No. 46

A VAR ANALYSIS OF ECONOMIC INTERDEPENDENCE: CANADA, THE UNITED STATES, AND THE REST OF THE WORLD

John Kuszczak
John D. Murray

Bank of Canada
Technical Reports

Rapports techniques
Banque du Canada

March 1987

Technical Report 46

A VAR ANALYSIS OF ECONOMIC INTERDEPENDENCE: CANADA, THE UNITED STATES, AND THE REST OF THE WORLD

By

John Kuszczak

and

John D. Murray

Presented at the conference "How Open is the U.S. Economy?" sponsored by the Federal Reserve Bank of St-Louis, October 11-12, 1985. The views expressed in this paper are those of the authors and no responsibility for them should be attributed to the Bank of Canada.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the invaluable assistance of Paul Gomme, a research assistant at the Bank of Canada, and Tracey Bartzak, a secretary at the Woodrow Wilson School of Public and International Affairs, Princeton. They would also like to thank their colleagues for many helpful suggestions and absolve them of any responsibility for the analysis that follows.

CONTENTS

ABSTRACT

The authors use vector autoregression (VAR) modelling techniques to examine the response of the domestic economy to foreign influences and to quantify some of the concepts and relationships relating to economic interdependence. Particular attention is given to the dynamic behaviour and interactions of the U.S. and Canadian economies over the past twenty years. Extensive empirical analysis reveals that U.S. variables are affected by international variables to a greater extent than many would think. While the Canadian economy is evidently more open than the U.S. economy, and therefore more vulnerable to external shocks, at least 20 to 30 per cent of the forecast variance of U.S. output and prices can be attributed to innovations in foreign variables. The authors also find that the shift from a fixed exchange rate regime to a flexible exchange rate regime did not seem to influence the behaviour of the time series for the variables studied.

RÉSUMÉ

Dans ce rapport, les auteurs utilisent des techniques de modélisation fondées sur l'autorégression vectorielle pour étudier la réaction de l'économie nationale aux facteurs d'origine étrangère et quantifier certains concepts et rapports liés à l'interdépendance économique. Ils étudient tout particulièrement, du point de vue dynamique, le comportement et l'interaction des économies canadiennes et américaine au cours des vingt dernières années. Les analyses empiriques approfondies qu'ils effectuent révèlent que les variables ayant trait à l'économie américaine subissent plus qu'on ne l'aurait pensé l'influence de facteurs internationaux. Même si l'économie canadienne est de toute évidence plus ouverte que l'économie américaine et a fortiori plus exposée aux chocs d'origine extérieure, au moins 20 à 30 % de la variance prévue des variables de production et de prix aux États-Unis sont attribuables à des chocs non anticipés sur les variables étrangères. Les auteurs constatent également que le passage d'un régime de taux de change fixes à un régime de taux de change flottants n'a pas semblé influer sur le comportement des séries chronologiques des variables étudiées.

1 INTRODUCTION

In this paper the techniques of vector autoregression (VAR) analysis are used to investigate the international transmission of business cycles among the major industrialized countries that comprise the G-7.[1] Particular attention is given to the dynamic behaviour and interactions of the Canadian and U.S. economies during the past twenty years. The reduced form nature of a VAR provides a natural and convenient means of (i) measuring the relative importance of domestic and foreign shocks on the evolution of certain key macro variables and (ii) comparing the effectiveness of various policy actions under fixed and flexible exchange rate regimes -- the two principal objectives of this study.[2]

First, Canada, the United States, and the Rest of the World (ROW) are modelled as three closed economies.[3] The regression results, impulse responses, and variance decompositions for these three closed-economy models are then compared to those for three open-economy models in which foreign output, prices, interest rates, money, and exchange rates are allowed to affect the domestic economies.

The major conclusions can be summarized as follows:

(1) Foreign variables exert an important and statistically significant influence on the economies of Canada, the United States, and the Rest of the World. Closed-economy models which exclude international influences are therefore likely to give a distorted view of the macroeconomic relationships in these economies and could misrepresent the strength and effectiveness of domestic policies.

(2) Although the Canadian economy is more open than the U.S. economy, and therefore more vulnerable to external shocks, at least 20 to 30 per cent of the forecast variance of U.S. output and prices can be attributed to innovations in foreign variables.

---

1. The G-7 countries include: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

2. Several papers have recently been published questioning the reliability and usefulness of VAR analysis. See for example Gordon and King (1982) or Offenbacher and Porter (1983). These and other related issues are dealt with later in the paper.

3. The ROW is modelled as an aggregate system representing the six countries in the G-7 excluding the United States.

(3) The money equations for both Canada and the United States are very sensitive to movements in foreign interest rates and exchange rates. Owing to the astructural nature of VAR models, however, it is impossible to determine whether this sensitivity is caused by currency substitution on the part of private agents (demand-side effects), or the policy actions of monetary authorities (supply-side effects).

(4) Over most of the 1962-84 period, Canadian interest rates and money have appeared to move primarily in response to U.S. shocks. This dependence could have been caused by the tight structural relationships that bind the U.S. and Canadian economies or, alternatively, by what Richard Cooper (1984) has termed "goal and policy interdependence."

(5) Finally, empirically the distinction between fixed and flexible exchange rate systems does not seem to have been very important over the 1962-84 period. Tests for structural stability suggest that the time series behaviour of Canadian, U.S., and ROW variables remained virtually unchanged following the move to flexible exchange rates in the early 1970s.

The remainder of the paper is divided into six sections. Section 2 briefly discusses the VAR methodology and the structure of the closed- and open-economy models employed. Section 3 describes the data series that were used in the Canadian and U.S. regressions as well as the trade-weighted indices that were constructed to estimate the ROW models. The regression results and variance decompositions of the models are presented in section 4, along with graphs of the impulse responses for selected domestic and foreign shocks. Section 5 examines the policy implications of our empirical work, and section 6 concludes the paper with a brief summary and some suggestions for future research.

2 MODELS AND METHODOLOGY

Two sets of linear, constant-coefficient, VAR models were estimated. The first set contains three closed-economy models representing Canada, the United States, and ROW, respectively. Each model has four endogenous variables[4] -- output, prices, money, and interest rates -- which are regressed on a constant term, their own lagged values, and lagged values of the other three endogenous variables in the system. The complete four-equation system for each country can be written in vector notation as

$$\underline{y}_t^i = \underline{\alpha} + \sum_{k=1}^{n} \beta(k)\, \underline{y}_{t-k}^i + \underline{\varepsilon}_t \qquad (1)$$

where $\underline{y}_t^i$ is a 4x1 vector of endogenous variables for country i,

$\underline{\alpha}$ is a 4x1 vector of constant terms,

$\beta(k)$ is a 4x4 matrix of estimated coefficients on the lagged values of $\underline{y}_t$, and

$\underline{\varepsilon}_t$ is a 4x1 vector of white noise error terms assumed to be independent and normally distributed with zero mean.

The second set of models has the same basic structure as the first but includes five foreign variables: output, prices, money, interest rates, and exchange rate. These augmented open-economy models represent the most important part of the analysis. They are compared to the more familiar closed-economy models in section 4 and are used to test the statistical significance and economic importance of foreign variables in the three domestic economies.

The structure of the open-economy models varies according to the relationship between the domestic and foreign economies. If the international system is truly interdependent, such that shocks to economy A affect economy B and vice versa (bidirectional causality), the vector $\underline{y}_{t-k}$ in equation (1) includes all nine endogenous variables (four domestic and five foreign). The matrix of parameters on lagged values of $\underline{y}$, $\beta(k)$, also expands from dimension 4x4 to 9x9 and contains few, if any, zero elements. If, on the other hand, the relationship between A and B is best

4. A fifth variable, the nominal value of government debt, was included in some preliminary work in an effort to identify the separate effects of monetary and fiscal policies. However, the addition of this fiscal proxy led to problems of collinearity and significantly reduced the available degrees of freedom, making it difficult to obtain reasonable parameter estimates on other more important variables. Since likelihood ratio tests indicated that government debt was statistically insignificant in all three models, it was excluded in subsequent analyses.

described as one of dependence as opposed to interdependence, lagged values of y from the small (dependent) economy have no impact on the large economy and at least 5x5 of the coefficients in the β(k) matrix of the large economy have zero values.

All the models described above have traditional VAR structures in the sense that:

(i) they impose a common lag length on all explanatory variables;

(ii) they include the same explanatory variables in each equation; and;

(iii) they use only lagged values of the endogenous variables and a constant term as regressors.

This symmetric structure makes it possible to obtain consistent and efficient coefficient estimates by running ordinary least squares on the individual equations (provided the error terms in equation (1) are not autocorrelated), thereby avoiding the necessity of costly systems estimation. The absence of contemporaneous variables on the right-hand side of the equations also eliminates the need to make arbitrary assumptions about the causal relationships of the variables.[5]

There are, however, some notable disadvantages associated with this unrestricted form of econometric analysis. First, traditional VAR models are very data intensive. Since the number of coefficients that have to be estimated expands by a factor of n(2j+1)+1 for every additional variable in the model, the specifications used are, by necessity, very parsimonious.[6] Consequently, several potentially important variables may have been omitted from our models. Second, by admitting only lagged endogenous variables on the right-hand side of each equation (in addition to a constant term), all the contemporaneous shocks that affect y_t are forced to feed through the residuals, ε_t. While this may not pose a problem in the estimation stage of the analysis, the impulse responses and variance decompositions derived from these initial estimates can be seriously affected. If the residuals have high contemporaneous

---

5. As noted on page 7, this is only true in the estimation stage of the analysis. It is necessary to make some implicit assumptions about the causal relationships of the variables when the impulse responses and variance decompositions of the models are examined.

6. 'j' is the number of endogenous varibles originally in the model and 'n' is the lag length on each right-hand-side variable.

correlations, any adjustment to the order in which the variables are entered in the system can change the results dramatically. More specifically, certain variables can assume exaggerated importance in the variance decompositions, while other, more significant, variables receive little or no weight. This problem arises because the Choleski decomposition that we use to convert the VAR models into their moving-average representations attributes all the contemporaneous correlation between two series to the variable that is ordered first in each model.

Some authors have tried to improve the efficiency of their VAR estimates and to save degrees of freedom by assigning different lag lengths to the various regressors. Batten and Thorton (1985), Fackler (1985), and others have proposed a number of heuristic algorithms for this purpose, based on the Akaike Final Prediction Error criterion. Unfortunately, these techniques are very cumbersome when more than two or three variables are involved, and typically yield results that are very sample sensitive.

With six models to estimate and the large number of variables contained in each, selective adjustment of the lags on individual variables did not seem to be a very practicable approach. Instead, the models have been kept as small as possible by running system-wide significance tests on alternative lag lengths for all the variables in each model. While the lag lengths that are ultimately assigned to the models are probably too long for some series and too short for others, there does not seem to be any obvious alternative to this more aggregative approach.

The sensitivity of the variance decompositions to the ordering of the variables, is addressed in a somewhat more satisfactory fashion, using a strategy recommended by Doan and Litterman (1980). By inspecting the contemporaneous correlations of the residuals in each model it is possible to identify variable combinations that could pose a problem. The variance decompositions and impulse responses can then be recomputed, switching the order of any variables that are highly correlated in order to check the sensitivity of the results. In none of the cases reported below did this appear to be a major problem.

3 DATA

To implement the VAR modelling techniques and test procedures described in section 2, suitable real world proxies were required for all the domestic and foreign variables in the models. Although several alternative measures were initially considered, most had to be rejected because they were either not available for all G-7 countries or extended only over short periods. The series finally chosen are shown below, along with their mnemonics[7]:

Output (U) = seasonally adjusted index of industrial production,
Prices (P) = seasonally adjusted Consumer Price Index,[8]
Money (M) = seasonally adjusted demand deposits plus currency,
Interest rate (R) = call loan rate on money market instruments,
Exchange rate (S) = price of foreign currency in U.S. dollars.

All series were defined on a quarterly basis and typically run from 1964Q1 to 1984Q4. Data for Canada and the United States, however, were extended back to 1960Q1.

Representative aggregate measures of output, prices, money, and the exchange rate were constructed for ROW by combining individual series for Canada, France, Germany, Italy, Japan, and the United Kingdom in four trade-weighted indices.[9] The specification used to aggregate the series can be written as

$$X_{w,t} = X_{w,t-1} \prod^{6} (X_{i,t} / X_{i,t-1})^{\tilde{S}_{i,t}} \qquad (2)$$

---

7. Most of the data were taken from the OECD publication, Main Economic Indicators, and the BIS databank.

8. The Consumer Price Index for the United States is defined exclusive of housing costs.

9. The indices for ROW have been defined from a U.S. perspective (i.e., including all countries in the G-7 except the United States), since their primary purpose is to serve as foreign variables in the open-economy model of the United States.

where X_w = index of aggregate output (prices, money, and the exchange rate) for ROW,

X_i = aggregate output (prices, money, and the exchange rate) for the ith country, and

$\tilde{S}_i$ = ith country's share of world trade.

The share weights, $\tilde{S}_{i,t}$, reflect the relative importance of each country in world trade and have been defined such that

$$\sum_{i=1}^{6} \tilde{S}_{i,t} = 1$$

The quarterly values of $\tilde{S}_{i,t}$ that are included in equation (2) were obtained by fitting a polynomial time series to annual data extracted from the IMF World Trade Statistics. Their average values over the 1964Q1-1984Q4 sample period are reported in Table 1.[10]

Table 1

AVERAGE TRADE WEIGHTS: 1964Q1-1984Q4

Canada	France	Germany	Italy	Japan	U.K.
0.12	0.16	0.26	0.12	0.15	0.19

The index constructed for ROW interest rates uses the same trade weights as (2) but has a simpler, linear specification.[11]

10. Masson and Blundell-Wignall (1984) have constructed similar proxies for ROW using a more comprehensive weighting scheme which ranks the countries in terms of their contribution to world trade and international financial flows. The weights they obtain from this more involved procedure are very close to the averages reported in Table 1.

