Asymmetric Adjustment In The Effects Of Monetary Policy On Output: Evidence In The USA And Canada Using A Cointegration Analysis.

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ABSTRACT

Using a set of cointegration and error correction models with Threshold Autoregressive (TAR) or Momentum Threshold Autoregressive (MTAR) asymmetric adjustment, we investigate whether the effects of monetary policy on output in the USA and Canada are asymmetric or not. Forty years of quarterly data on output, money supply, price of oil and interest rate for the USA and Canada obtained from the International Monetary Fund's International Financial Statistics CD-ROM were used for the different tests. Empirical results show that the effects of monetary policy on output are asymmetric in both countries. Furthermore, the impulse response functions indicate that the results are consistent with a dynamic asymmetry in the behavior of money supply movements in both countries.

INTRODUCTION

Recent US experience suggests that tight monetary policy slows the economy more than easy monetary policy accelerates the economy. The suggestion that monetary policy has such asymmetric is not altogether new.

Recent research has shown that the effects of money supply shocks on output are asymmetric: monetary contractions reduce output by more than monetary policy expansions raise output. A study by Cover (1992) found evidence that monetary policy has asymmetric effects. Using quarterly data beginning in 1948, Cover studied the effects of changes in M1 on output growth. He discovered that declines in money growth usually have a substantial and statistically significant effect on output. In contrast, he found that increases in money growth usually have a small and statistically insignificant effect on output. However, Cover's paper was not concerned with whether anticipated changes in the money supply affect output, rather only with whether positive and negative money-supply shocks have asymmetric effects. Subsequently, others have explored Cover's finding using different sample periods and different data. Delong and Summers (1988) in an earlier study found similar results using annual data. These authors found very similar results using the broader monetary aggregates, M2 and M3, which sometimes-as is the case recently-diverge from the narrower M1 aggregate. However, Weise (1999) using a Nonlinear Vector Autoregression Approach found that positive and negative monetary shocks have nearly symmetric effects. Ravn and Sola (1996) find that positive and negative monetary shocks have stronger effects during recessions than booms, although Evans (1986) finds no evidence for this type of asymmetry. Thoma (1994) finds that negative monetary shocks have stronger effects on output during high- growth periods than low-growth periods, while the effects of positive monetary shocks do not vary over the business cycle.

The significance of our study will stem from the improvement of the past studies by not assuming a linear and symmetric adjustment and by using the methods of unit-roots and cointegration with the possibility of asymmetric error-correction with threshold (either TAR or MTAR)

Empirical Method

A number of economic theories imply that monetary policy may have asymmetric effects. Morgan (1993) argues that asymmetry is a feature of many widely accepted economic models, including the standard Keynesian with "Keynesian" and "Classical" regions of the aggregate supply curve, the liquidity trap theory, credit constraint models, and menu cost models. Kandil (1995) points to asymmetric wage indexation and price adjustment as possible causes of asymmetric effects of monetary policy.

Karras' (1996) methodology is very similar to that of Cover (1992), and thus will be described briefly. The money supply process is described by the equation:

$$m_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} m_{t-i} + \sum_{i=1}^{n} \alpha_{2i} y_{t-i} + \sum_{i=1}^{n} \alpha_{3i} r_{t-i} + u_t \tag{1}$$

Where:

m is the money growth rate
y is the output growth rate;
r is the first difference of the interest rate;
The $\alpha' s$ are coefficients and
u is the money-supply shock.[1]

The output equation is originally specified as:

$$y_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} y_{t-i} + \sum_{i=1}^{n} \beta_{2i} o_{t-i} + \sum_{i=1}^{n} (\beta_i^+ u_{t-i}^+ + \beta_i^- u_{t-i}^-) + e_t \tag{2}$$

Where:

o is the growth rate of the real price of oil;
The $\beta' s$ are coefficients and
e is the output shock.

Oil prices have been included as a proxy for supply shocks.

Building upon the model used by Karras (1996) and Cover (1992), the following model will be used to test the asymmetric adjustments in monetary policy:

$$y_t = \beta_0 + \beta_1 m_t + \beta_2 o_t + \beta_3 r_t + \mu_t \tag{3}$$

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[1] Karras (1996) defined $u_t^+ = \max(u_t, 0)$ and $u_t^- = \min(u_t, 0)$ as the positive and negative money supply shocks respectively.

Where:

> *m* represents the logarithm of money supply;
> *o* is the logarithm of real price of oil;
> *r* represents the nominal interest rate (three-month treasury bill rate);
> and μ delineates the disturbance term.

In terms of Equation 3, if the output, the money supply, the real price of oil and the interest rate are all I (1) and the linear combination $y_t - \beta_0 - \beta_1 m_t - \beta_2 o_t - \beta_3 r_t = \mu_t$ is stationary, then the variables are cointegrated of order (1,1). The vector x_t is $(y_t, 1, m_t, o_t, r_t)'$ and the cointegrating vector β is $(1, -\beta_0, -\beta_1, -\beta_2, -\beta_3)$. According to Enders (1995), the system is in long-run equilibrium when $\beta x_t = 0$.

Equation 3 will be estimated for long-run relationship and for cointegration allowing for TAR and MTAR adjustment following Engle and Granger's (1987) methodology. The testing procedure is described in the following section.

