i=1}^{r_1} \Delta \ln dpi_{t-i}$	F_1	$\sum_{i=1}^{s_1} \Delta r_{tb10_{t-i}}$	F_2	$\sum_{i=1}^{k_1} \Delta r_{ff_{t-i}}$	F_3	
Δln*dpi*	0.01 (9.4)***	-0.01 (-5.5)***	-0.43 [6.3]***	8.85***	0.00 [1.56]	7.14***	0.00 [1.39]	5.15***	(10)
Δr_{tb10}	-0.10 (-2.8)***	0.41 (3.03)***	16.91 [2.28]**	2.4**	0.29 [18.2]***	16.5***	-0.09 [3.14]***	3.83***	(11)
Δr_{ff}	-0.17 (2.48)***	0.59 (2.32)**	27.64 [2.39]**	2.26**	0.63 [12.14]***	10.62***	-0.05 [13.11]***	11.83***	(12)

***, **,* denote significance at 1%, 5%, and 10% levels, respectively.
Note. The figures in parentheses and brackets are *t* and *F* statistics, respectively.

According to equation (10) of the estimated VECM, statistical evidence of long-run causality existed from r_{ff} and r_{tb10} to ln*dpi*, meaning that the two interest rates jointly caused ln*dpi*. The evidence was supported at the 1% significance level as indicated by the relatively high negative *t*-value of the θ_{t-1} coefficient of -5.5. An increase in r_{tb10}, assuming ln*dpi* and r_{ff} remained constant, would result in a negative value of θ_{t-1} according to cointegrating equation (9). A negative θ_{t-1} would increase ln*dpi*. This was supported by equation (10) of the VEC model, where the coefficient of θ_{t-1} was negative and statistically significant. Exactly the opposite occurred if we assumed that r_{ff} increases and ln*dpi* and r_{tb10} were held constant. In this case, as seen from equation (9), θ_{t-1} would be positive. A positive value of θ_{t-1}, multiplied by the negative coefficient of θ_{t-1}, as shown in equation (10), would lead to a reduction of ln*dpi*. These findings indicated that the estimated cointegrating equation and the empirical results of the estimated VEC model were consistent. Nominal ln*dpi*, a proxy for nominal GDP, was positively related to the long-term interest rates, r_{tb10}, and negatively related to federal funds rate, r_{ff}.

No statistical evidence existed for short-run causality from r_{tb10} to ln*dpi*. This is shown by the low *F*-value of 1.56 appearing in brackets below the summation term of $r_{tb10.}$ Each summation term consists of the sum of the coefficients of six lagged differences that are compacted to facilitate the presentation of the model. Likewise, there was no statistical evidence of short-run causality from r_{ff} to ln*dpi*, as indicated by the low *F*-value of 1.39 shown in brackets below the summation term of r_{ff}. Statistical evidence of overall causality from r_{tb10} to ln*dpi* was supported at the 1% level of significance indicated by the high *F*-value of 7.14 under column F_2. Similarly, statistical evidence of overall causality from r_{ff} to ln*dpi* was supported at the 1% significance level, as indicated by the *F*-value of 5.15 in column F_3 in equation (10).

Long-run, short-run, and overall, Granger causality was strongly supported from r_{ff} and ln*dpi* to r_{tb10} in equation (11). Lastly, from the estimated equation (12), statistical evidence exists for long-run, short-run, and overall Granger causality from ln*dpi* and r_{tb10} to r_{ff}. These empirical results indicate that the Fed reacted to changes in ln*dpi*, a proxy for the nominal GDP, and to long-term interest rates by changing r_{ff}. This Fed reaction constitutes a countercyclical monetary policy that contributed to the formation of a stable relationship between the three variables, ln*dpi*, r_{ff}, and r_{tb10}.

The meaning of these results is that the Fed, by controlling r_{ff}, first affects the long-term bond interest rate, and, indirectly, national income. This finding provided evidence that the Fed was effective in achieving its goals, with reference to nominal GDP in the long-run. Such evidence does not imply that the Fed, by changing the r_{ff}, was able to affect ln*dpi* in the short-run. This result was inferred from equation (10) by observing the absence of statistical evidence for short-run causality from r_{ff} to ln*dpi*.