11. Only five countries were included in equation (3), since reliable interest rate data were not available for Italy prior to 1975.

$$R_{w,t} = \sum_{i=1}^{5} \tilde{S}_{i,t} (R_{i,t}) \qquad (3)$$

A final point that should be mentioned regarding the data concerns the procedures used to render the series stationary. VAR analysis assumes that all the stochastic processes in the autoregressive system are variance-covariance stationary. If this condition is not met, little confidence can be placed in the VAR regression results. Since most, if not all, of the data are highly autocorrelated and tend to drift over time, some form of detrending is required before the models can be estimated.

Two popular methods of detrending are (i) regressing the data on time (or a function of time), and (ii) differencing the data. A priori it is not clear which method should be preferred, but using an inappropriate procedure could have serious consequences for the empirical work that follows.

Although various alternatives were considered, the data were eventually transformed into first differences of their natural logarithms (roughly equivalent to using percentage changes).[12] The decision to first-difference was influenced in part by some recent work by Nelson and Plosser (1982). Using a test developed by Dickey and Fuller (1979), they have shown that most U.S. time series are well represented as difference-stationary processes. In addition, they have found that data that are detrended with time, as opposed to using first differences of logarithms, often produce "spurious regression results."[13]

4 RESULTS

4.1 Closed-Economy Models

The results for the closed-economy models will not be discussed in much detail since there is reason to believe that the models are seriously misspecified. The significance tests reported below with respect to the

---

12. The one exception was interest rates which were simply first-differenced.

13. See also Nelson and Kang (1984).

open-economy models show that the closed-economy models exclude several important foreign variables. Nevertheless, these restricted, four-equation models do provide useful control solutions that can be used for testing the results of the open-economy models in section 4.2. These results are also of some interest in their own right since most of the VAR analyses published to date employ similar closed-economy specifications and readers may wish to compare their results with those contained in this study.

4.1.1 Parameter Estimates

The first stage of the analysis involved selecting an appropriate lag length for the (endogenous) explanatory variables in each of the models. As noted earlier, this was done on a system-wide basis (i.e., the whole model is tested rather than individual equations or variables), using a modified likelihood-ratio test first proposed by Sims (1980b).[14] The results are reported in Table 2.

The lag lengths assigned to the Canadian and U.S. models were much longer than those assigned to the ROW model (6 lags versus 2). This difference might be explained by the aggregation procedure that was used to create the ROW variables. Averaging the data across six different countries may have removed some of the variation that made longer lags necessary in the other models.

Parameter estimates and summary statistics for the final versions of the closed-economy models are presented in Tables 3 through 5.[15] Though it is often difficult to interpret the coefficients in VAR models, plausible explanations can be provided for most of the results.

---

14. The test statistic is distributed as $\chi^2(r)$ and is computed as,

$$V = (T-c)\,[\log \Omega^R - \log \Omega^U]$$

where T is the number of observations, c is the number of parameters in the unrestricted model, Ω^R and Ω^U are the determinants of the covariance matrices of the restricted and unrestricted models, and r is the number of restrictions.

15. The Canadian regressions, unlike those for the United States, begin in 1962Q3 rather than 1962Q1. This was done in order to avoid the instability associated with Canada's 1961-62 exchange rate crisis and the uneasy transition from flexible to fixed exchange rates that followed.

Table 2

TESTING THE LAG STRUCTURES OF CLOSED-ECONOMY MODELS

Canada: 1962Q3 - 1984Q4		
8 vs. 6 lags	χ^2 (32)* = 28.5	Accept 6
6 vs. 4 lags	χ^2(32) = 47.6**	Reject 4
United States: 1962Q1 - 1984Q4		
8 vs. 6 lags	χ^2(32) = 36.3	Accept 6
6 vs. 4 lags	χ^2(32) = 72.7**	Reject 4
Rest of the World: 1965Q3 - 1984Q4		
8 vs. 6 lags	χ^2(32) = 28.7	Accept 6
6 vs. 4 lags	χ^2(32) = 26.0	Accept 4
4 vs. 3 lags	χ^2(16) = 16.0	Accept 3
3 vs. 2 lags	χ^2(16) = 21.0	Accept 2
2 vs. 1 lags	χ^2(16) = 27.8**	Reject 1

* Likelihood ratio test statistic distributed as a χ^2 with (r) degrees of freedom.

** Significant at 5.0 per cent level.

According to the model, real growth (U) is negatively related to increases in interest rates and inflation[16] and is positively related to money growth and its own lagged values (except in Canada where lagged values of U_c bear a negative but statistically insignificant relationship to current real growth). Inflation, however, appears to be positively related to interest rates and lagged inflation, as well as output and money growth -- at least in Canada and the United States. The positive sign on lagged interest rates in the Canadian and U.S. price equations is somewhat unexpected, but the same response has been recorded elsewhere by Sims (1980a), and Litterman and Weiss (1983).[17] The result can be interpreted in terms of a Fisher effect (i.e., nominal interest rates correctly anticipating future inflation) and/or what Driskill and Sheffrin (1985) have recently labelled a "Patman effect." The latter refers to the direct, cost-push effect that higher interest rates might have on prices.

Money growth (M) is depressed by higher interest rates in all three economies, and generally bears a positive relationship to its own lagged values. The sole exception is M_w in the ROW model. Interest rates (R) tend to rise with real growth, inflation, and money, but the relationships are often statistically insignificant.

The only troublesome result in Tables 3 to 5 is the negative and statistically significant coefficient on U_c in the Canadian money supply equation.[18] For the most part, however, the qualitative results are very similar across all three models. There are, nevertheless, two inter-country differences that deserve special attention.

First, the U.S. equations seem to contain more significant variables and generally have greater explanatory power than either the Canadian or ROW equations. This could be taken as evidence that the closed-economy specification is more acceptable in the case of the United States,

---

16. The negative signs on lagged inflation are not surprising given the supply shocks of the 1970s. The same effects are observed, however, when the equations are run on pre-1973 data.

17. Although higher interest rates seem to produce a temporary increase in the rate of inflation in Canada, the long-run relationship is negative (see Figure 4, p. 23).

18. Financial innovations, which have recently lowered the demand for transactions balances in Canada, could be responsible for the negative sign on U_c. See Freedman (1983). This result disappears, however, once foreign variables are added to the model in section 4.2.

Table 3

PARAMETER ESTIMATES FOR THE CLOSED-ECONOMY MODEL OF CANADA: 1962Q3-1984Q4

Equation	Constant	$A(L)U_c$	$B(L)P_c$	$C(L)M_c$	$D(L)R_c$	$\bar{R}^2$	D-W	S.E.	Q(27)+
U_c	0.017	-0.195†	-1.190	0.736	-0.788	0.389	1.99	0.015	13.42
	(2.14)**	(0.55)††	(1.91)*	(2.06)*	(1.38)				
P_c	-0.005	0.227	1.10	0.066	0.107	0.843	1.99	0.003	18.51
	(2.68)**	(3.18)**	(29.88)**	(1.76)	(0.57)				
M_c	0.009	-0.062	-0.164	0.723	-1.172	0.394	2.09	0.014	25.54
	(1.19)	(2.13)*	(0.91)	(4.81)**	(4.74)**				
R_c	-0.013	0.397	0.443	0.158	-0.135	0.241	1.98	0.001	11.99
	(2.30)**	(2.32)**	(1.26)	(1.85)*	(1.11)				

+ Q(r) = Box-Pierce Q-Statistic for autocorrelation, distributed as χ^2 with r degrees of freedom.

† Sum of lagged coefficients on U, P, M, and R, where A(L), B(L), C(L), and D(L) are lag operators of order 6.

†† F-statistic testing the joint significance of all lagged coefficients.

* Significant at 10.0 per cent level.

** Significant at 5.0 per cent level.

Table 4

PARAMETER ESTIMATES FOR THE CLOSED-ECONOMY MODEL OF THE UNITED STATES: 1962Q1-1984Q4 [a]

Equation	Constant	$A(L)U_{us}$	$B(L)P_{us}$	$C(L)M_{us}$	$D(L)R_{us}$	$\bar{R}^2$	D-W	S.E.	Q(27)+
U_{us}	0.011	0.226†	-0.597	0.315	-1.351	0.619	2.05	0.014	22.50
	(1.80)**	(3.70)**††	(4.13)**	(1.73)	(6.34)**				
P_{us}	-0.002	0.052	0.842	0.212	0.301	0.724	2.01	0.004	16.34
	(0.83)	(2.23)**	(10.69)**	(2.63)**	(2.66)**				
M_{us}	0.005	-0.059	0.013	0.703	-0.447	0.461	1.86	0.006	16.76
	(1.97)**	(0.88)	(3.12)**	(4.01)**	(4.01)**				
R_{us}	-0.010	0.316	0.108	0.413	0.161	0.551	1.98	0.009	11.69
	(2.38)**	(2.37)**	(4.42)**	(5.59)**	(4.70)**				

a See notes to Table 2.

Table 5

PARAMETER ESTIMATES FOR THE CLOSED-ECONOMY MODEL OF THE REST OF THE WORLD: 1964Q1-1984Q4[a]

Equation	Constant	A(L)U_w	B(L)P_w	C(L)M_w	D(L)R_w	$\bar{R}^2$	D-W	S.E.	Q(27)+
U_w	0.015	0.409↑	-0.600	0.012	-0.213	0.310	2.02	0.013	23.62
	(3.20)**	(6.47)**↑↑	(3.79)**	(0.03)	(0.26)				
P_w	0.001	0.033	0.935	-0.011	0.167	0.815	2.10	0.003	37.10
	(0.81)	(2.15)*	(126.24)**	(0.72)	(2.31)*				
M_w	0.027	0.234	1.116	-0.988	-2.361	0.283	2.19	0.049	10.68
	(1.52)	(0.09)	(0.96)	(18.67)**	(2.91)**				
R_w	-0.004	0.245	0.120	0.008	0.217	0.277	1.99	0.006	25.44
	(1.80)**	(3.62)**	(1.16)	(0.36)	(1.56)				

a See notes to Table 2. A(L), B(L), C(L), and D(L) are lag operators of order 2.

although clearly it is impossible to make any direct comparisons as the models specify different dependent variables in each equation. Second, money and interest rates have much less influence in the ROW model than in the U.S. model. While this could be a consequence of aggregation, it could also reflect the more heavily regulated nature of Japanese and European financial markets.

4.1.2 Variance Decomposition and Impulse Responses

The variance decompositions of the closed-economy models are reported in Tables 6 to 8. The statistics measure the proportion of the error variance in each domestic variable that can be attributed to shocks (or "innovations") in output, prices, money, and interest rates over forecast horizons ranging from 1 to 12 quarters. As one might expect, the most important shocks come from lagged values of the dependent variables themselves. Nevertheless, shocks from other variables typically account for a significant proportion of the error variance in each variable by the 12th quarter. The one exception is M_w (see Table 8), which is virtually exogenous.[19]

To test the sensitivity of these results to changes in the ordering of the variables, the variance decompositions were rerun reversing the positions of the most highly correlated variables. The only pairs displaying high cross correlation were R-U in the case of Canada and the United States, and R-U and R-P in the Rest of the World (see Table 9). The results did not change significantly after the variables were reordered, suggesting that the residual correlations must be much higher than those recorded in Table 9 before any major changes will appear in the variance decompositions.

The impulse responses for the closed-economy models are shown in Figures 1 to 4. Each figure contains three plots, representing the responses of Canadian, U.S., and ROW variables to innovations in U, R, M, and P. The adjustment paths are all dynamically stable and are very

---

19. Contrary to the results reported by Sims (1980a), interest rates and money have almost identical weights in the variance decompositions of U.S. output. Sims' use of monthly numbers and the substitution of the 30-day treasury bill rate for the call loan rate could account for this difference.

Table 6

CANADA: VARIANCE DECOMPOSITION OF PREDICTION ERRORS*

		Proportion of Error Attributed to Shocks in ...				
Variable	Quarter	U_c	P_c	M_c	R_c	S.E.
U_c	1	100.0	0.0	0.0	0.0	0.124-01
	4	85.5	4.6	5.1	4.8	0.136-01
	8	78.3	8.8	5.5	7.3	0.170-01
	12	69.2	8.7	9.4	12.7	0.181-01
P_c	1	0.2	93.8	5.6	0.4	0.287-02
	4	6.0	62.3	25.5	6.3	0.476-02
	8	9.0	48.7	31.5	10.8	0.612-02
	12	7.1	36.8	38.3	17.8	0.730-02
M_c	1	0.0	0.0	94.3	5.7	0.116-01
	4	13.5	3.2	59.0	24.2	0.155-01
	8	16.1	4.3	56.4	23.2	0.168-01
	12	15.8	5.3	54.5	24.5	0.173-01
R_c	1	10.5	0.0	0.0	89.5	0.867
	4	18.8	3.3	7.1	70.8	1.060
	8	20.9	4.6	10.3	64.2	1.135
	12	20.7	4.9	10.6	63.7	1.158

* Equations were estimated over the sample period 1962Q3-1984Q4 with six lags on each explanatory variable. The ordering of the variables in the variance decompositions was U, R, M, and P.

Table 7

UNITED STATES: VARIANCE DECOMPOSITION OF PREDICTION ERRORS*

Variable	Quarter	U_{us}	P_{us}	M_{us}	R_{us}	S.E.
		... Proportion of Error Attributed to Shocks in ...				
U_{us}	1	100.0	0.0	0.0	0.0	0.117-01
	4	76.25	2.4	6.0	15.4	0.163-01
	8	60.0	7.9	13.3	18.8	0.204-01
	12	54.6	12.4	16.1	16.9	0.219-01
P_{us}	1	0.2	98.8	0.1	0.9	0.381-02
	4	3.2	70.4	17.8	8.6	0.579-02
	8	6.7	60.9	25.0	7.4	0.722-02
	12	6.4	58.0	28.5	7.1	0.770-02
M_{us}	1	1.3	0.0	98.5	0.2	0.493-02
	4	8.4	4.7	77.8	9.1	0.603-02
	8	12.4	11.5	64.8	11.4	0.698-02
	12	12.9	14.3	60.3	12.5	0.728-02
R_{us}	1	19.6	0.0	0.0	80.4	0.796
	4	20.0	9.1	17.6	53.3	1.114
	8	17.0	15.0	17.6	50.4	1.252
	12	18.3	17.9	18.6	45.2	1.34

* See note to Table 6.