THRESHOLD AND MOMENTUM MODELS OF COINTEGRATION

The Engle and Granger (1987) methodology as applied to the efficiency wage model begins by positing a long-run equilibrium relationship of the form given in equation (3).

The next step in the Engle and Granger procedure focuses on the OLS estimate of ρ in the following regression equation:

$$\Delta \mu_t = \rho \mu_{t-1} + \varepsilon_t \qquad (4)$$

Where the estimated regression residuals from (3) are used to estimate (4).

Rejecting the null hypothesis of no cointegration (i.e., accepting the alternative hypothesis $-2 < \rho < 0$) implies that the residuals in (4) are stationary with mean zero. As such, equation (3) is an attractor such that its pull is strictly proportional to the absolute value of μ_{t-1}. The change in μ_t equals ρ multiplied by μ_{t-1} regardless of whether μ_{t-1} is positive or negative.

The implicit assumption of symmetric adjustment is problematic if money-supply shock adjustment is asymmetric. A formal way to introduce asymmetric adjustment is to let the deviations from the long-run equilibrium in equation (3) behave as a Threshold Autoregressive (TAR) process. Thus, it is possible to replace (4) with:

$$\Delta \mu_t = I_t \rho_1 \mu_{t-1} + (1 - I_t) \rho_2 \mu_{t-1} + \varepsilon_t \qquad (5)$$

Where I_t is the Heaviside indicator such that:

$$I_t = \begin{cases} 1 \ if \ \mu_{t-1} \geq 0 \\ 0 \ if \ \mu_{t-1} < 0 \end{cases} \qquad (6)$$

Asymmetric adjustment is implied by different values of ρ_1 and ρ_2; when μ_{t-1} is positive, the adjustment is $\rho_1 \mu_{t-1}$, and if μ_{t-1} is negative, the adjustment is $\rho_2 \mu_{t-1}$. A sufficient condition for stationarity of $\{\mu_t\}$ is: $-2 < (\rho_1, \rho_2) < 0$. Moreover, if the $\{\mu_t\}$ sequence is stationary, the least squares of estimates of ρ_1 and ρ_2 have an asymptotic multivariate normal distribution if the value of the threshold is known (or consistently estimated). Thus, if the null

hypothesis $\rho_1 = \rho_2 = 0$ is rejected, it is possible to test for symmetric adjustment (i.e., $\rho_1 = \rho_2$) using a standard *F*-test. Since adjustment is symmetric if $\rho_1 = \rho_2$, the Engle-Granger test for cointegration is a special case of (5).

Since the exact nature of the non-linearity may not be known, it is also possible to allow the adjustment to depend on the change in μ_{t-1} (i.e. $\Delta\mu_{t-1}$) instead of the level of μ_{t-1}. In this case, the Heaviside indicator of (6) becomes:

$$I_t = \begin{cases} 1 \ if \ \Delta\mu_{t-1} \geq 0 \\ 0 \ if \ \Delta\mu_{t-1} < 0 \end{cases} \qquad (7)$$

Even though Hansen (1997) shows that setting the Heaviside indicator using $\Delta\mu_{t-1}$ can perform better than the specification using pure TAR adjustment, Enders and Granger (1998) and Enders and Siklos (2001) show that the series exhibits more "momentum" in one direction than the other. They call this model Momentum-Threshold Autoregressive (MTAR) model. Respectively, the *F*-statistics for the null hypothesis

$\rho_1 = \rho_2 = 0$ using the TAR specification of (6) and the MTAR specification of (7) are called Φ_μ and Φ_μ^*. As there is generally no presumption as to whether to use (6) or (7), the recommendation is to select the adjustment mechanism by a model selection criterion such as the Akaike Information Criterion (*AIC*).

If the errors in equation (5) are serially correlated, it is possible to use an augmented threshold model for the residuals. In this circumstance, equation (5) is replaced by:

$$\Delta\mu_t = I_t \rho_1 \mu_{t-1} + (1 - I_t)\rho_2 \mu_{t-1} + \sum_{i=1}^{P} \beta_i \Delta\mu_{t-i} + \varepsilon_t \qquad (8)$$

The distributions of Φ_μ and Φ_μ^* depend on the number of observations, the number of lags p in equation (8) and the number of variables in the cointegrating relationship. Enders and Siklos (2001) report critical values using cointegrating vectors containing up to three variables. Since the model used in this study contains four variables in the cointegrating relationship, there was a need first to develop critical values for the four-variable case (see Appendix A for the method of developing the critical values)

DATA

The International Monetary Fund's International Financial Statistics provides the core data for the USA and Canada. Series on output, money supply, price of oil and interest rate are collected from 1960 through 2000 on a quarterly basis which yields 164 observations for each series. We use the Real Gross Domestic Product (RGDP) for output, the monetary aggregate M1 for money supply and the government bond yield (medium and/or long-term) for interest rate to test the asymmetric effects of money supply shocks on output.

IMPULSE RESPONSE FUNCTIONS

According to Enders (1995), the shape of the impulse response functions and the results of the variance decompositions can indicate whether the dynamic responses of the variables conform to theory. We shall examine different responses of productivity to capital shocks, employment (or unemployment) shocks and real wage shocks.