Two Alternative Estimated VECMs for the U.S. Economy

The VECM also was re-estimated for the same period 1959:02-2005:01, using the monthly variables r_{ff}, r_{tb10}, and ln*ip*, i.e., by replacing the ln*dpi* with ln*ip*, the natural logarithm of industrial production, a proxy for real output. The empirical results based on this model, shown in Tables 3 and 4, were consistent with the results of the model discussed in equations (9)-(12). A difference, nonetheless, exists on the coefficient of θ_{t-1} in equation (16) where r_{ff} appears as a left-hand side variable. In this equation θ_{t-1} has the theoretically correct expected sign (positive), but it was statistically insignificant. This implies that the Fed was not reactive to changes in real economic activity as the latter was measured with ln*ip*, a proxy for real output.

Table 3. *Johansen Cointegration Test Between U.S. Monthly Variables*

H_0	Eigenvalue	λ_{max}	Critical Value at 5%	*p*-value	λ_{trace}	Critical Value at 5%	*p*-value
$r = 0$	0.117	68.089	22.300	0	88.080	35.193	0
$r \leq 1$	0.030	16.606	15.892	0.039	19.990	20.262	0.054
$r \leq 2$	0.006	3.384	9.165	0.511	3.384	9.165	0.511

$$\ln ip = .648379 r_{tb10} - .653492 r_{ff} + 4.508248 \text{ (Model 2, 6 lags)} \quad (13)$$

Table 4. *Estimated VECM for U.S. Monthly Variables 1959:02 – 2005:01*

Dependent Variable	θ_{t-1}	$\sum_{i=1}^{r_1} \Delta \ln ip_{t-i}$	F_1	$\sum_{i=1}^{s_1} \Delta r_{tb10_{t-i}}$	F_2	$\sum_{i=1}^{k_1} \Delta r_{ff_{t-i}}$	F_3	
Δlnip	-0.002 (-7.1)***	0.250 [6.3]***	27***	-0.001 [1.58]	5.30	0.005 [2.46]**	8.09***	(14)
Δr_{tb10}	0.03 (3.08)***	-7.8000 [2.86]***	2.9***	0.230 [14.4]***	16.42***	-0.150 [3.27]***	3.60***	(15)
Δr_{ff}	0.009 (.45)	17.600 [2.58]**	2.87***	0.570 [11.38]***	9.76	-0.110 [12.04]***	10.35***	(16)

***, **,* denote significance at 1%, 5%, and 10% levels, respectively.

Note. The figures in parentheses and brackets are *t* and *F* statistics, respectively.

Based on a U.S. quarterly data set for the period 1957:Q1-2005:Q4 consisting of the variables r_{ff}, r_{tb10}, and the natural logarithm of real GDP (ln*rgdp*), monetary policy was found to be effective in positively influencing ln*rgdp* as shown by the statistically significant coefficients of θ_{t-1} in equation (18) in Table 6. The reaction of the Fed to changes in real economic activity, however, was unexpected. According to these results, monetary policy is destabilizing as can be seen by the negative coefficient of the lagged error term, θ_{t-1}, in equation (20) of the estimated VEC model. If ln*rgdp* increases above its long-run equilibrium value based on the cointegrating equation (17), it will lead to a positive value of θ_{t-1}. A positive value of θ_{t-1}, multiplied by its negative coefficient (-0.058), will result in a negative r_{ff}, indicating that the Fed will reduce r_{ff} during an expansionary period. This result indicated a destabilizing U.S. monetary policy in reference to real GDP. Such finding should be a major concern to monetary authorities, but should not be a surprise as central banks did not respond to changes to real output, because this is not known when monetary policy is conducted.