Table 8

REST OF WORLD: VARIANCE DECOMPOSITION OF PREDICTION ERRORS*

Variable	Quarter	Proportion of Error Attributed to Shocks in ... U_w	P_w	M_w	R_w	S.E.
U_w	1	100.0	0.0	0.0	0.0	0.120-01
	4	91.9	4.8	0.1	3.2	0.135-01
	8	83.6	10.5	0.2	5.7	0.145-01
	12	81.1	12.4	0.2	6.3	0.149-01
P_w	1	0.6	93.0	0.2	6.2	0.326-02
	4	13.0	68.9	0.9	17.1	0.562-02
	8	20.2	61.0	0.8	18.1	0.715-02
	12	22.1	59.0	0.7	18.1	0.767-02
M_w	1	0.3	0.0	99.2	0.5	0.460-01
	4	0.5	0.5	95.1	3.9	0.567-01
	8	0.8	0.7	94.6	3.9	0.571-01
	12	0.8	0.8	94.4	4.0	0.572-01
R_w	1	9.3	0.0	0.0	90.7	0.565
	4	33.1	0.7	0.4	65.8	0.681
	8	33.1	1.7	0.5	64.8	0.690
	12	33.1	2.3	0.5	64.1	0.694

* See note to Table 6. Equations were estimated over the sample period 1964Q1-1984Q4 with two lags on each explanatory variable.

Table 9

RESIDUAL CROSS CORRELATIONS FOR CLOSED-ECONOMY MODELS

Canada

	U_c	P_c	M_c	R_c
U_c	1.000			
P_c	-0.048	1.000		
M_c	0.013	0.214	1.000	
R_c	0.324*	-0.042	-0.221	1.000

United States

	U_{us}	P_{us}	M_{us}	R_{us}
U_{us}	1.000			
P_{us}	-0.048	1.000		
M_{us}	0.113	-0.026	1.000	
R_{us}	0.442*	0.064	0.093	1.000

Rest of World

	U_w	P_w	M_w	R_w
U_w	1.000			
P_w	0.078	1.000		
M_w	0.053	-0.052	1.000	
R_w	0.305*	0.261*	-0.050	1.000

* Significant at 5.0 per cent level.

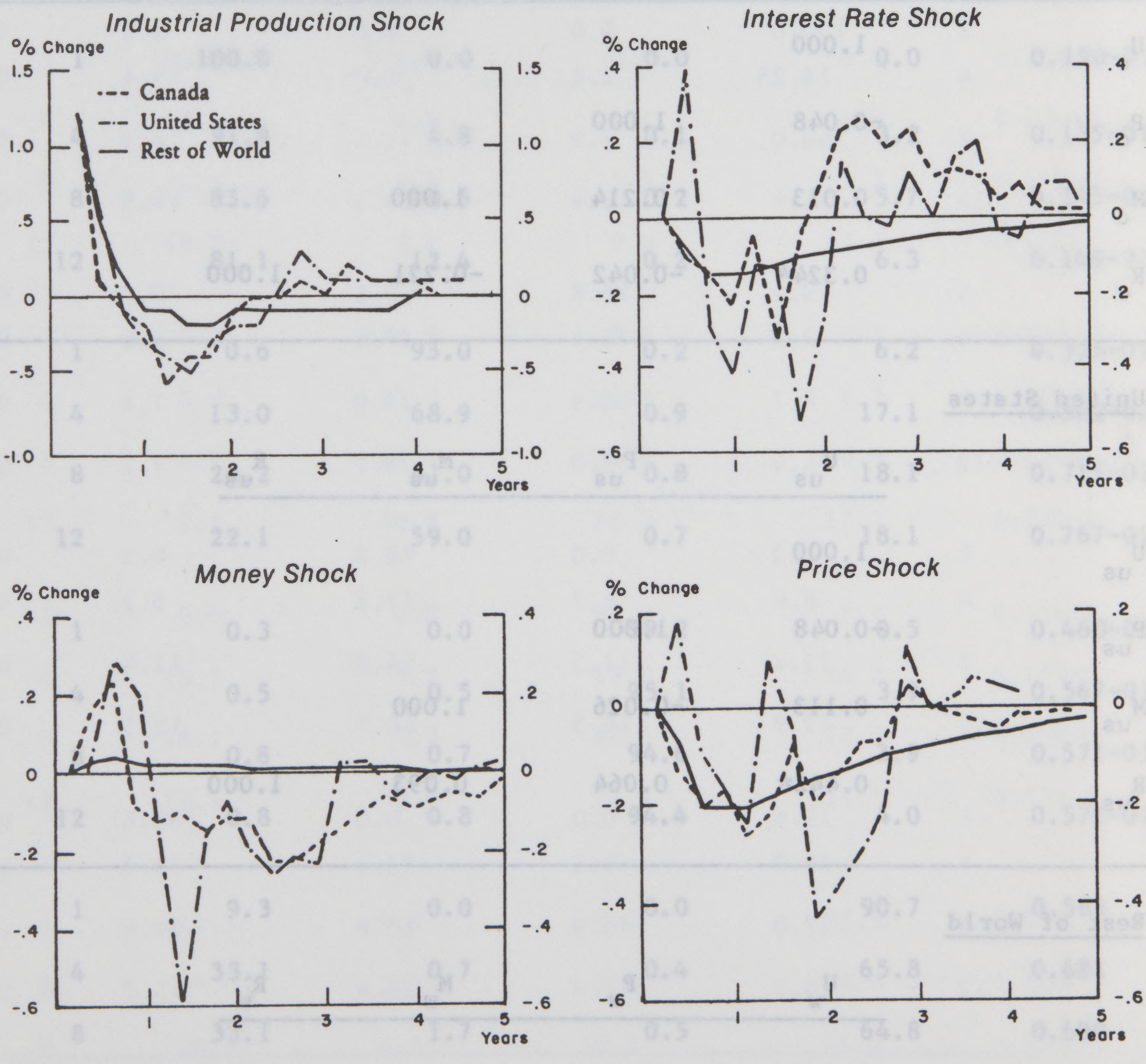

Figure 1. Closed-Economy Responses in Output to Industrial Production, Interest Rate, Money, and Price Shocks

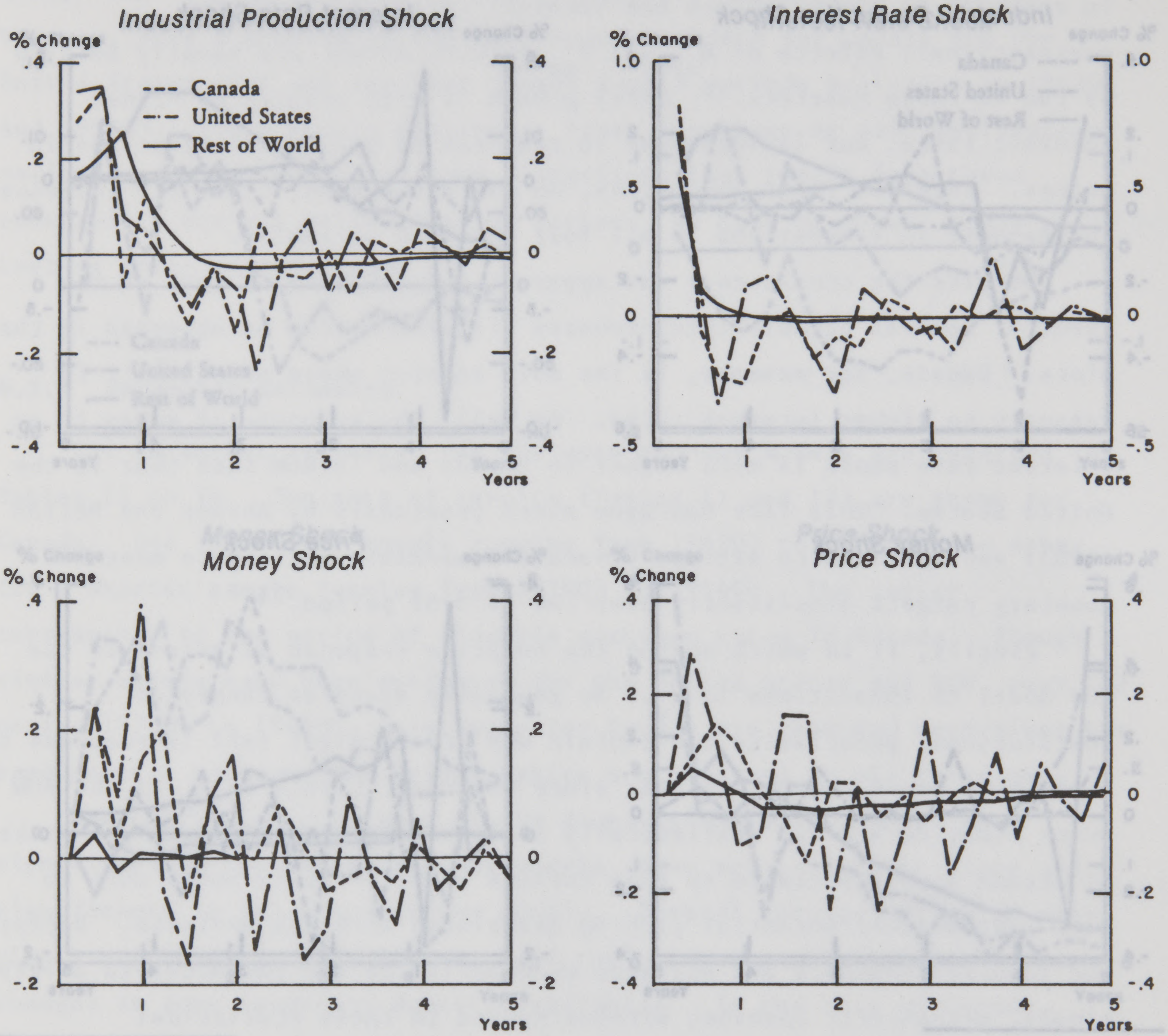

Figure 2. Closed-Economy Responses in Interest Rates to Industrial Production, Interest Rate, Money, and Price Shocks

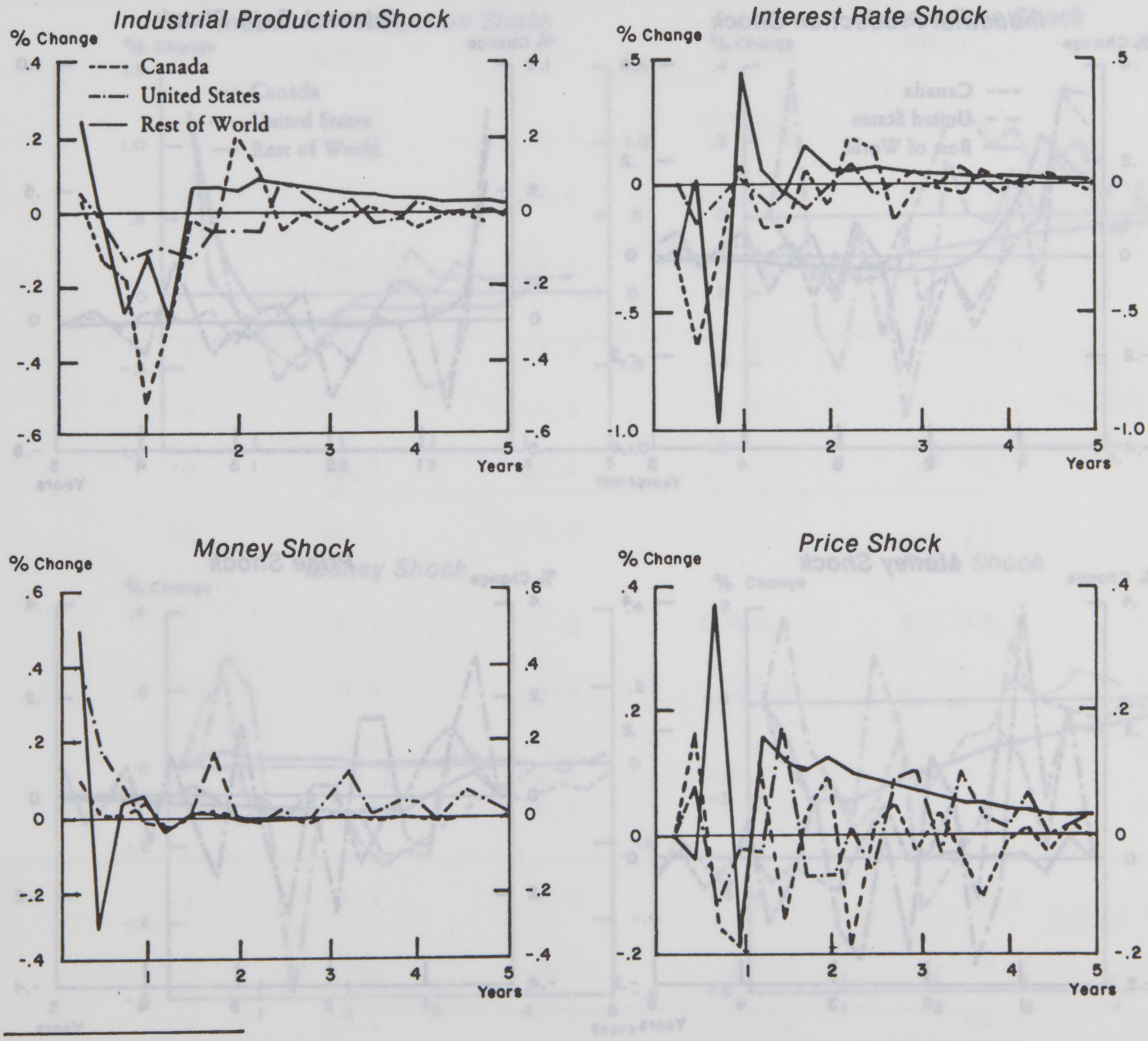

Figure 3. Closed-Economy Responses in Money to Industrial Production, Interest Rate, Money, and Price Shocks