EMPIRICAL RESULTS

Results For The Test Of Stationarity

Since by definition cointegration necessitates that the variables be integrated of the same order, we pretested the variables for their order of integration. The Dickey-Fuller (DF) test and the Augmented Dickey-Fuller

(ADF) test are used to infer the number of unit roots (if any) in the output, money supply, price of oil and interest rate series for each country. Lag 8, which is determined by the Akaike Information Criterion, is used in the ADF test. Table 1 provides the summary of the findings. Both the DF and ADF tests fail to reject the null hypothesis (all the t-statistics are less than the DF critical values) of any of the variables. These findings suggest that the series are all I (1). As a result the series are non-stationary and we proceed by taking first differences of the series and test for cointegration.

RESULTS OF THE LONG RUN RELATIONSHIPS

We use OLS to estimate the long run relationships of the variables output, money supply, price of oil and interest rate as implied by Equation (1) above. The long run cointegrating equations for the USA and Canada are respectively as follow (the t-statistics are in parentheses):

USA:
$$y_t = 3.538 + 0.714m_t - 0.098o_t - 0.063r_t \tag{9}$$
$$(3.72) \quad (3.96) \qquad (-7.08) \quad (-3.84)$$

Canada:
$$y_t = 3.349 + 0.445m_t - 0.142o_t - 0.119r_t \tag{10}$$
$$(7.66) \quad (7.12) \qquad (-5.16) \quad (-3.37)$$

Economic theory predicts that the coefficients on the money supply variable should be positive and less than one. It predicts also that the coefficient on the price of oil and interest rate variables should be negative and less than one. As anticipated, all the cointegrating parameters in the above equations turn out to be consistent with the prediction of economic theory.

The cointegrating parameters of the variables are all statistically significant at conventional significance levels for both countries.

The residuals derived from equations 9 and 10 are used to proceed with the cointegration and asymmetric adjustment tests.

RESULTS OF THE COINTEGRATION AND ASYMMETRIC TESTS

To test for cointegration and asymmetry, we saved the residuals of the long-run relation equations (9 and 10) in the sequences $\{\mu_{1t}, \mu_{2t}\}$. For each type of asymmetry, we set the indicator function I_t according to Equation (6) or Equation (7) and estimated an equation in the form of Equation (8). The AIC was used to select the most appropriate lag length p and adjustment mechanism (i.e. TAR versus MTAR adjustment). The sample value of the F-statistic for the null hypothesis $\rho_1 = \rho_2 = 0$ was compared with the appropriate critical value reported in Table 2 and/or 3. If the alternative hypothesis is accepted (i.e., the null hypothesis of no cointegration is rejected), we then used Chan's (1993) methodology to find the consistent estimate of the threshold. After all, there is no reason to presume that the threshold is identically equal to zero. Once the threshold is properly estimated, we test for symmetric versus asymmetric adjustment (i.e., we test the null hypothesis $\rho_1 = \rho_2$) using the usual F-statistic.

Table 4 reports the estimated values for the ρ_i and the sample F-statistics for the null hypothesis $\rho_1 = \rho_2 = 0$ as well as the F-statistics for the null hypothesis $\rho_1 = \rho_2$ using the lag length and adjustment mechanism selected by the AIC. The lag length is selected such the Akaike Information Criterion is minimized. As such AIC selects 8 lags for both countries.

The estimated $\phi^{*}{}'s$ for the null hypothesis $\rho_1 = \rho_2 = 0$ are 9.83 and 9.45 respectively for the USA and Canada. The critical value reported in Table 3 at the 5% significance level with 150 observations and 8 lags is 9.10. As such, we reject the null hypothesis of a unit root in favor of stationarity with asymmetric adjustment in the USA and Canada.

The point estimates of the ρ_i suggest that negative deviations from the long-run equilibrium are eliminated much faster than positive deviations in Canada whereas in the USA positive deviations from the long-run equilibrium are eliminated much faster than negative deviations. Specifically in Canada, 11% of a negative deviation is eliminated within a quarter while 9% of a positive deviation is eliminated during the same time frame. In the USA, 38% of a positive deviation is eliminated within a quarter while 17% of a negative deviation is eliminated during the same time frame.

The F-statistics for asymmetric adjustment ($\rho_1 = \rho_2$) are given in Table 4. For the USA and Canada, the F-statistics (3.05 and 3.41 respectively) reject symmetric adjustment at 5% significance level in favor of asymmetric MTAR adjustment. According to Lutkepohl (1994) the coefficients of cointegration relations cannot be interpreted as elasticities; this is because the ceteris paribus cannot be meaningful. The error correction specifications can be more informative.

THE ERROR-CORRECTION REPRESENTATION: THE DYNAMIC ADJUSTMENT OF MONEY SUPPLY, REAL PRICE OF OIL AND INTEREST RATE

USA:

Having found evidence supporting asymmetric adjustment in the USA and using the long-run relationship implied in the Equation (9), the estimated error-correction equations assuming Momentum Threshold Autoregressive (MTAR) adjustment (with t-statistics in parentheses) are:

$$\Delta o_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \tag{11}$$
$$+0.5018 z_{t-1}^{+} + 0.06975 z_{t-1}^{-}$$
$$\quad (0.81) \qquad (1.03)$$

$$\Delta y_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \tag{12}$$
$$-0.0199 z_{t-1}^{+} - 0.0019 z_{t-1}^{-}$$
$$\quad (-1.83) \qquad (-0.86)$$

$$\Delta m_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \tag{13}$$
$$+0.0645 z_{t-1}^{+} + 0.1241 z_{t-1}^{-}$$
$$\quad (1.47) \qquad (2.59)$$

$$\Delta r_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \tag{14}$$
$$-0.0960 z_{t-1}^{+} + 0.1824 z_{t-1}^{-}$$
$$\quad (-0.40) \qquad (0.70)$$