Table 5. *Johansen Cointegration Test Between U.S. Quarterly Variables*

H_0	Eigenvalue	λ_{max}	Critical Value at 5%	*p*-value	λ_{trace}	Critical Value at 5%	*p*-value
$r = 0$	0.204	42.583	17.797	0	55.236	24.276	0.00
$r \leq 1$	0.055	10.503	11.225	0.067	12.653	12.321	0.044
$r \leq 2$	0.011	2.150	4.130	0.168	2.150	4.130	0.168

$$\ln rgdp = 3.081401 r_{tb10} - 2.741690 r_{ff} \text{ (Model 1, 8 lags)} \quad (17)$$

Table 6: *Estimated VECM for U.S. Quarterly Variables: 1957:Q1 – 2005:Q4*

Dependent Variable	θ_{t-1}	$\sum_{i=1}^{r_1} \Delta \ln rgdp_{t-i}$	F_1	$\sum_{i=1}^{s_1} \Delta r_{tb10t-i}$	F_2	$\sum_{i=1}^{k_1} \Delta r_{fft-i}$	F_3	
Δlnrgdp	0.0001 (0.57)***	0.873 [8.73]***	17.895***	0.004 [0.52]	0.503	-0.011 [5.13]***	4.82***	(18)
Δr_{tb10}	0.032 (2.97)**	-13.546 [2.74]***	2.711***	-0.410 [3.68]***	4.253***	0.225 [2.55]**	4.20***	(19)
Δr_{ff}	-0.058 (-3.02)**	27.521 [3.56]***	3.436***	-0.387 [4.42]***	4.972***	0.849 [3.63]***	3.39***	(20)

***, **,* denote significance at 1%, 5%, and 10% levels, respectively.
Note. The figures in parentheses and brackets are t and F statistics, respectively.

It is possible that one or more structural break may have taken place during the sample period. One such structural break could have occurred during the period of October 1979 to October 1982 when the Fed abandoned targeting the federal funds rate and focused on unborrowed reserves. To allow for possible structural break during the 1979-1982 period, the study estimated two VECMs for the subperiods before and after the reserve targeting period during the Paul Volcker Fed presidency. The first subsample was for 1959:02-1979:10 and the second was for 1982:10-2005:01. The two estimated VECMs did not indicate substantial differences from the estimated VECM based on the entire sample. These results raised confidence for the validity of the results based on the entire sample. Sims and Zha (2006) estimated a multivariate model that identified monetary policy and allowed for regime switching in coefficients and variances. The empirical results of the dynamic simultaneous equation model of Sims and Zha (2006) indicated that their model of best fit suggests no change in the coefficients, but a change in the variance. This result allowed combining the two samples into one, which also included the subperiod when unborrowed reserves targeting was exercised by the Fed.

Estimated VECM For The Canadian Monthly Data Set:1975:01–2005:02

The Johansen cointegration test was performed on the Canadian variables, natural logarithm of industrial production (ln*ip*), the 10-year government bond yield (r_{gb10}), and the overnight rate (r_{ov}). The ln*ip* was a proxy variable for real economic activity, r_{gb10} was the Canadian long-term government bond yield interest rate, and r_{ov} was the monetary policy variable controlled by the BOC equivalent to the r_{ff}. According to both λ_{trace} and λ_{max} statistics, evidence existed for exactly one cointegrating vector as shown in Table 7 below.

Table 7. *Johansen Cointegration Test*

H_0	Eigenvalue	λ_{max}	Critical Value at 5%	*p*-value	λ_{trace}	Critical Value at 5%	*p*-value
$r = 0$	0.09	32.19	17.80	0.00	37.07	24.28	0.00
$r \leq 1$	0.01	4.26	11.23	0.59	4.88	12.32	0.58
$r \leq 2$	0.00	0.62	4.13	0.49	0.62	4.13	0.49

Since the three variables are cointegrated, a trivariate VECM was estimated. This model is shown below in equations (21)-(24). The estimated cointegrating vector is shown below in equation (21).

$$\ln ip = 2.391436\ r_{gb10} - 1.983475\ r_{ov} + \theta_t \text{ (model 1, 6 lags)} \tag{21}$$

The three Canadian variables were related in a similar way as the three U.S. variables were. This is revealed from the cointegrating equation (21) above. In this equation, the proxy variable for the real business cycle, ln*ip*, is positively related to the long-term interest rate, r_{gb10}, and negatively related to r_{ov}, which is similar to the relationship supported by the US model.