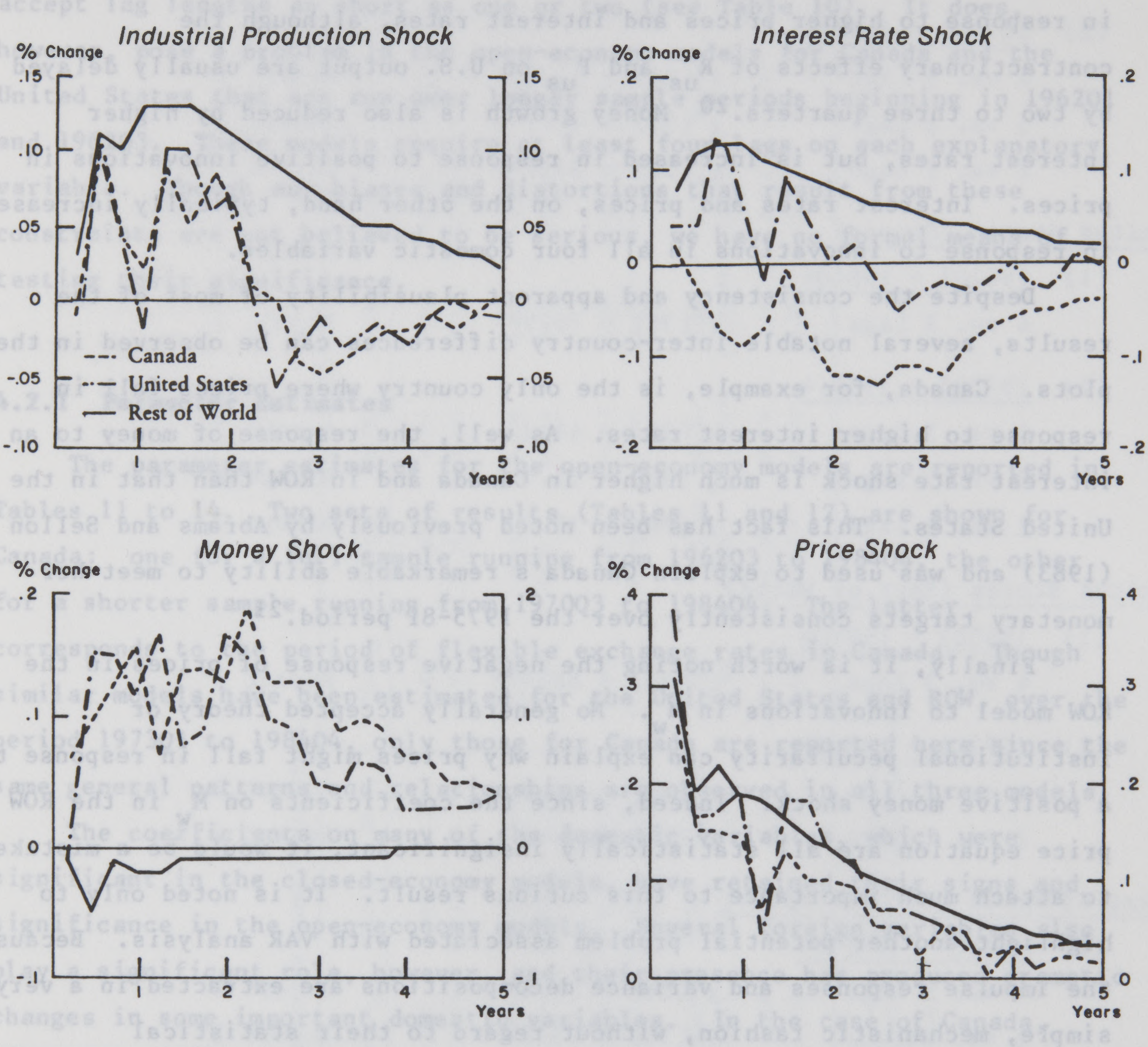

Figure 4. Closed-Economy Responses in Prices to Industrial Production, Interest Rate, Money, and Price Shocks

similar across the three models, though the cycles are much smoother in the case of ROW and typically display less variability -- a consequence of the shorter lags that were assigned to the ROW model.

In general, the impact and short-term effects of the various shocks are consistent with the parameter estimates in Tables 3 to 5. Output in each economy increases in response to positive money shocks and decreases in response to higher prices and interest rates, although the contractionary effects of R_{us} and P_{us} on U.S. output are usually delayed by two to three quarters.[20] Money growth is also reduced by higher interest rates, but is increased in response to positive innovations in prices. Interest rates and prices, on the other hand, typically increase in response to innovations in all four domestic variables.

Despite the consistency and apparent plausibility of most of the results, several notable inter-country differences can be observed in the plots. Canada, for example, is the only country where prices fall in response to higher interest rates. As well, the response of money to an interest rate shock is much higher in Canada and in ROW than that in the United States. This fact has been noted previously by Abrams and Sellon (1983) and was used to explain Canada's remarkable ability to meet her monetary targets consistently over the 1975-81 period.[21]

Finally, it is worth noting the negative response of prices in the ROW model to innovations in M_w. No generally accepted theory or institutional peculiarity can explain why prices might fall in response to a positive money shock. Indeed, since the coefficients on M_w in the ROW price equation are all statistically insignificant, it would be a mistake to attach much importance to this curious result. It is noted only to highlight another potential problem associated with VAR analysis. Because the impulse responses and variance decompositions are extracted in a very simple, mechanistic fashion, without regard to their statistical significance, it is not unusual to obtain a few unexpected results.

---

20. The same "perverse" initial responses to innovations in R_{us} and P_{us} have been reported by Litterman and Weiss (1983).

21. Abrams and Sellon claim that Canadian authorities were able to maintain tight control over aggregate M1 through relatively minor adjustments in Canadian short-term interest rates because of the high interest elasticity of Canadian money demand. See also Thiessen (1982).

4.2 Open-Economy Models

Once the five foreign variables are added to the models, the longest lag length that the equations can reasonably accommodate is four.[22] This restriction is not binding in any of the regressions run over shorter sample periods beginning in either 1970Q3 or 1973Q1, since the models accept lag lengths as short as one or two (see Table 10). It does, however, pose a problem in the open-economy models for Canada and the United States that are run over longer sample periods beginning in 1962Q1 and 1962Q3. These models require at least four lags on each explanatory variable. Though any biases and distortions that result from these constraints are not believed to be serious, we have no formal means of testing their significance.

4.2.1 Parameter Estimates

The parameter estimates for the open-economy models are reported in Tables 11 to 14. Two sets of results (Tables 11 and 12) are shown for Canada: one for a full sample running from 1962Q3 to 1984Q4, the other for a shorter sample running from 1970Q3 to 1984Q4. The latter corresponds to the period of flexible exchange rates in Canada. Though similar models have been estimated for the United States and ROW, over the period 1973Q1 to 1984Q4, only those for Canada are reported here since the same general patterns and relationships are observed in all three models.

The coefficients on many of the domestic variables, which were significant in the closed-economy models, have retained their signs and significance in the open-economy models. Several foreign variables also play a significant role, however, and their presence has produced dramatic changes in some important domestic variables. In the case of Canada,

---

22. The foreign variables for U, P, M, and R in the Canadian and ROW models are proxied by U.S. output, prices, money, and interest rates. In the U.S. model, these foreign variables are proxied by the aggregate indices constructed for ROW. S_{C-US}, the exchange rate in the Canadian model, is the U.S. dollar price of one Canadian dollar. S_{W-US}, the exchange rate in the U.S. and ROW models, is the ROW price of one U.S. dollar.

Table 10

TESTING THE LAG STRUCTURES OF OPEN-ECONOMY MODELS

Canada (United States)*			
(1)	1962Q3 - 1984Q4		
	4 vs. 3 lags	$\chi^2(36) = 63.6$**	Reject 3
(2)	1970Q3 - 1984Q4		
	4 vs. 3 lags	$\chi^2(36) = 41.9$	Accept 3
	3 vs. 2 lags	$\chi^2(36) = 42.9$	Accept 2
	2 vs. 1 lags	$\chi^2(36) = 64.2$**	Reject 1
United States (Canada)			
(1)	1962Q1 - 1984Q4		
	4 vs. 3 lags	$\chi^2(36) = 76.9$**	Reject 3
(2)	1970Q3 - 1984.4		
	4 vs. 3 lags	$\chi^2(36) = 44.2$	Accept 3
	3 vs. 2 lags	$\chi^2(36) = 33.4$	Accept 2
	2 vs. 1 lags	$\chi^2(36) = 39.6$	Accept 1
United States (Rest of World)			
(1)	1965Q1 - 1984Q4		
	4 vs. 3 lags	$\chi^2(36) = 88.4$**	Reject 3
(2)	1973Q1 - 1984Q4		
	3 vs. 2 lags	$\chi^2(36) = 33.2$	Accept 2
	2 vs. 1 lags	$\chi^2(36) = 30.8$	Accept 1
Rest of World (United States)			
(1)	1965Q1 - 1984Q4		
	4 vs. 3 lags	$\chi^2(36) = 37.6$	Accept 3
	3 vs. 2 lags	$\chi^2(36) = 33.2$	Accept 2
	2 vs. 1 lags	$\chi^2(36) = 58.6$**	Reject 1
(2)	1973Q1 - 1984Q4		
	3 vs. 2 lags	$\chi^2(36) = 21.92$	Accept 2
	2 vs. 1 lag	$\chi^2(36) = 45.71$	Accept 1

* Dependent variables for country x are regressed on lagged variables from x and (y).

** Significant at the 5.0 per cent level.

Table 11

PARAMETER ESTIMATES FOR OPEN-ECONOMY MODEL OF CANADA: 1962Q3-1984Q4

Equation	Constant	$A(L)U_c$	$B(L)P_c$	$C(L)M_c$	$D(L)R_c$	$E(L)U_{us}$	$F(L)P_{us}$	$G(L)M_{us}$	$H(L)R_{us}$	$I(L)S_{c-us}$	$\bar{R}^2$	D-W	S.E.	Q(27)+
U_c	0.012	-0.618†	-2.29	0.540	0.078	0.509	0.768	0.793	-0.798	-0.440	0.446	1.85	0.014	22.10
	(1.75)**	(0.81)††	(3.07)**	(2.63)**	(0.74)	(0.93)	(1.27)	(1.63)	(0.73)	(2.00)*				
P_c	-0.002	0.048	0.800	0.053	0.087	0.0429	0.225	0.039	-0.065	-0.071	0.834	2.13	0.003	17.13
	(1.35)	(1.24)	(6.87)*	(1.43)	(0.75)	(2.00)*	(1.01)	(0.76)	(0.98)	(2.09)*				
M_c	0.005	0.014	-0.815	0.596	0.567	-0.169	0.474	0.713	-1.587	-0.165	0.394	1.95	0.014	24.58
	(0.72)	(1.84)	(1.74)	(3.18)**	(0.99)	(1.84)	(1.08)	(1.19)	(2.76)**	(0.84)				
R_c	0.004	0.375	-0.155	0.238	-0.249	-0.154	0.557	-0.343	0.429	-0.303	0.613	1.80	0.007	9.17
	(1.96)**	(0.96)	(1.61)	(2.89)**	(0.63)	(0.50)	(2.20)*	(3.30)**	(10.31)**	(2.93)**				
S_{c-us}	0.014	-0.018	0.012	0.328	0.311	-0.717	-1.150	-0.036	1.147	0.320	0.412	1.93	0.010	22.12
	(2.90)**	(1.41)	(0.46)	(2.22)*	(0.63)	(3.42)*	(2.43)*	(0.75)	(3.87)**	(1.50)				

\+ Box-Pierce Q-statistic
† Sum of lagged coefficients. A(L), B(L),...are lag operators of order 4.
†† F-statistic testing the joint significance of all lagged coefficients.
* Significant at 10.0 per cent level.
** Significant at 5.0 per cent level.

Table 12

PARAMETER ESTIMATES FOR OPEN-ECONOMY MODEL OF CANADA: 1970Q3-1984Q4[a]

Equation	Constant	$A(L)U_c$	$B(L)P_c$	$C(L)M_c$	$D(L)R_c$	$E(L)U_{us}$	$F(L)P_{us}$	$G(L)M_{us}$	$H(L)R_{us}$	$I(L)S_{c-us}$	$\bar{R}^2$	D-W	S.E.	Q(21)+
U_c	-0.003	-0.298†	-1.497	0.767	0.654	0.313	0.149	1.195	-0.509	-0.076	0.457	1.91	0.016	22.49
	(0.23)	(0.74)††	(3.76)**	(8.45)**	(1.08)	(1.68)	(0.06)	(2.52)*	(1.03)	(0.42)				
P_c	0.001	0.209	0.860	-0.020	-0.863	-0.136	0.202	-0.108	0.023	-0.031	0.758	2.04	0.004	1.93
	(1.31)	(6.57)**	(21.62)**	(2.10)	(0.30)	(4.67)*	(1.89)	(0.28)	(0.08)	(1.86)				
M_c	0.015	0.079	-0.636	0.515	0.204	-0.303	0.109	0.382	-0.648	-0.082	0.536	2.07	0.013	24.38
	(1.55)	(1.45)	(12.58)**	(5.47)**	(0.29)	(5.33)**	(0.66)	(2.67)*	(3.36)**	(1.18)				
R_c	-0.014	0.317	0.250	0.198	-0.005	-0.119	0.381	-0.163	0.264	-0.094	0.503	1.81	0.010	11.65
	(1.93)**	(2.85)*	(0.78)	(1.92)**	(0.42)	(0.48)	(0.87)	(0.99)	(4.87)**	(0.68)				
S_{c-us}	0.007	-0.146	0.054	0.204	0.219	-0.067	-0.541	-0.241	0.265	0.459	0.125	2.11	0.014	9.62
	(0.65)	(0.18)	(0.04)	(0.96)	(1.41)	(0.07)	(0.74)	(0.49)	(0.81)	(5.85)**				

a See notes to Table 11.