Where:
$$z_t^{+} = I_t\left(y_t - 3.538 - 0.714 m_t + 0.098 o_t + 0.063 r_t\right)$$

$$z_t^- = (1 - I_t)(y_t - 3.538 - 0.714m_t + 0.098o_t + 0.063r_t)$$

I_t = Threshold Heaviside Indicator Function,

$A_{ij}(L)$ is a polynomial in the lag operator L, and the lag length is selected using the multivariate version of AIC, which selected 8 lags.

In Equation (12), the real output in the USA seems to adjust faster when there is a positive discrepancy from the long-run equilibrium than when there is a negative discrepancy. Specifically, the point estimates imply that the output adjusts by 2% of a positive deviation from long-run equilibrium, but by only 0.2% of a negative gap. The t-statistics imply that the coefficient on the positive error-correction term (i.e., z^+) is significant at conventional significance levels while the coefficient on the negative error correction term (i.e., z^-) is not. This finding suggests that the real output in the USA is more responsive to positive than negative deviations from the long-run equilibrium.

In equation (13) only the coefficient of the negative error-correction term (i.e., z^-) is significant at conventional significance levels whereas in the Equations (11 and 14) neither of the coefficients of the negative error-correction terms is significant at conventional significance levels. These findings suggest that the real price of oil and the interest rate in the USA are not responsive to discrepancies from the long-run equilibrium and that adjustments towards the long-run equilibrium are accomplished via changes in the money supply.

Canada:

Having found evidence supporting asymmetric adjustment in Canada and using the long run relationship implied in Equation (10), the estimated error-correction equations assuming Momentum Threshold Autoregressive adjustment (with t-statistics in parentheses) are:

$$\Delta o_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \qquad (15)$$
$$+0.1541z_{t-1}^+ - 0.3820z_{t-1}^-$$
$$\quad (0.51) \qquad\quad (-1.30)$$

$$\Delta y_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \qquad (16)$$
$$-0.0036z_{t-1}^+ - 0.0023z_{t-1}^-$$
$$\quad (-0.32) \qquad\quad (-1.93)$$

$$\Delta m_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \qquad (17)$$
$$+0.0147z_{t-1}^+ + 0.1913z_{t-1}^-$$
$$\quad (0.15) \qquad\quad (2.11)$$

$$\Delta r_t = A_{11}(L)\Delta o_{t-1} + A_{12}(L)\Delta y_{t-1} + A_{13}(L)\Delta m_{t-1} + A_{14}(L)\Delta r_{t-1} \qquad (18)$$
$$+0.0005z_{t-1}^+ - 0.009z_{t-1}^-$$
$$\quad (0.003) \qquad\quad (-0.06)$$

Where:

$$z_t^+ = I_t(y_t - 3.349 - 0.445m_t + 0.142o_t + 0.119r_t)$$
$$z_t^- = (1 - I_t)(y_t - 3.349 - 0.445m_t + 0.142o_t + 0.119r_t)$$

I_t = Threshold Heaviside Indicator Function,

A_{ij} (L) is a polynomial in the lag operator L, and the lag length is selected using the multivariate version of AIC, which selected 8 lags.

In Equation (16) the real output in Canada seems to adjust faster when there is a negative deviation from the long-run equilibrium than when there is a positive deviation. Specifically, the point estimates ρ_i imply that the real output adjusts by 0.2% of a negative discrepancy from the long-run equilibrium, but by only 0.4% of a positive deviation. The t-statistics imply that the coefficient on the negative error-correction term (i.e., z^-) is significant at conventional significance levels while the coefficient on the positive error-correction term (i.e., z^+) is not. This finding suggests that the real output in Canada is more responsive to negative deviations than positive deviations from the long-run equilibrium.

In Equation (17), only the coefficient of the negative error-correction term (i.e. z^-) is significant at conventional significance levels whereas in Equation (15 and 18) neither of the coefficients of the error-correction terms is significant at conventional significance levels. These results indicate that the price of oil and interest rate are not responsive to deviations from the long-run equilibrium and that adjustments toward long-run equilibrium are accomplished via changes in the money supply.

IMPULSE RESPONSE FUNCTIONS

We also investigate the dynamic adjustment of money supply, real price of oil, output and real interest rate using the Impulse Response Functions, which trace out the effect of an exogenous shock in one variable on the other variables in the system. We assume that the system is in long-run equilibrium and consider the impulse responses from a one-standard deviation shock obtained using Choleski decomposition with an ordering $o_t \rightarrow y_t \rightarrow m_t \rightarrow r_t$. The response of the real output to positive and negative shocks for the USA is given in Figure 1.