Table 8. *Estimated VECM for Canadian Monthly Data*

Dependent Variable	θ_{t-1}	$\sum_{i=1}^{r_1} \Delta \ln ip_{t-i}$	F_1	$\sum_{i=1}^{s_1} \Delta r_{gb10\,t-i}$	F_2	$\sum_{i=1}^{k_1} \Delta r_{ov\,t-i}$	F_3	
Δlnip	-0.00 (-3.7)***	0.12 [4.60]***	[7.77]***	-0.01 [3.93]***	[5.58]***	0.01 [1.72]	[3.83]***	(22)
Δr_{gb10}	0.03 (3.50)***	14.15 [2.78]**	[3.04]***	0.06 [2.04]*	[3.44]***	-0.11 [1.81]*	[3.06]***	(23)
Δr_{ov}	-0.03 (-1.45)	20.98 [1.73]	[2.76]***	2.21 [8.68]***	[8.83]***	-0.82 [5.51]***	[8.88]***	(24)

***, **,* denote significance at 1%, 5%, and 10% levels, respectively.
Note. The figures in parentheses and brackets are t and F statistics, respectively.

Equation (22) of the estimated Canadian VECM supports long-run Granger causality originating from r_{ov} and r_{gb10} to ln*ip* at 1% significance level. This result implies that the BOC affected ln*ip*. Likewise, strong evidence exists for short-run and overall Granger causality, from r_{gb10} to ln*ip*. However, no statistical evidence was found for short-run causality from r_{ov} to ln*ip*. These results imply that the BOC was effective in influencing output (ln*ip*) in the long run. Nevertheless, the BOC cannot affect output in the short-run, since it takes several months for businesses to adjust production in response to monetary and financial incentives.

Statistical evidence for long-run Granger causality was supported from ln*ip* and r_{ov} to r_{gb10}, as shown in equation (23). The two variables jointly affected r_{gb10}. Short-run and overall causality also was supported from ln*ip* and r_{ov} to r_{gb10}.

Lastly, according to equation (24), long-run causality was not statistically supported from ln*ip* and r_{gb10} to r_{ov}. Since the coefficient of θ_{t-1} was negative, it implied that the BOC reacted procyclically to changes in ln*ip*; this reaction, however was not statistically significant. Such an empirical result provided evidence that the BOC was not reactive to changes in real economic activity and to long-term interest rates. A similar result was found with the estimation of VECM for the U.S. economy, which also employed the ln*ip* as a proxy for real economic activity. We concluded that neither central bank responded correctly to changes in real economic activity, thus raising doubt in the effectiveness of the monetary policies of the two central banks in stabilizing their respective economies. Still, the BOC responded in the short run to changes in long-term interest rates as shown by the statistical evidence of both short and overall causality from r_{gb10} to r_{ov}. This response of the BOC is plausible because the BOC has immediate knowledge of the contemporaneous changes in the nominal long-term interest rate, but it has no such knowledge when real output changes.

Two Joint U.S. and Canadian VECMs.

To study possible effects of monetary policy of one country on the economy of the other, two trivariate VECMs were estimated using both U.S. and Canadian variables for the 1975:01-2005:02 period. One of the VECMs is presented in Table 9 in equations (25)-(28). This model employs the natural logarithm of Canada's industrial production, $\ln ip_c$, Canada's 10-year government bond yield, r_{gb10c}, and the US. federal funds rate, r_{ff}.[15] In this model, possible effects of US monetary policy on the Canadian economy were examined.

$$\ln ip_c = 3.946492 + 0.001930{*}trend + 0.008324{*}r_{gb10c} - 0.015151{*}r_{ff} + \theta_t \text{ (Model 4, 6 lags)} \quad (25)$$

This relation was consistent with increasing economic and financial integration of the two countries, and to the notion that the U.S. Fed affects economic activity in Canada. The index of industrial production in Canada is negatively related with r_{ff} and positively related with r_{gb10c}.

Table 9. Estimated VECM for Cross Canadian and U.S. Monthly Data

Dependent Variable	C	θ_{t-1}	$\sum_{i=1}^{r_a} \Delta \ln ip_{c_{t-i}}$	F_1	$\sum_{i=1}^{s_1} \Delta r_{gb10_{c_{t-i}}}$	F_2	$\sum_{i=1}^{k_1} \Delta r_{ff_{t-i}}$	F_3	
$\Delta \ln ip_c$	0.00 (1.93)*	-0.03 (-2.75)***	0.35 [5.56]***	6.03***	-0.01 [3.88]***	4.92***	0.00 [1.23]	2.32**	(26)
Δr_{gb10c}	-0.03 (-1.20)	0.89 (2.68)***	5.90 [1.49]	2.34**	-0.14 [2.23]**	2.83***	-0.01 [0.92]	1.89*	(27)
Δr_{ff}	-0.06 (-1.83)*	0.65 (1.39)	23.99 [4.93]***	4.43***	0.38 [5.47]***	5.17***	-0.26 [12.94]***	11.21***	(28)

***, **,* are significant at the 1%, 5%, and 10% levels, respectively.
Note. The figures in parentheses and brackets are t and F statistics, respectively.