Table 13

PARAMETER ESTIMATES FOR OPEN-ECONOMY MODEL OF THE UNITED STATES: 1965Q1-1984Q4[a]

Equation	Constant	$A(L)U_{us}$	$B(L)P_{us}$	$C(L)M_{us}$	$D(L)R_{us}$	$E(L)U_{w}$	$F(L)P_{w}$	$G(L)M_{w}$	$H(L)R_{w}$	$I(L)S_{w-us}$	$\bar{R}^2$	D-W	S.E.	Q(24)+
U_{us}	-0.001	0.682†	0.927	1.112	-1.601	-0.238	0.188	-0.008	1.444	-0.438	0.589	2.05	0.015	15.88
	(0.02)	(1.89)††	(1.22)	(2.49)*	(3.36)**	(2.29)*	(0.94)	(1.06)	(1.15)	(3.60)**				
P_{us}	-0.006	-0.028	0.544	0.286	0.056	0.061	0.138	0.234	0.669	-0.023	0.846	1.57	0.003	14.81
	(2.99)**	(3.60)**	(3.61)**	(5.00)**	(0.19)	(0.49)	(0.38)	(10.46)**	(3.32)**	(2.43)*				
M_{us}	0.002	0.121	0.258	0.798	-0.767	-0.014	0.204	0.011	-0.481	-0.087**	0.358	1.99	0.006	19.06
	(0.57)	(0.60)	(1.34)	(5.89)	(6.87)**	(0.89)	(0.82)	(1.30)	(1.14)	(2.32)*				
R_{us}	-0.018	0.801	1.379	0.507	-1.424	-0.330	-1.125	0.269	2.170	-0.139	0.524	1.82	0.010	16.80
	(2.62)**	(5.01)**	(1.41)	(8.80)**	(5.48)	(1.09)	(2.90)**	(1.48)	(3.03)**	(0.96)				
S_{w-us}	0.004	0.395	0.687	0.417	-1.354	-0.685	-0.885	-0.060	3.293	0.444	0.254	2.17	0.025	22.79
	(0.26)	(0.57)	(1.68)	(1.18)	(2.62)**	(1.20)	(0.61)	(1.27)	(2.38)*	(2.87)**				

a See notes to Table 11.

Table 14

PARAMETER ESTIMATES FOR OPEN-ECONOMY MODEL OF THE REST OF THE WORLD: 1965Q1-1984Q4[a]

Equation	Constant	$A(L)U_w$	$B(L)P_w$	$C(L)M_w$	$D(L)R_w$	$E(L)U_{us}$	$F(L)P_{us}$	$G(L)M_{us}$	$H(L)R_{us}$	$I(L)S_{w-us}$	$\bar{R}^2$	D-W	S.E.	Q(24)+
U_w	0.011	0.116†	-0.487	0.005	0.405	0.271	-0.192	0.331	-0.215	-0.012	0.356	1.93	0.012	8.72
	(1.82)**	(1.62)††	(0.89)	(0.03)	(0.81)	(2.48)*	(0.21)	(1.99)	(0.52)	(0.52)				
P_w	-0.005	0.473	1.013	-0.018	0.150	-0.028	-0.128	0.123	0.042	-0.037	0.828	2.16	0.003	34.87
	(0.30)	(2.54)*	(51.60)**	(0.80)	(1.06)	(0.76)*	(1.31)	(1.22)	(0.68)	(6.43)**				
M_w	0.043	-0.151	4.408	-1.259	-2.822	-0.271	-3.86	-0.651	1.020	-0.357	0.290	2.12	0.050	11.10
	(1.78)**	(0.163)	(4.32)**	(22.05)**	(2.32)*	(1.31)	(2.81)*	(0.71)	(0.53)	(1.03)				
R_w	-0.004	0.216	0.036	0.008	0.023	-0.050	0.0737	0.065	0.340	-0.011	0.447	1.91	0.005	17.78
	(1.50)	(3.70)**	(0.19)	(0.32)	(0.23)	(0.77)	(0.59)	(1.93)	(9.61)**	(0.72)				
S_{w-us}	0.005	0.126	-0.195	0.074	-0.091	-0.216	0.279	-0.309	0.936	0.432	0.141	1.94	0.003	12.13
	(0.39)	(0.40)	(0.04)	(2.34)*	(2.66)*	(1.90)	(2.35)*	(0.12)	(1.61)	(6.27)**				

a See notes to Table 11.

lagged domestic interest rates (R_c) now enter the money equation with a positive and statistically insignificant coefficient. Most of their influence appears to have been usurped by R_{us}.[23]

There are other instances, however, in which the addition of foreign variables seems to have enhanced the importance of domestic variables. Notable examples include M_{us} in the United States output equation and P_w in the ROW money equation. It is therefore difficult to identify any consistent pattern among the domestic variables in the closed- versus open-economy models, although the results across countries are once again very similar.

While the performance of some of the foreign variables in our equations is rather mixed, foreign interest rates and exchange rates have a strong and statistically significant impact in all the open-economy models tested. An appreciation of the exchange rate in the Canadian and U.S. models (represented by higher values of S_{c-us} and S_{w-us}) depresses domestic output, prices, and money growth (See Tables 11 and 13). A strong Canadian dollar also lowers short-term interest rates in Canada, but it is not clear how this result should be interpreted. It could reflect expectations of lower inflation following a currency appreciation, or a tendency on the part of Canadian monetary authorities to "lean against the wind" and to resist exchange rate pressures with offsetting movements in R_c.[24] A similar response is observed in the U.S. equation for R_{us}, but the coefficient on S_{w-us} is not statistically significant.

Higher foreign interest rates reduce money growth in Canada and the United States, and put upward pressure on domestic interest rates. They also cause the domestic currencies in both countries to appreciate. Although this positive reaction is difficult to explain, it is consistent with other published work which has shown that future spot rates are

---

23. Because we suspected that this result might have been caused by the choice of interest rates, the Canadian money equation was rerun with treasury bill rates and 90-day commercial paper rates substituted for the call loan rate. The same results were obtained in every case.

24. In Canada, sterilized intervention has never been considered a viable policy option, except in the very short run, as Canadian and U.S. securities are believed to be almost perfect substitutes. See Boothe et al. (1985), and Freedman (1982).

systematically misforecast by movements in international interest rates and the forward premiums on foreign exchange.[25] Alternatively, it could reflect the long interval that separates the current value of the exchange rate and lagged values of the foreign interest rate. Higher foreign interest rates may produce an immediate depreciation in the domestic currency, followed in subsequent periods by an appreciation -- as predicted by the uncovered interest parity relationship. Since the VAR system includes only lagged values of the variables on the right-hand side of each equation, it may be unable to capture this initial depreciation.

Foreign interest rates and exchange rates are less significant in the ROW model (see Table 14), but the signs on their coefficients are usually the same as those in the Canadian and U.S. models. In any case, likelihood-ratio tests indicate that the foreign variables taken as a group are significant in all three models. Therefore, none of the "countries" in our sample is adequately represented by a closed-economy specification.

The previous discussion was based on regression results obtained from models estimated over the full sample period, spanning both fixed and flexible exchange rate regimes. As noted earlier, however, the models have also been estimated over shorter samples corresponding to the most recent period of flexible exchange rates. The Canadian estimates for the shorter sample are reported in Table 12. As the reader can see, the results are not noticeably different from those reported in Table 11 for the full sample, suggesting that the major macro relationships linking the U.S. and Canadian economies have remained relatively stable throughout the 1962-84 period. Some differences can be observed in the price and exchange rate equations, but tests for structural stability cannot reject the hypothesis of no significant change between the fixed and flexible exchange rate periods. While this result was not expected, identical results were obtained for the open-economy models of the United States and ROW (see Table 15).[26]

---

25. Longworth et al. (1983), Boothe (1983), and Longworth (1985).

26. There is a possibility that the test statistics are biased towards false "non-rejection" of the stability hypothesis because of the limited number of observations in each subperiod. However, Litterman and Weiss Ibid, p. 7, claim that the bias produced by a low "observation-to-parameter ratio" actually runs in the opposite direction and favours false rejection.

Table 15

TESTS FOR PARAMETER STABILITY OF CLOSED- AND OPEN-ECONOMY MODELS

CLOSED ECONOMY		
Canada: 1962Q3 - 70Q2 vs. 1970Q3 - 84Q4		
3 lags*	$\chi^2(52) = 70.1$**	Reject stability
United States: 1962Q1 - 72Q4 vs. 1973Q1 - 84Q4		
6 lags	$\chi^2(100) = 74.4$	Accept stability
Rest of World: 1964Q1 - 72Q4 vs. 73Q1 - 84Q4		
2 lags	$\chi^2(36) = 25.5$	Accept stability
OPEN ECONOMY		
Canada/United States: 1962Q3 - 70Q2 vs. 1970Q3 - 84Q4		
2 lags	$\chi^2(76) = 70.8$	Accept stability
United States/Rest of World: 1964Q1 - 72Q4 vs. 1973Q1 - 84Q4		
1 lag	$\chi^2(40) = 41.8$	Accept stability
Rest of World/United States: 1964Q1 - 72Q4 vs. 1973Q1 - 84Q4		
1 lag	$\chi^2(40) = 34.2$	Accept stability

* Number of lags on each explanatory variable.
** Significant at the 5.0 per cent level.

Table 16

RESULTS OF GRANGER CAUSALITY TESTS

A. United States → Canada†

(1) 1962Q3 - 84Q4 (4 lags)††

$\chi^2(80) = 124.7$** Reject zero restrictions

(2) 1970Q3 - 84Q4 (2 lags)

$\chi^2(40) = 68.7$** Reject zero restrictions

B. Canada → United States

(1) 1962Q3 - 84Q4 (4 lags)

$\chi^2(80) = 95.5$ Accept zero restrictions

(2) 1970Q3 - 84Q4 (2 lags)

$\chi^2(40) = 41.0$ Accept zero restrictions

C. United States → Rest of the World

(1) 1965Q1 - 84Q4 (2 lags)

$\chi^2(80) = 69.3$** Reject zero restrictions

(2) 1973Q1 - 84Q4 (2 lags)

$\chi^2(40) = 52.9$* Reject zero restrictions

D. Rest of World → United States

(1) 1965Q1 - 84Q4 (4 lags)

$\chi^2(80) = 122.0$** Reject zero restrictions

(2) 1973Q1 → 84Q4 (2 lags)

$\chi^2(40) = 35.7$ Accept zero restrictions

† Granger causality from country x to country y.
†† (x lags) refers to the number of lags included on each explanatory variable.
* Significant at 10.0 per cent level.
** Significant at 5.0 per cent level.

As a further check on the reliability of our regression results, a number of Granger causality tests were run. The first two results reported in Table 16 (A and B) can be regarded as a kind of "acid test" of the VAR methodology, at least as it applies to the present paper. Canadian variables were added to a closed-economy model of the United States, and U.S. variables were added to a closed-economy model of Canada, in order to test the exogeneity of the domestic variables in each economy. The test results indicate that U.S. variables are highly significant in the Canadian model (i.e., the zero restrictions on the U.S. variables are strongly rejected), but that Canadian variables are not significant in the U.S. model. In terms of our earlier discussion in section 3, Canada's relationship with the United States might be characterized as one of dependence as opposed to interdependence.[27] Although these results are not very surprising, strong evidence of bidirectional causality between the two countries, or "unidirectional" causality running from Canada to the United States, would have clearly weakened the credibility of our analysis.[28]

Similar tests on the U.S. and ROW models found evidence of bidirectional causality in the full sample, and unidirectional causality running from the United States to ROW in the shorter sample. Because earlier tests could not reject structural stability over the fixed and flexible exchange rate periods, the discussion that follows concentrates on the full-sample results and assumes bidirectional causality between these two economies.

4.2.2 Variance Decompositions and Impulse Responses

The calculation of variance decompositions for open-economy models is complicated by the fact that consideration must be given to the order of

27. The terms "dependence" and "interdependence" are used only as a convenient means of classifying the causal relationships in Table 16. They are not meant to imply anything about the political or economic sovereignty of the countries in question.

28. Certain Canadian variables did have significant explanatory power in the U.S. equations. Lagged values of M_c, for example, seemed to be a reliable leading indicator of U.S. output. Taken as a group, however, the Canadian variables were insignificant.

the variables both within and across countries. In the case of Canada and the United States, the order of the variables across countries does not pose a problem since it is clear that U.S. variables should be given priority. The situation is more ambiguous in the case of the United States and ROW, however. In order to minimize any biases that might be introduced by inadvertently entering the variables in the wrong order, two sets of variance decompositions are calculated, alternatively inserting the variables from each country first.

Table 17 presents the residual correlations for Canada, the United States, and ROW. Since 0.51 is the largest value reported, the variance decompositions are not expected to be very sensitive to changes in the order of the variables.

According to the figures reported in Table 18, over 50 per cent of the forecast variance in Canadian output, prices, interest rates, and money can be attributed to innovations in foreign (U.S.) variables. Indeed, for variables R_c and P_c, the U.S. proportions exceed 60 per cent. Greater independence is observed in the flexible exchange rate period (Table 19), but the differences are not as large as one might expect, especially for nominal variables such as P_c and M_c.

It is well known that flexible exchange rates will not insulate economies from real external shocks. The primary attraction of flexible exchange rates is the independence that they presumably give policymakers with regard to controlling inflation. It would therefore seem surprising that such a large proportion of M_c variance is explained by U.S. output and interest rates. The importance of these U.S. variables in the Canadian money equation could have been caused by (i) currency substitution,[29] (ii) exchange rate targeting by the Bank of Canada,[30] or (iii) "goal and policy interdependence."[31] While there is some evidence suggesting currency substitution is statistically significant in Canadian money demand equations, it is not generally regarded as economically important. The other explanations, which focus on the objectives and

29. See Alexander (1981), McKinnon (1982, 1984), Miles (1978), and Poloz (1982).

30. Courchene (1976, 1981) and Bordo and Choudhri (1982).

31. Cooper (1984) and Freeman (1974).

Table 17

RESIDUAL CROSS CORRELATIONS FOR OPEN-ECONOMY MODELS

Canada - United States

	U_c	P_c	M_c	R_c	U_{us}	P_{us}	M_{us}	R_{us}	S_{c-us}
U_c	1.000								
P_c	-0.056	1.000							
M_c	0.172	0.201	1.000						
R_c	0.374*	0.036	-0.092	1.000					
U_{us}	0.342*	0.041	0.065	0.345*	1.000				
P_{us}	-0.091	0.091	-0.021	0.004	-0.029	1.000			
M_{us}	0.260	0.057	0.017	-0.104	0.110	-0.019	1.000		
R_{us}	0.278*	0.166	0.093	0.427*	0.431*	0.076	0.094	1.000	
S_{c-us}	0.088	-0.313*	-0.128	-0.045	-0.024	0.083	-0.074	-0.149	1.000

United States - Rest of the World

	U_{us}	P_{us}	M_{us}	R_{us}	U_w	P_w	M_w	R_w	S_{us-w}
U_{us}	1.000								
P_{us}	-0.062	1.000							
M_{us}	0.249	0.084	1.000						
R_{us}	0.490*	0.125	0.249	1.000					
U_w	0.380*	-0.147	0.212	0.188	1.000				
P_w	-0.175	0.258	0.112	-0.082	0.133	1.000			
M_w	-0.319*	-0.142	0.039	-0.027	0.011	-0.065	1.000		
R_w	0.131	0.247	0.028	0.306*	0.223*	0.373*	-0.121	1.000	
S_{us-w}	0.250	0.192	0.115	0.040	0.144	0.511*	-0.354*	0.346*	1.000

* Significant at 5.0 per cent level.