The upper panel of Figure 1 shows the response of output to the money supply shocks. The real output rises in a slow but steady pace up to the 15th quarter in response to a positive money supply shock then declines reverting back to the long-run equilibrium. In contrast, the real output falls steadily in response to a negative money supply shock with no sign of reverting back to the long-run equilibrium. It is quite evident that the effects of money supply shocks on output in the USA are asymmetric: a negative money supply shock produces a significantly larger response in output than its positive counterpart. Furthermore, the impact on output diminishes faster when there is a positive money supply shock than when there is a negative shock.

The middle panel of Figure 1 shows the response of output to real price of oil shocks. Following a unit negative real price of oil shock, the real output increases steadily up to the 12th quarter then decreases and reverts back to the long-run equilibrium by the 21st quarter. It reverts in sign afterwards. The real output declines steadily in response to a positive real price of oil shock. From this panel, the positive real price of oil brings about a seemingly larger response in output than its negative counterpart does. Moreover, the impact on output dwindles more quickly when there is a negative real price of oil shock than when there is a positive shock.

The lower panel of Figure 1 displays the response of output to interest rate shocks. The real output rises slowly up to the 9th quarter in response to a negative interest rate shock, then levels off between the 10th and 14th quarter and reverts back to the long-run equilibrium. In contrast, the real output declines steadily in response to a positive interest rate shock with no tendency to revert back to the long-run equilibrium. Asymmetric effects on output of the real price of oil shocks are visible in this panel: a positive interest rate shock produces a larger response in output than its negative counterpart does. However, the effects on output of a negative interest rate shock vanish more rapidly than that of a positive shock.

The response of the real output to positive and negative shocks for Canada is given in Figure 2. The upper panel of Figure 2 shows the response of the real output to money supply shocks. Following a unit positive money supply shock, the real output rises in a slow but steady pace without any tendency to revert back to the long-run

equilibrium after 24 quarters. Following a unit negative money supply shock, the real output declines steadily and did not revert back to the long-run equilibrium during the 25 quarters time frame. Figure 2 shows some asymmetric effects of the money supply on output: a negative money supply shock brings about a slightly larger response in output than its positive counterpart.

The middle panel of Figure 2 displays the response of the real output to real price of oil shocks. After an initial positive real price of oil shock, the real output decreases steadily up to the 13th quarter and then levels off between the 13th and 16th quarter. After the 16th quarter, the real output starts rising and by the 22nd quarter the effects of the shock are completely exhausted and the effect of real output becomes positive. After an initial negative real price of oil shock, the real output rises up to 12 quarters and seems to level off afterwards without reverting back to the long-run equilibrium. Overall, a negative real price of oil shock seems to have a much more definitive effect on output than a positive real price of oil shocks does.

The bottom panel of Figure 2 depicts the response of the real output to interest rate shocks. Following a unit negative interest rate shock, the real output rises up to 11 quarters and starts declining steadily reverting back to the long-run equilibrium. Following a positive interest rate shock, the real output decreases steadily without any tendency to revert back to the long-run equilibrium. The bottom panel of Figure 2 clearly shows asymmetric effects of the interest rate shock on output: a positive interest shock produces a significantly larger response in output as compared to its negative counterpart.

CONCLUSION AND POLICY IMPLICATIONS

This study investigates the asymmetric adjustment of monetary policy on output in the USA and Canada. Forty years of quarterly series on output, money supply, price of oil and interest rate for these two countries are obtained from the International Monetary Fund's International Financial Statistics CD-ROM. We use a cointegration analysis developed by Engle and Granger (1987) to test the effects of the monetary policy shocks on output in each country.

The Engle-Granger cointegration analysis finds that the variables are cointegrated, which is an indication of the existence for long-term equilibrium relationships between the output, money supply, price of oil and interest rate in both countries. The cointegrating parameters turn out to be consistent with the economic theory prediction. Moreover, they indicate that monetary policy seemingly has similar effects on output in the USA and in Canada. The asymmetric adjustment tests conclusively indicate that the effects of monetary policy on output are asymmetric in both countries.

The impulse response function indicates that the results are consistent with a dynamic asymmetry in the behavior of the money supply movements in both countries. Specifically, a negative money supply shock produces a significantly larger response in output as compared to its positive counterpart. Further, the error-correction representation reveals that the effects of negative money supply movements dwindle rather quickly in Canada. The results for a positive money supply change, however, do not. But for the USA, the error-correction representation reveals the opposite: the effects of positive money supply movements diminish rather rapidly. These results found in the USA and Canada are consistent with the findings of the studies of previous authors such as Karras (1996), Morgan (1993), Cover (1992) and Delong and Summers (1988).

These findings have interesting policy implications. Positive monetary shocks may constitute an inadequate policy during recessions in the USA and Canada, as their effect on output is statistically insignificant. In fact, they may also be counter-productive since asymmetry means that their effects will be mostly absorbed by prices requiring a more significant offsetting future monetary contraction. More generally, the optimal monetary policy under asymmetry will almost certainly be less activist as pointed out by Karras (1996) and as Cover (1992) notes, this result is 'Friedmanesque' as it counsels in favor of reducing uncertainty about the money supply process. On the other hand, negative monetary shocks may be used as an effective and adequate police tool to slow down the economy during booms as their effect on output is statistically significant. It is interesting to notice the impact of the negative monetary shock is persistent in both countries.