According to equation (26) of the estimated trivariate model, there exists strong statistical evidence of long-run causality from r_{ff} and r_{gb10c} to $\ln ip_c$. Similarly, equation (27) provided strong statistical evidence of long-run causality from r_{ff} and $\ln ip_c$ to r_{gb10c}. These results indicated that the Fed affects both long-term interest rates and output in Canada. In equations (26) and (27), no evidence was seen for short-run causality from r_{ff} to $\ln ip_c$ and r_{gb10c}, respectively. This finding suggests that although the Fed affected both interest rates and production in Canada in the long-run, in the short-run the Fed did not affect $\ln ip_c$ or r_{gb10c}. Frankel, Schmukler, and Serven (2004) found that international interest rates, set by a large country, affect a small country's interest rates regardless of the choice of the exchange rate regime.

Lastly, equation (28) did not provide evidence for long-run causality from lnip_c and r_{gb10c} to r_{ff}. The interpretation of this result was that the Fed did not react by changing the r_{ff} in response to changes in Canadian production and interest rates. However, short-run and overall causality appeared in equation (28) from r_{gb10c} and lnip_c to r_{ff}. This result should not be interpreted that the Fed was reacting to changes in Canadian lnip_c and r_{gb10c}. The Fed, instead, responded to changes in the corresponding U.S. variables, that is, the r_{tb10us} and lnip_{us}, which correlated closely to the corresponding Canadian variables, since the business cycles of the two economies are synchronized, because the two countries are economically and financially integrated.

To examine for possible effects of Canadian monetary policy on the U.S. economy, a trivariate VECM was estimated. This model employed the natural logarithm of the U.S. industrial production, lnip_{us}, the U.S. long-term bond yield, r_{tb10us}, and the Canadian overnight market interest rate, r_{ov}. The estimated model is shown in equation (29) and Table 10 in equations (30)-(32).

$$\ln ip_{us} = .019376 r_{tb10us} - .038747 r_{ov} + .001569 Trend + 4.237393 \text{ (Model 4, 6 lags)} \quad (29)$$

Cointegrating equation (29) is similar to the cointegrating equations of all other estimated VECMs. This equation indicates that lnip_{us} was positively related to r_{gb10us} and negatively to r_{ov}. The latter result should not be interpreted that the BOC, by changing r_{ov}, affected output in the U.S. This result arose because r_{ov} and r_{ff} were closely correlated.

Table 10. *Estimated VECM for Cross U.S. and Canadian Monthly Data*

Dependent Variable	C	θ_{t-1}	$\sum_{i=1}^{r_1} \ln ip_{us_{t-i}}$	F_1	$\sum_{i=1}^{s_1} r_{tb10_{us_{t-i}}}$	F_2	$\sum_{i=1}^{k_1} r_{ov_{t-i}}$	F_3	
$\Delta \ln ip_{us}$	0.00 (4.05)	-0.02 (-4.83)	0.34 [2.27]**	11.01***	0.00 [3.50]***	6.64***	0.00 [0.43]	4.45***	(30)
Δr_{tb10us}	-0.03 (-1.39)	0.32 (1.39)	8.07 [4.02]***	3.47***	0.19 [11.28]***	10.03***	-0.05 [1.10]	1.13	(31)
Δr_{ov}	-0.08 (-1.09)	-0.15 (-0.19)	32.78 [1.58]	1.68	2.20 [7.70]***	6.64***	-0.80 [6.47]***	7.05***	(32)

***, **,* are significant at the 1%, 5%, and 10% levels, respectively.
Note. The figures in parentheses and brackets are *t* and *F* statistics, respectively.