Table 18

CANADA - UNITED STATES: VARIANCE DECOMPOSITION OF PREDICTION ERRORS*
(1962Q3 - 1984Q4)

Variable	Quarter	Proportion of Error Attributed to Shocks in ... U_c	P_c	M_c	R_c	Total Can.	U_{us}	P_{us}	M_{us}	R_{us}	Total U.S.	S_{c-us}**	S.E.
U_c	1	80.7	0.0	0.0	0.0	80.7	11.7	0.8	4.7	2.1	19.3	0.0	0.107-01
	4	49.6	8.5	7.8	0.7	66.6	11.6	5.4	8.8	5.0	30.8	2.6	0.137-01
	8	30.9	8.3	7.8	0.8	47.8	20.3	6.2	7.0	13.1	46.6	5.6	0.179-01
	12	27.5	7.3	10.5	0.8	46.1	21.5	6.6	9.0	11.6	50.8	5.1	0.193-01
P_c	1	1.2	90.5	4.6	0.0	96.3	0.2	0.6	0.2	2.7	3.7	0.0	0.266-02
	4	1.5	52.0	19.1	0.4	73.0	3.4	9.4	10.3	2.4	25.5	1.5	0.442-02
	8	4.0	28.9	14.9	1.1	48.9	2.4	27.0	18.1	1.9	49.4	1.7	0.601-02
	12	3.1	21.2	12.8	0.8	37.9	3.3	32.4	22.7	2.0	60.4	1.7	0.724-02
M_c	1	2.3	0.0	92.1	4.6	99.1	0.4	0.0	0.0	0.5	0.9	0.0	0.105-01
	4	3.5	4.2	47.8	2.6	58.1	26.2	1.5	3.6	9.0	40.3	1.6	0.177-01
	8	3.7	6.4	38.6	2.4	51.1	26.2	1.8	5.1	12.3	45.4	3.5	0.200-01
	12	3.9	7.1	35.5	2.1	48.6	23.9	7.8	4.8	10.5	47.1	4.3	0.219-01
R_c	1	7.4	0.0	0.0	68.6	76.0	11.9	0.0	2.5	9.5	24.0	0.0	0.559
	4	5.9	2.9	2.1	27.2	38.1	9.2	7.2	8.6	31.9	58.1	3.8	0.912
	8	4.3	5.1	4.9	18.3	32.6	7.8	20.7	11.4	24.0	63.8	3.6	1.124
	12	3.9	4.8	6.3	16.1	31.1	9.0	21.1	11.4	23.7	65.3	3.6	1.283
S_{c-us}	1	0.2	6.4	2.3	0.2	9.1	0.0	0.9	0.4	2.4	3.7	84.8	0.743-02
	4	1.5	5.9	9.6	1.5	18.5	4.8	9.3	3.7	14.4	32.3	46.0	0.107-01
	8	1.2	5.1	13.9	1.2	21.4	16.8	9.1	4.5	11.4	41.8	34.0	0.125-01
	12	1.2	6.3	13.3	1.2	22.0	17.2	9.5	6.0	11.0	43.7	31.7	0.131-01

* Equations were estimated with 4 lags on each explanatory variable. The order of the variables in the variance decompositions was U_{us}, R_{us}, M_{us}, P_{us}, U_c, P_c, M_c, R_c, and S_{c-us}.

** The numbers across each row may not sum to 100.0 due to rounding errors.

Table 19

CANADA - UNITED STATES: VARIANCE DECOMPOSITION OF PREDICTION ERRORS*
(1970Q3-1984Q4)

Variable	Quarter	Proportion of Error Attributed to Shocks in ... U_c	P_c	M_c	R_c	Total Can.	U_{us}	P_{us}	M_{us}	R_{us}	Total U.S.	S_{c-us}**	S.E.
U_c	1	81.1	0.0	0.0	0.0	81.1	10.4	2.4	6.1	0.1	19.9	0.0	0.127-01
	4	54.9	2.8	12.7	1.0	71.4	10.8	2.6	10.4	3.1	26.9	1.6	0.159-01
	8	37.9	8.3	10.5	0.7	57.4	15.0	8.5	13.6	4.0	41.1	1.4	0.192-01
	12	33.4	8.5	10.9	0.6	53.4	14.0	12.2	14.4	4.3	44.9	1.3	0.208-01
P_c	1	9.0	86.2	3.9	0.2	99.3	0.1	0.0	0.6	0.0	0.7	0.0	0.314-02
	4	8.5	64.2	6.8	0.7	80.2	2.7	5.4	6.5	0.3	14.9	5.0	0.514-02
	8	9.9	46.4	14.3	0.5	71.1	3.0	8.5	11.4	2.2	25.1	3.8	0.615-02
	12	3.7	12.4	29.4	2.2	47.7	19.4	9.5	8.5	12.2	49.6	2.8	0.718-02
M_c	1	1.6	0.0	87.8	7.1	96.5	0.4	1.9	0.5	0.7	3.5	0.0	0.110-01
	4	3.4	8.4	41.1	2.9	55.8	19.3	2.8	6.7	11.7	40.5	3.9	0.187-01
	8	3.3	13.0	33.0	2.6	51.9	18.2	5.5	9.2	12.0	44.9	3.2	0.211-01
	12	3.7	12.4	29.4	2.2	47.7	19.4	9.5	8.5	12.2	49.6	2.8	0.231-01
R_c	1	3.1	0.0	0.0	81.7	84.4	4.8	0.8	2.1	7.6	15.3	0.0	0.799
	4	11.2	1.4	7.1	43.8	63.7	5.3	4.6	7.8	17.1	34.8	1.8	1.111
	8	9.7	3.5	9.3	36.7	59.2	6.7	4.7	10.9	16.9	39.2	1.5	1.215
	12	8.7	5.3	8.4	31.2	53.6	8.2	7.0	12.4	17.4	45.0	1.3	1.320
S_{c-us}	1	4.7	7.0	0.8	9.3	21.8	0.2	1.7	5.0	0.4	7.3	70.9	0.118-01
	4	4.2	7.9	4.7	7.8	24.6	1.4	5.9	5.3	3.1	15.7	59.7	0.148-01
	8	4.1	7.4	6.3	7.2	25.0	2.6	6.4	6.7	5.8	21.5	53.5	0.157-01
	12	4.0	8.0	6.2	6.9	25.1	3.3	6.9	7.2	6.2	23.6	51.3	0.161-01

* Equations were estimated with 2 lags on each explanatory variable. The order of the variables in the variance decompositions was U_{us}, R_{us}, M_{us}, P_{us}, U_c, R_c, M_c, P_c, and S_{c-us}.

** The numbers across each row may not sum to 100.0 due to rounding errors.

Table 20

UNITED STATES - REST OF THE WORLD: VARIANCE DECOMPOSITION OF PREDICTION ERRORS*
(1965Q1-1984Q4)

Variable	Quarter	Proportion of Error Attributed to Shocks in ...											
		U_{us}	P_{us}	M_{us}	R_{us}	Total Can.	U_w	P_w	M_w	R_w	Total ROW	S_{us-w}**	S.E.
U_{us}	1	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.110-01
	4	58.6	1.5	2.6	18.5	81.2	7.4	4.1	3.2	1.2	15.9	2.8	0.169-01
	8	44.3	2.7	7.4	13.7	68.1	5.7	8.2	3.8	6.3	24.0	8.0	0.218-01
	12	40.2	3.0	10.3	13.1	66.6	5.6	7.6	4.1	6.2	23.5	9.9	0.225-01
P_{us}	1	0.4	95.7	0.8	3.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.234-02
	4	6.5	24.4	29.5	9.4	69.8	5.2	0.8	15.1	6.4	27.5	2.8	0.466-02
	8	6.1	13.6	30.8	5.0	55.5	10.8	0.9	15.4	4.2	31.3	13.1	0.658-02
	12	6.4	12.5	26.1	4.0	49.0	10.7	1.2	11.9	6.2	30.0	21.6	0.777-02
M_{us}	1	6.2	0.0	93.1	0.7	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.463-02
	4	7.6	0.8	62.3	16.5	87.2	1.4	1.2	1.4	3.5	7.5	5.1	0.707-02
	8	8.1	3.1	57.4	15.1	83.7	2.6	1.5	2.0	3.8	9.9	6.5	0.707-02
	12	7.7	3.8	48.6	15.7	75.8	3.7	2.7	4.6	4.6	15.6	8.0	0.756-02
R_{us}	1	24.0	0.0	0.0	76.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.755
	4	15.4	0.3	15.7	47.9	79.3	3.9	3.5	8.0	2.1	17.5	3.1	1.155
	8	16.0	3.1	15.8	39.0	73.9	3.2	4.3	5.9	3.4	16.8	9.2	1.361
	12	14.7	3.7	15.5	37.7	71.6	4.2	4.2	6.2	4.8	19.4	8.9	1.449

U_w	1	14.5	1.9	1.5	0.0	17.9	82.2	0.0	0.0	0.0	82.2	0.0	0.932-02
	4	13.7	5.0	6.7	3.6	29.0	58.0	8.1	0.2	2.8	69.1	1.7	0.114-01
	8	11.1	4.4	9.9	4.4	29.8	48.9	7.5	0.9	8.4	65.7	4.5	0.137-01
	12	10.9	4.1	11.5	4.2	30.7	43.5	7.4	1.2	8.6	60.7	8.5	0.460-01
P_w	1	3.0	5.7	2.6	0.0	11.3	5.5	71.3	0.8	11.1	88.7	0.0	0.242-02
	4	3.1	3.5	15.5	1.4	23.5	13.6	39.8	2.1	16.9	72.4	4.0	0.415-02
	8	4.2	3.3	19.3	1.4	24.2	16.4	23.1	2.0	10.9	52.4	19.5	0.584-02
	12	5.6	4.8	17.3	1.1	28.8	14.5	16.5	1.5	9.2	41.7	29.5	0.736-02
M_w	1	10.2	4.1	1.2	2.2	17.7	1.0	0.0	80.2	1.1	82.3	0.0	0.356-01
	4	9.2	2.4	3.6	3.2	18.4	3.7	1.2	69.3	5.5	79.7	1.9	0.540-01
	8	9.0	3.3	4.5	3.5	20.3	6.1	2.8	62.1	5.8	76.8	2.8	0.573-01
	12	8.9	3.5	4.6	3.7	20.7	6.6	3.0	61.0	5.9	76.5	2.9	0.583-01
R_w	1	1.7	4.6	0.3	7.7	14.3	5.3	0.0	0.0	80.4	85.7	0.0	0.378
	4	3.7	3.7	12.5	28.2	48.1	8.7	1.5	1.1	38.4	49.7	2.2	0.567
	8	5.3	3.1	12.2	21.9	42.5	8.4	5.9	1.5	31.8	47.6	9.9	0.660
	12	5.4	3.6	12.6	20.5	42.1	7.9	5.8	2.1	32.2	48.0	9.9	0.697
S_{us-w}	1	6.3	5.0	0.4	0.9	12.6	0.6	17.3	4.8	9.5	31.7	55.1	0.181-01
	4	10.1	5.9	2.1	3.3	21.4	6.6	12.7	6.6	11.2	37.1	41.5	0.232-01
	8	8.9	6.7	2.5	9.9	28.0	6.9	10.7	7.5	12.9	38.0	34.0	0.268-01
	12	9.5	6.7	5.4	9.9	31.5	6.8	10.6	7.2	12.6	37.2	31.5	0.279-01

* Equations were estimated with 4 lags on each explanatory variable. The order of the variables in the variance decompositions was U_{us}, R_{us}, M_{us}, P_{us}, U_w, R_w, M_w, P_w, and S_{us-w}.