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APPENDIX A

In order to develop critical values that can be used to test for cointegration, we generated 50,000 random-walk processes of the following form:

$$x_{it} = x_{it-1} + v_{it} \tag{19}$$

Where $i = 1,\dots,4, and\ t = 1,\dots,T,$

For $T = 50, 100, 150, \cdots, 500$, sets of T normally distributed and uncorrelated pseudo-random numbers with standard deviation equal to unity were drawn to represent the $\{v_{it}\}$ sequences. Randomizing the initial values of $\{x_{it}\}$, the next T values of each were generated using equation (19). For each of the 50,000 series, the TAR and MTAR models given by (7 and 8) were estimated. Since the value of the threshold τ is typically unknown, for

each of the 50,000 replications, we used Chan's (1993) method for obtaining the consistent estimate of the threshold. For each estimated equation, we estimated ρ_1 and ρ_2 and recorded the F-statistics for the joint hypothesis $\rho_1 = \rho_2 = 0$. These F-statistics are called ϕ_μ for TAR specification and ϕ_μ^* for the MTAR specification. Tables 2 and 3 report the appropriate critical values for both ϕ_μ and ϕ_μ^* for the case of four variables in the cointegrating relationship for various values of sample sizes (T) and lag lengths p.

Table 1: Unit Root Test Results

	DF Test			ADF Test		
	Lag	t		Lag	AIC	t
USA						
rgdp	0	2.37		8	-443.55	-0.43
M1	0	0.84		8	-443.55	-1.34
rpo	0	-1.79		8	-443.55	-1.87
r	0	-1.53		8	-443.55	-2.38
Canada						
rgdp	0	-1.89		8	-246.13	0.29
M1	0	-1.87		8	-246.13	0.86
rpo	0	-1.80		8	-246.13	-1.98
r	0	-2.28		8	-246.13	-2.15

The Dickey Fuller (DF) critical values for T = 100 are –3.51, -2.89, -2.58, at 1%, 5% and 10% levels respectively.
Rgdp = Real output; m1 = money supply; rpo = real price of oil; r = interest rate.
ADF: Augmented Dickey Fuller

Table 2: Distribution for the F-Statistic for the Null Hypothesis rho 1 = rho 2, in the 4-variable case

T	LAGGED CHANGES											
	1 LAG			2 LAGS			3 LAGS			4 LAGS		
	90%	95%	99%	90%	95%	99%	90%	95%	99%	90%	95%	99%
TAR MODEL: ϕ_μ												
50	8.98	10.53	13.91	8.28	9.63	12.85	7.92	9.31	12.39	7.36	8.64	11.56
100	8.45	9.77	12.63	8.09	9.36	12.05	7.92	9.13	11.82	7.61	8.84	11.39
150	8.40	9.65	12.42	8.17	9.41	11.97	8.04	9.22	11.88	7.84	9.00	11.61
200	8.53	9.71	12.44	8.33	9.57	12.17	8.27	9.47	12.13	8.11	9.24	11.74
250	8.54	9.79	12.58	8.46	9.66	12.28	8.41	9.62	12.05	8.31	9.45	12.01
500	8.81	10.03	12.73	8.74	9.92	12.60	8.69	9.86	12.40	8.70	9.92	12.44
MTAR MODEL: ϕ_μ^*												
50	9.85	11.47	14.91	9.05	10.53	13.81	8.75	10.18	13.58	8.14	9.53	12.58
100	9.55	10.89	13.81	9.12	10.46	13.33	8.91	10.21	13.03	8.62	9.84	12.66
150	9.28	10.63	13.44	9.01	10.28	12.99	8.86	10.08	12.76	8.62	9.88	12.46
200	9.19	10.46	13.17	8.98	10.28	13.04	8.83	10.07	12.68	8.72	9.95	12.50
250	9.10	10.36	13.09	8.96	10.17	12.90	8.87	10.16	12.82	8.72	9.90	12.54
500	9.05	10.30	12.99	8.99	10.24	12.81	8.92	10.18	12.76	8.80	10.03	12.54

Table 3: Distribution for the F-Statistic for the Null Hypothesis rho 1 = rho 2, in the 4-variable case

T	LAGGED CHANGES											
	5 LAGS			6 LAGS			7 LAGS			8 LAGS		
	90%	95%	99%	90%	95%	99%	90%	95%	99%	90%	95%	99%
TAR MODEL: ϕ_μ												
50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
100	7.45	8.60	11.15	7.19	8.29	10.71	7.02	8.15	10.57	6.80	7.89	10.22
150	7.65	8.80	11.26	7.48	8.60	10.91	7.40	8.56	10.95	7.19	8.29	10.66
200	7.95	9.13	11.65	7.78	8.93	11.38	7.76	8.91	11.37	7.61	8.71	11.14
250	8.22	9.40	12.01	8.03	9.19	11.71	8.00	9.13	11.68	7.87	8.96	11.34
500	8.63	9.83	12.36	8.53	9.73	12.20	8.49	9.67	11.98	8.48	9.66	12.12
MTAR MODEL: ϕ_μ^*												
50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
100	8.40	9.66	12.25	8.17	9.36	12.08	8.05	9.26	11.85	7.75	8.91	11.52
150	8.47	9.67	12.34	8.29	9.46	12.07	8.16	9.33	11.93	7.97	9.10	11.66
200	8.60	9.82	12.39	8.42	9.60	12.23	8.32	9.51	12.05	8.19	9.35	11.81
250	8.63	9.84	12.40	8.53	9.76	12.20	8.45	9.62	12.12	8.33	9.49	12.02
500	8.77	10.04	12.65	8.72	9.87	12.43	8.72	9.88	12.41	8.58	9.78	12.19

Note: NA indicates not available. We do not provide the critical values for the model with more than 5 lags using only 50 observations.