According to the estimated VECM above, no statistical evidence existed for long-run causality in any of the three equations. According to equation (30), r_{ov} and r_{tb10} did not Granger cause lnip_{us}. This result suggests that Canadian monetary policy did not influence U.S. output. From equation (32) it can be seen that the coefficient of θ_{t-1} was statistically insignificant, which implied that the BOC did not respond to changes in the U.S. economic activity and in US interest rates. Such results are plausible, particularly if one considers the size of the Canadian economy in relation to the US economy.

Conclusions

It is concluded that both central banks were successful in influencing long-term interest rates and economic activity in their respective countries. The reaction of the two central banks to changes in real economic activity was unexpected, ranging from passive to procyclical. The latter depended on the output proxy employed in the VECMs. The U.S. monetary policy was found effective in influencing nominal disposable personal income and to be correctly (countercyclically) reacting to changes in it.

Similar tests could not be carried out for Canada because Canadian nominal GDP and proxies for it either did not have the necessary stability properties, or they were not cointegrated with the two interest rates employed in the model. The BOC was effective in influencing real economic activity and long-run interest rates. The BOC, however, was found not to be reacting correctly to changes in real economic activity. Because central banks are primarily interested in controlling inflation, they mainly focus on nominal GDP. Since nominal and real GDP are not perfectly correlated, the results showed that the Fed applied countercyclical monetary policy in relation to nominal GDP, but unintended and destabilizing procyclical monetary policy in relation to real GDP, or output. Several economists criticized central banks for failing to intervene at the appropriate time and phase of the business cycle, when applying monetary policy. The results of this study suggested that a case can be made for this criticism; therefore further research on this issue is encouraged.

The cross-country effects of the two central banks' monetary policies on the other country's economy were found asymmetric. As was expected, the Fed's monetary policy was effective across the border to the Canadian economy, but Canada's monetary policy had no impact onto the U.S. economy.

Endnotes

[1] An increasing number of central banks starting in 1989 began also announcing a target inflation rate, whereas a few others ceased targeting and controlling monetary aggregates.
[2] This is a policy that the European Central Bank (ECB) has adopted for its repo rate since its inception in 1998.
[3] See, for example, Cook and Hahn (1989), and Garfinkel and Thornton (1995).
[4] See for example Campbell and Shiller (1991).
[5] This is a result of the optimizing behavior of investors who diversify their portfolios by holding securities of different maturities (Rudebusch, 1995).
[6] The source of the Canadian data is the BOC's Web site: http://www.bankofcanada.ca.
[7] This short-term interest rate is mainly used by the BOC for the implementation of monetary policy. It is the rate at which financial institutions borrow funds overnight from one another in order to meet the reserve requirement. The BOC sets a target for r_{ov} and employs open market operations to maintain the market or effective r_{ov} close to target r_{ov}. It is the equivalent to the US r_{ff}.
[8] The error correction model was introduced by Phillips (1954), and Sargan (1964) and was popularized by David Hendry and a few other authors. See, for example Davidson and Hendry (1981) and Hendry and Richards (1983).
[9] The coefficients, α_x, β_Y, and γ_Z, are known as the speed of adjustment coefficients, because they capture the effect of the deviations of the three endogenous variables from their long-run equilibrium values onto each of the three endogenous variables.
[10] These tests follow Granger (1988).
[11] Because the three variables are cointegrated, their error term is a stationary variable. As a result, the *t*-ratio of the coefficients of θ_{t-1} follows an asymptotic standard normal distribution and a valid *t*-test can be performed. (See Stock and Watson, 1988.)

[12] The optimum number of lags was chosen according to Akaike (AIC) and Schwarz (SIC) information criteria. Consequently, the ADF test was performed four times.
[13] In equation (8), a unit root test is simply a *t*-test on the statistical significance of β_2, the coefficient of the one period lagged variable, $X_{t\text{-}1}$. This *t*-test is carried out using the MacKinnon (1996) critical values.
[14] Within the parenthesis next to equation (9), the employed cointegration model selected with *EViews 6* is listed along with the number of included lagged differences in the model.
[15] Subscripts *c* and *us* are used to denote whether the variable is for Canada or the US. These variables are exactly the same ones employed in the models discussed previously.

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