** The numbers across each row may not sum to 100.0 due to rounding errors.

Table 21

REST OF WORLD - UNITED STATES: VARIANCE DECOMPOSITION OF PREDICTION ERRORS*
(1965Q1-1984Q4)

Variable	Quarter	Proportion of Error Attributed to Shocks in ...											
		U_w	P_w	M_w	R_w	Total ROW	U_{us}	P_{us}	M_{us}	R_{us}	Total U.S.	S_{us-w}**	S.E.
U_w	1	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.932-02
	4	74.8	8.7	0.6	2.8	86.9	0.9	1.4	5.9	3.0	11.2	1.7	0.114-01
	8	63.6	8.5	1.9	8.3	82.3	0.9	1.4	7.7	3.1	13.1	4.5	0.137-01
	12	56.6	7.9	2.9	8.4	75.8	1.4	1.4	9.7	3.1	15.6	8.5	0.146-01
P_w	1	1.8	85.7	0.1	12.4	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.242-02
	4	10.0	55.0	3.6	16.0	84.6	1.4	1.4	8.2	0.4	11.4	4.0	0.415-02
	8	12.7	35.1	5.1	9.5	62.4	3.9	2.4	11.0	0.7	18.0	19.5	0.584-02
	12	10.9	26.4	5.3	10.1	52.7	4.9	2.7	9.4	0.9	17.7	29.5	0.736-02
M_w	1	0.0	0.0	88.4	1.6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.356-01
	4	5.2	0.5	77.2	5.8	88.7	0.7	3.0	4.0	1.7	9.4	1.9	0.540-01
	8	7.3	2.1	69.9	6.0	85.3	0.9	3.6	5.1	2.2	11.8	2.8	0.581-01
	12	8.1	2.2	68.3	6.2	84.8	1.2	3.5	5.1	2.5	12.3	2.9	0.581-01
R_w	1	5.0	0.0	0.0	95.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.378
	4	11.6	1.1	3.0	46.1	61.8	1.4	1.0	12.0	21.7	36.1	2.2	0.567
	8	11.5	4.8	2.9	38.3	57.5	1.9	0.9	13.0	16.7	32.5	9.9	0.660
	12	10.6	4.9	3.8	39.1	58.4	1.9	0.9	13.5	15.5	31.8	9.9	0.697

U_{us}	1	14.5	7.2	10.3	0.2	32.2	67.8	0.0	0.0	0.0	67.8	0.0	0.111-01
	4	18.5	8.3	8.9	5.8	41.5	35.4	1.0	4.4	14.8	55.6	2.8	0.169-01
	8	16.4	10.7	6.4	9.2	42.7	26.7	1.7	9.9	11.1	49.4	8.0	0.213-01
	12	15.3	9.8	7.6	8.8	41.5	24.0	1.6	12.1	10.8	48.5	9.9	0.225-01
P_{us}	1	2.2	3.6	1.1	8.2	15.1	0.0	81.8	1.1	2.1	85.0	0.0	0.234-02
	4	7.5	3.6	23.4	10.2	44.7	5.0	21.0	23.7	3.1	52.8	2.6	0.466-02
	8	13.8	3.9	20.8	5.6	44.1	4.3	11.6	24.4	2.4	42.7	13.1	0.658-02
	12	12.6	4.3	16.2	9.3	42.5	5.0	9.4	19.7	2.0	36.1	21.6	0.777-02
M_{us}	1	4.5	1.2	0.1	0.2	6.0	6.5	0.0	86.5	1.0	94.0	0.0	0.463-02
	4	3.7	1.3	0.4	4.9	10.3	7.2	1.1	60.7	15.6	84.6	5.1	0.645-02
	8	5.8	2.2	1.5	4.8	14.1	6.7	3.2	55.3	13.9	79.1	6.5	0.707-02
	12	6.0	2.3	4.3	5.1	17.7	6.4	3.2	49.2	15.4	74.2	8.2	0.756-02
R_{us}	1	3.5	4.8	0.0	7.4	15.7	17.9	0.0	0.0	66.4	84.3	0.0	0.755
	4	9.7	3.6	4.3	4.9	22.5	10.8	0.3	16.7	46.4	74.2	3.1	1.155
	8	9.5	4.6	4.2	6.4	24.7	10.5	2.1	16.5	36.9	66.0	9.2	1.361
	12	9.8	4.6	5.8	7.1	27.3	9.7	2.2	16.2	35.7	63.8	8.9	1.45
S_{us-w}	1	2.1	16.1	10.1	10.4	38.7	5.1	0.1	0.0	1.0	6.2	55.1	0.181-01
	4	9.7	11.8	11.5	10.9	43.9	5.4	1.4	2.1	5.8	14.7	41.5	0.232-01
	8	8.9	9.6	13.5	14.0	46.0	5.3	1.6	2.6	10.6	20.1	34.0	0.268-01
	12	8.8	9.2	12.1	13.5	43.6	5.5	1.8	6.3	10.5	24.1	31.5	0.279-01

* Equations were estimated with 4 lags on each explanatory variable. The order of the variables in the variance decompositions was U_w, R_w, M_w, P_w, U_{us}, R_{us}, M_{us}, P_{us}, and S_{us-w}.

** The numbers across each row may not sum to 100.0 due to rounding errors.

reactions of Canadian policymakers, represent more plausible alternatives. These issues are discussed in section 5.

Foreign variables also have a significant influence in the variance decompositions of the U.S. and ROW models (see Tables 20 and 21), but the proportion of forecast variance explained by domestic shocks is generally much higher than in Canada.[32]

The impulse-response functions for the open-economy models provide a convenient and often more effective means of presenting many of the results described above. As an alternative to examining all of the variable combinations that are contained in Tables 18 to 21, emphasis is placed on the impulse responses of Canadian and U.S. money equations. The differences observed in their responses provide some indication of the extent to which monetary policy might have been affected by international influences in the two countries.

Figure 5 compares the responses of Canadian and U.S. money to five foreign shocks. With the exception of the exchange rate shocks, the response of Canadian money is always much larger than that of U.S. money. Because these responses are based on the full-sample estimates of the Canadian and U.S. models, one might suspect that the results have been biased by Canada's experience during the fixed exchange rate period. However, the same response patterns are observed in Figure 6 when the shocks are rerun on data drawn exclusively from the flexible exchange rate period, 1970Q3-1984Q4.

The Canadian money supply appears to be much more sensitive to foreign shocks than the U.S. money supply. Figures 7 and 8 present the impulse responses of Canadian and U.S. money to domestic shocks, in both closed- and open-economy models. While the introduction of foreign variables greatly reduces the influence of R_c, U_c, and P_c on Canadian money, the response of U.S. money to R_{us}, U_{us}, and P_{us} remains virtually unchanged. Evidently, foreign shocks do not affect financial markets in the United States to the same extent that they affect those in Canada,

---

32. Although the proportions that are assigned to each country are sensitive to the order in which the countries appear, the qualitative results in Tables 20 and 21 are generally very consistent.