Table 4: The Estimated Adjustment Equations

Industries	ρ_1	ρ_2	ϕ^a	$\rho_1 = \rho_2^b$	$Lags^c$	AIC	Flag
USA	−0.38	−0.17	9.83**	3.05**	8	−443.55	MTAR
	(-3.39)	(-3.31)					
Canada	−0.09	0.11	9.45**	3.41**	8	−246.13	MTAR
	(-2.68)	(1.00)					

[a] *Entries* are the sample values of ϕ_μ or ϕ_μ^* for the adjustment process shown in column 8.

*,**,*** *indicate* significance level at 10, 5 and 1% levels respectively.
t-statistics are in parentheses.

[b] *Entries* in this column are the values for the sample F-statistic for the Null Hypothesis that the adjustment equations are equal.

[c] *Entries* in this column are the number of lags of $\{\Delta\mu_t\}$ selected by AIC.
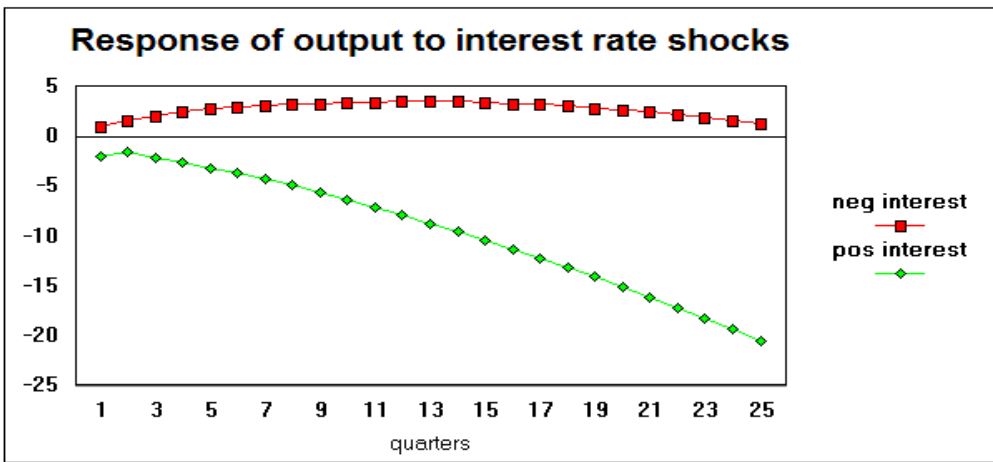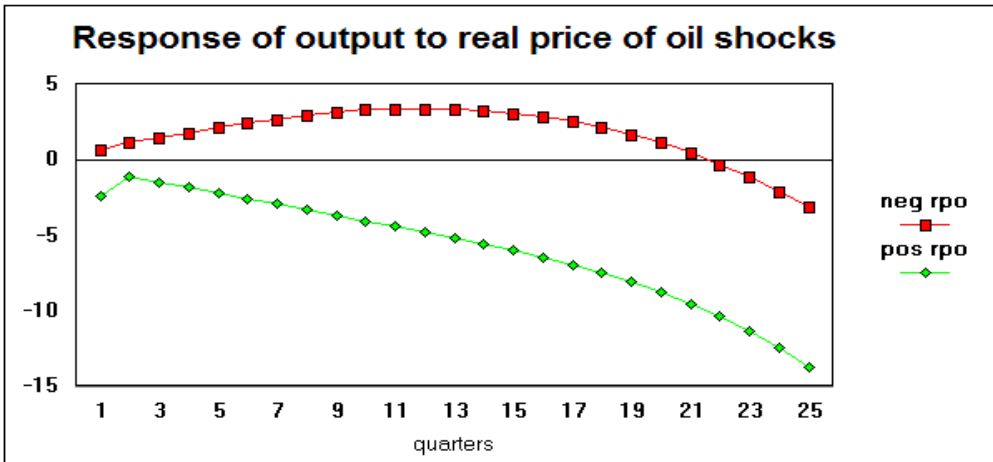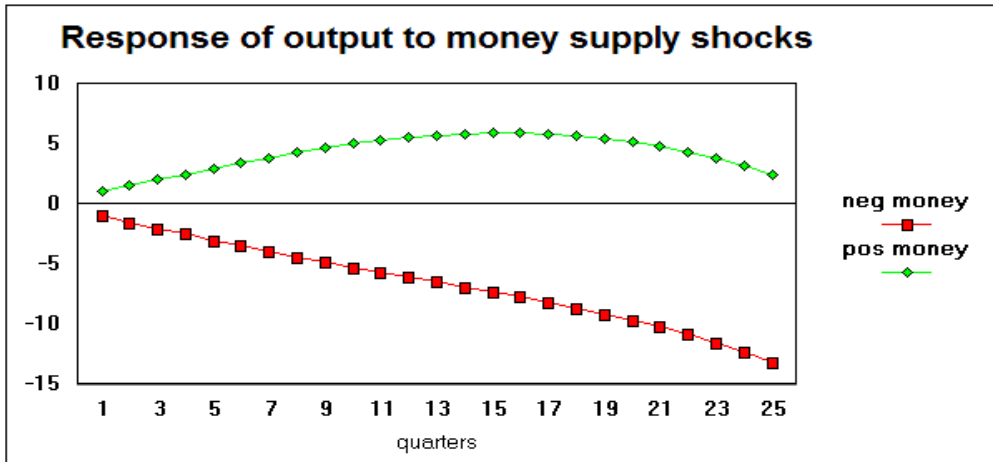
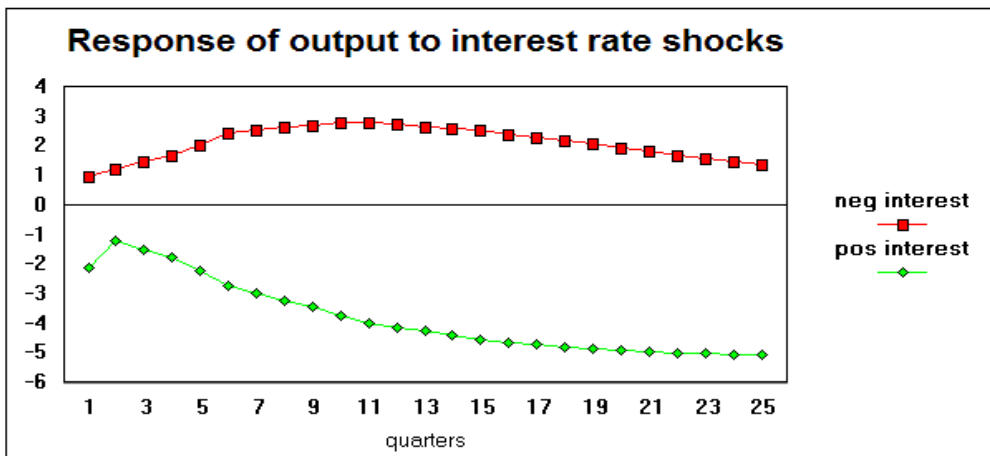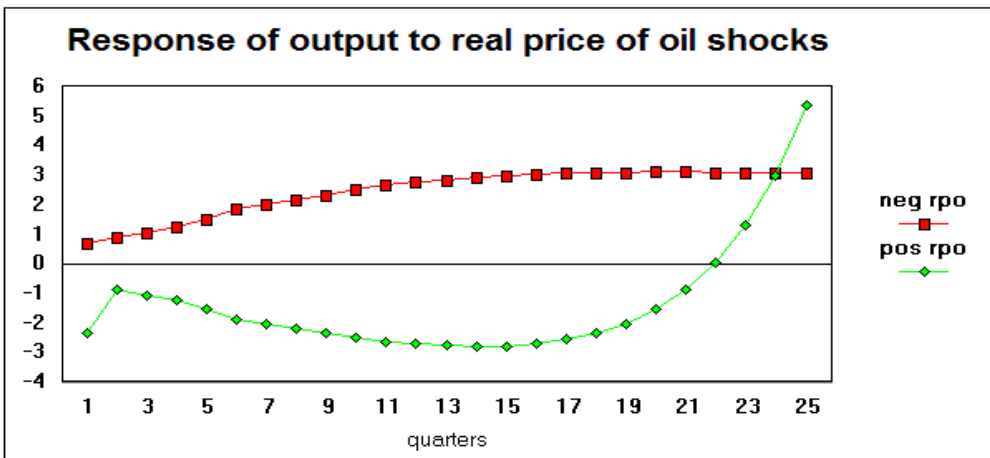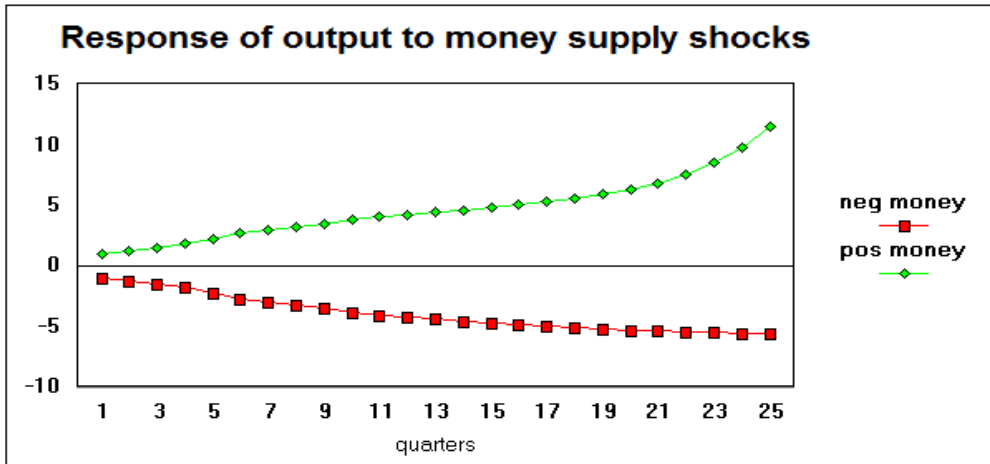**Figure 1: Output Responses to money supply, real price of oil and interest rate shocks: USA**

Figure 2: Output Responses to money supply, real price of oil and interest rate shocks: Canada