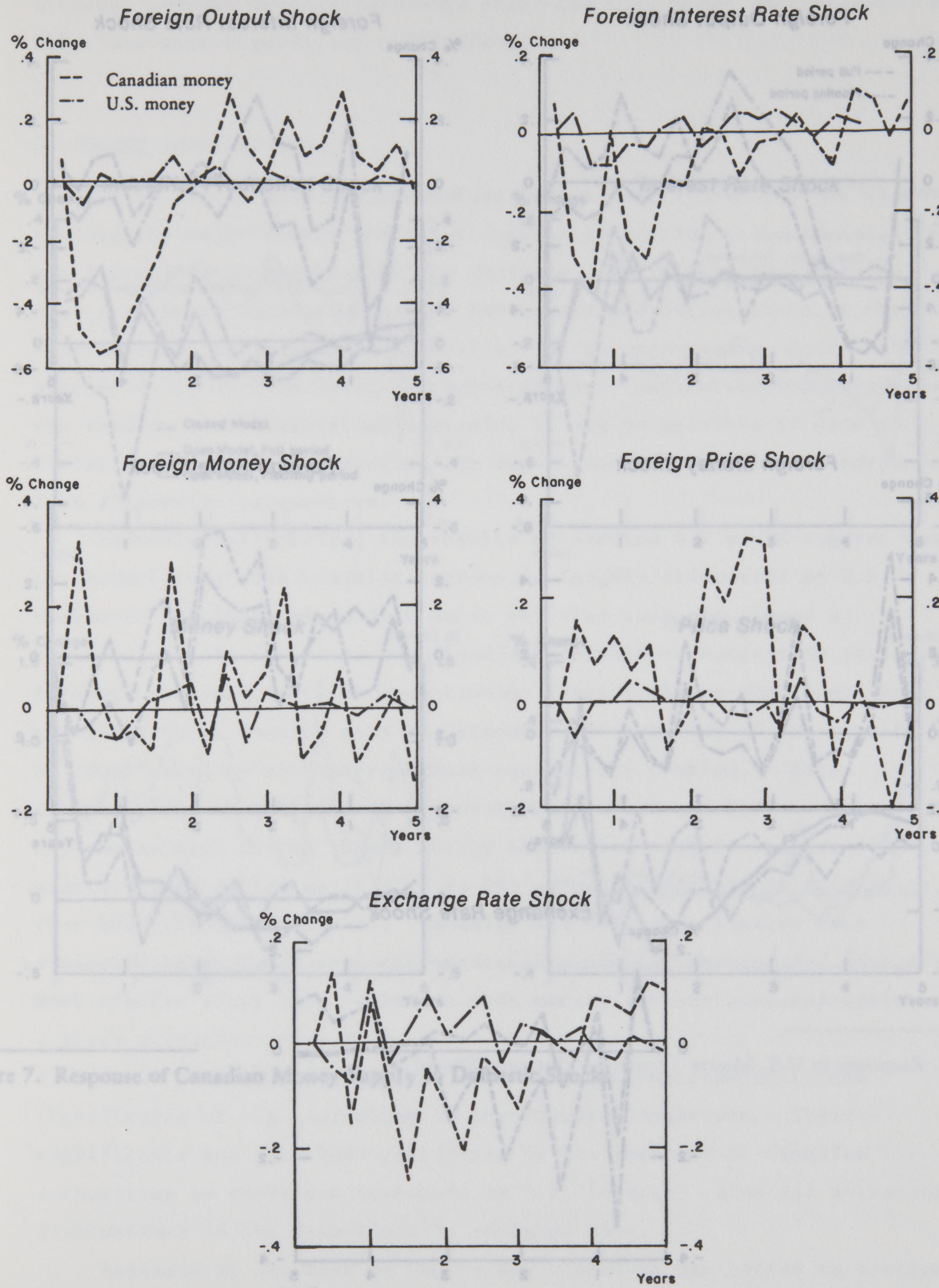

Figure 5. Response of Canadian and U.S. Money Supply to Foreign Shocks

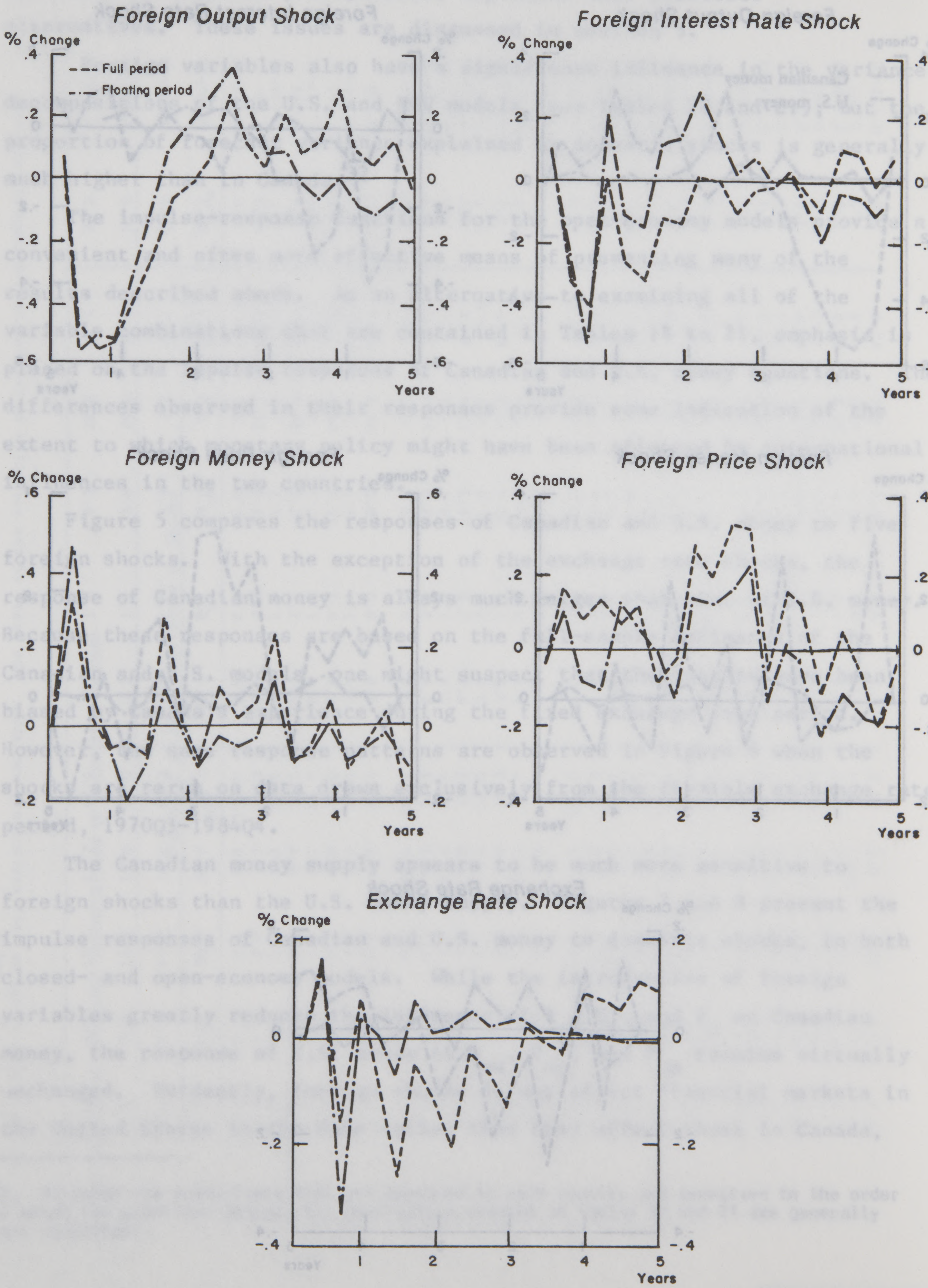

Figure 6. Response of Canadian Money Supply to Foreign Shocks

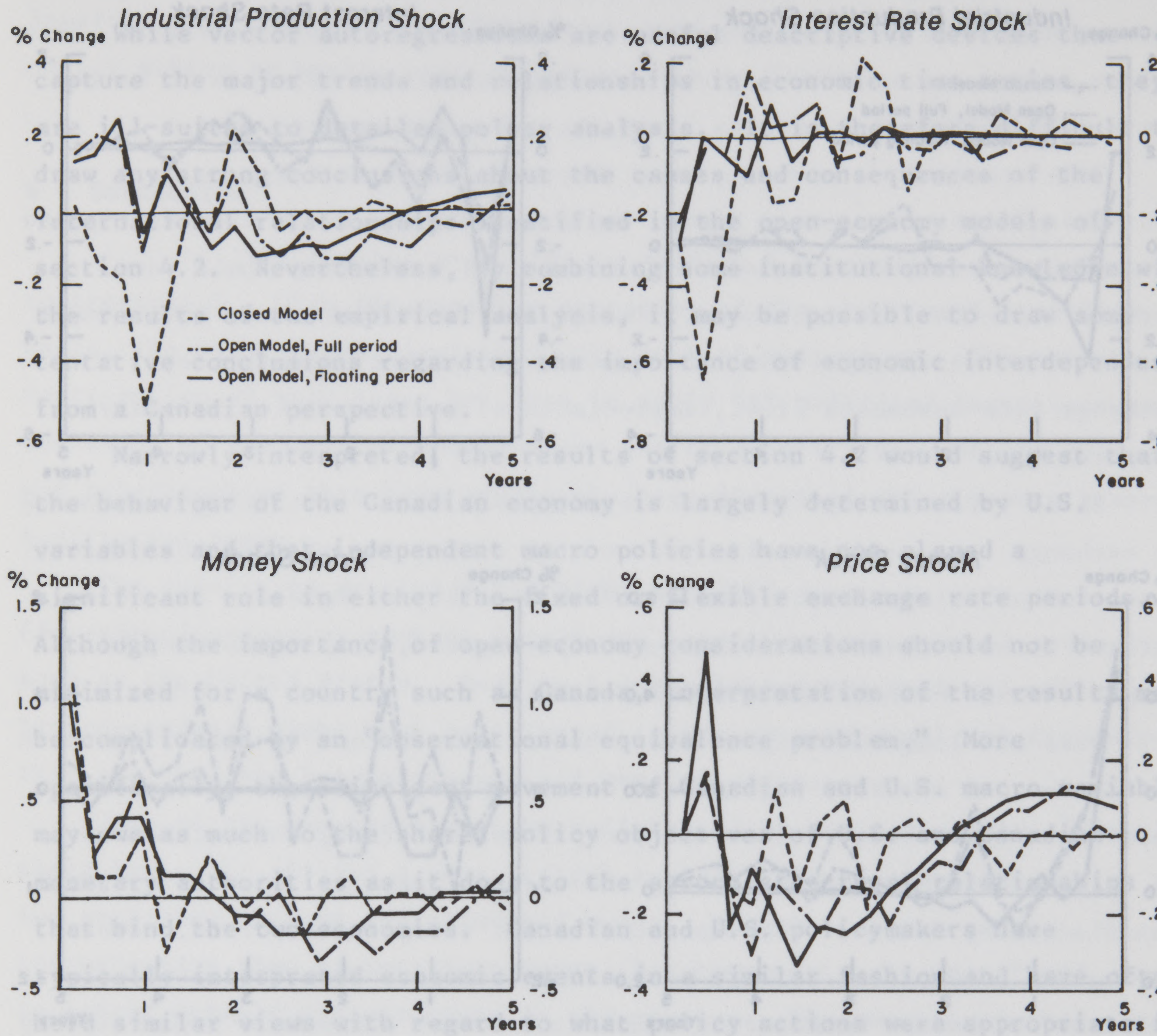

Figure 7. Response of Canadian Money Supply to Domestic Shocks

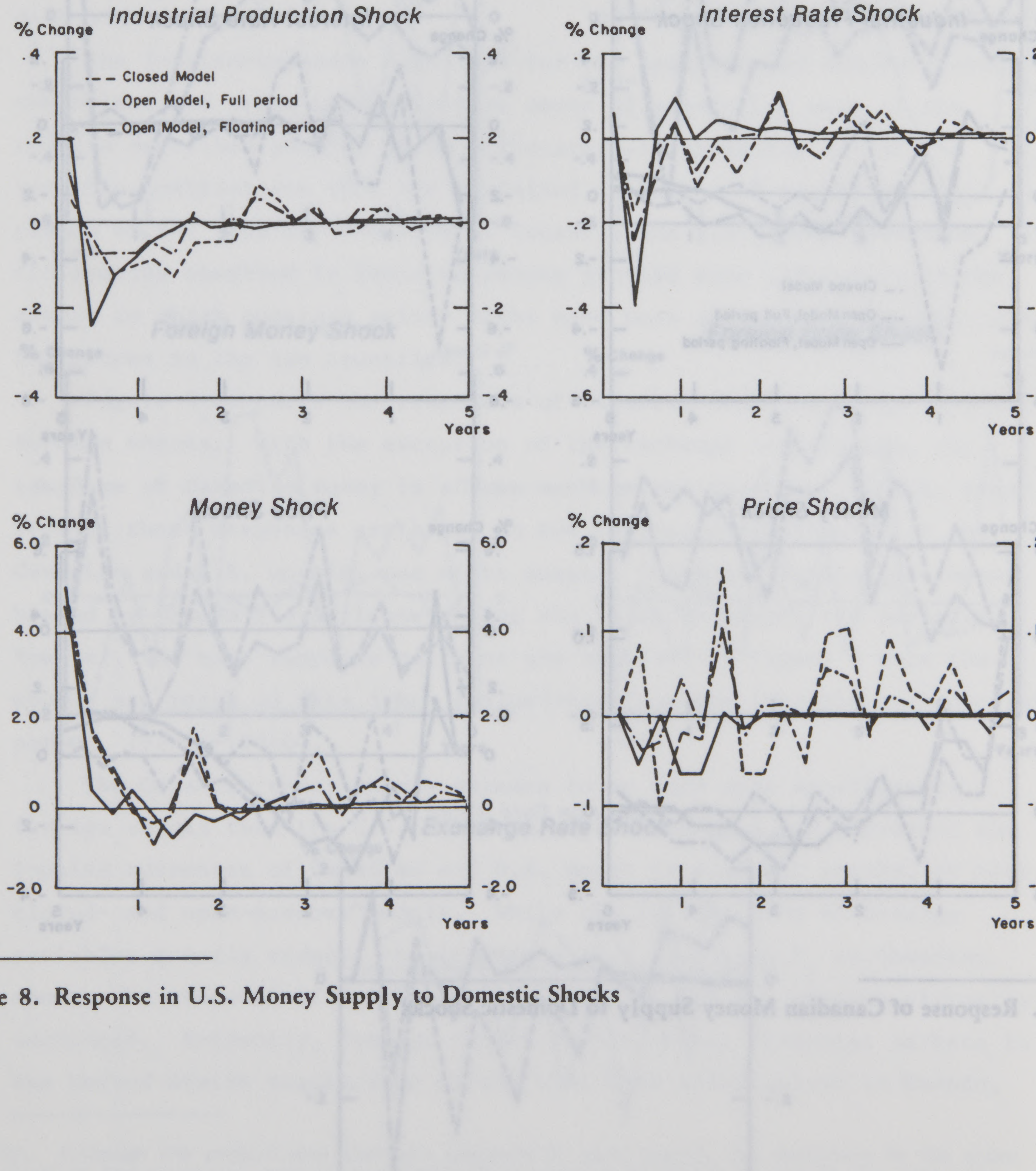

Figure 8. Response in U.S. Money Supply to Domestic Shocks

although several foreign variables enter the U.S. money and interest rate equations with significant coefficients.

5 POLICY IMPLICATIONS

While vector autoregressions are useful descriptive devices that capture the major trends and relationships in economic time series, they are ill-suited to detailed policy analysis. It is therefore difficult to draw any strong conclusions about the causes and consequences of the international relationships identified in the open-economy models of section 4.2. Nevertheless, by combining some institutional knowledge with the results of the empirical analysis, it may be possible to draw some tentative conclusions regarding the importance of economic interdependence from a Canadian perspective.

Narrowly interpreted, the results of section 4.2 would suggest that the behaviour of the Canadian economy is largely determined by U.S. variables and that independent macro policies have not played a significant role in either the fixed or flexible exchange rate periods. Although the importance of open-economy considerations should not be minimized for a country such as Canada, interpretation of the results may be complicated by an "observational equivalence problem." More specifically, the coincident movement of Canadian and U.S. macro variables may owe as much to the shared policy objectives of U.S. and Canadian monetary authorities as it does to the strong structural relationships that bind the two economies. Canadian and U.S. policymakers have typically interpreted economic events in a similar fashion and have often held similar views with regard to what policy actions were appropriate in a given situation.

These policy considerations have no doubt contributed to the significance of U.S. variables in the Canadian equations. Their significance has also been reinforced by the reaction of Canadian authorities to short-run movements in U.S. interest rates and attendant fluctuations in the Canadian/U.S. exchange rate.

Research at the Bank of Canada and elsewhere has tended to confirm the working hypothesis of many central bankers that exchange rate markets are subject to "bandwagon" effects and often appear to be driven by extrapolative expectations.[33] In a technical sense, the markets are either "irrational" or inefficient or both. This has given rise over the years to a policy reaction on the part of the Bank of Canada in which short-term exchange rate pressures caused by changes in U.S. interest rates are partially resisted by similar movements in Canadian rates. This policy is not intended to peg the exchange rate or to maintain it at an artificial level but merely to limit the amount of overshooting.

This response to exchange rate fluctuations is believed to be desirable for two reasons. First, the exchange rate is an important price in an open economy like Canada and unnecessary volatility could have serious efficiency consequences. Second, in the inflationary environment of the 1970s and early 1980s, there was concern that "unwarranted" exchange rate movements (i.e., depreciations) could fuel inflationary expectations.

It is worth noting that this strategy of "short-circuiting" movements in exchange rates and domestic prices with offsetting changes in interest rates was not inconsistent with the Bank's policy of monetary targeting. Rather, it was viewed as a complementary response, helping to keep M1 on target through much of the 1975-81 period.[34]

Over the long run many of the problems that Canada has experienced in the conduct of monetary policy have been domestic in origin rather than international. These include misperceptions concerning the natural rate of unemployment and the unsettling effects of financial innovations on Canadian money demand. One important recent exception occurred, however, during the 1984 period of high world interest rates when attempts to moderate the upward movement in Canadian interest rates were frustrated by the reactions of agents in international money markets.[35]

To summarize, the policy options of a small, open economy may not be as circumscribed as the earlier empirical evidence would indicate.

---

33. See Boothe (1983) and Longworth (1985).

34. A more detailed discussion of the "short-circuiting" concept is contained in Freedman (1982).

35. Bank of Canada Annual Report, 1984.

Although greater economic integration and international capital mobility may lead to policy complications, monetary policy remains a very potent tool whose effectiveness under normal conditions has probably been enhanced (à la Mundell), rather than diminished, by the near-perfect substitutability of Canadian and U.S. financial instruments. International economic interdependence need not preclude some independent policy action by small, open economies such as Canada.

6 CONCLUSION

The results presented in section 4 are hardly surprising or controversial. With the possible exception of the structural stability tests, the evidence is consistent with most of our priors. The primary contribution of this paper has been to apply VAR modelling techniques to the study of economic interdependence and to quantify some of the concepts and relationships that have previously been discussed only in very general qualitative terms.

The results in section 4 highlight the differences between small (dependent) economies such as Canada and large (interdependent) economies such as the United States. Section 5 demonstrated how goal and policy interdependence might have contributed to the strong causal relationships that are observed between Canada and the United States.

Many of the results have been anticipated by earlier studies,[36] but these typically offered a very partial analysis directed at only one or two variables such as inflation and money. We have taken a more comprehensive view of interdependence, but have obviously sacrificed some important details and structure in the process. The results of this study could be extended by substituting alternative proxies for some of the foreign variables in the regressions and rerunning the models on monthly data. Higher frequency data would allow the short-run dynamics of the models to be examined in greater detail and would provide more degrees of

---

36. See for example Batten and Ott (1985), Bordo and Choudhri (1982), Choudhri (1983), and Burbidge and Harrison (1983).

freedom if shorter lag lengths were accepted in the monthly specifications. This in turn would improve the efficiency of the estimates and allow experimentation with additional variables, including improved fiscal proxies.

REFERENCES

Abrams, R.K. and G.H. Sellon (1983). "Monetary Control: A Comparison of the U.S. and Canadian Experiences, 1975-1979." Mimeo, IMF, December.

Alexander, W.E. (1981). "Foreign Influences on the Demand for Money in an Open Economy: The Canadian Case." *Monetaria*, vol. 4, no. 1, January/March, pp. 17-38.

Bank of Canada (1984). *Annual Report*.

Batten, D.S. and R.W. Hafer (1984a). "Currency Substitution and the Link Between Money and GNP in the U.S.: 1972-83." Mimeo, Federal Reserve Bank of St. Louis.

Batten, D.S. and R.W. Hafer (1984b). "The Impact of International Factors on U.S. Inflation: An Empirical Test of the Currency Substitution Hypothesis." Mimeo, Federal Reserve Bank of St. Louis.

Batten, D.S. and M. Ott (1985). "The Interrelationship of Monetary Policies Under Floating Exchange Rates." *Journal of Money, Credit and Banking*, vol. 17, February, pp. 103-110.

Boothe, P.M. (1983). "Speculative Profit Opportunities in the Canadian Foreign Exchange Market, 1974-78." *Canadian Journal of Economics*, vol. 16, no. 4, November, pp. 603-11.

Boothe, P.M.; K. Clinton; Agathe Côté; and D. Longworth (1986). *International Asset Substitutability: Theory and Evidence for Canada*, Bank of Canada, Ottawa.

Bordo, M.D. and E.U. Choudhri (1982). "The Link Between Money and Prices in an Open Economy: The Canadian Evidence from 1971 to 1980." *Review*, Federal Reserve Bank of St. Louis, vol. 64, no. 7, August/September, pp. 13-23.

Burbidge, J. and A. Harrison (1983). "(Innovation) Accounting for U.S.-Canada Business Cycles." Mimeo, McMaster University.

Choudhri, E.U. (1983). "The Transmission of Inflation in a Small Economy: An Empirical Analysis of the Influence of U.S. Monetary Disturbances on Canadian Inflation, 1962-80." *Journal of International Money and Finance*, vol. 2, August, pp. 167-178.

Cooper, R.N. (1984). "Economic Interdependence and Coordination of Economic Policies." In *Handbook of International Economics*, Vol. II, R.W. Jones and P.B. Kenen (eds.), pp. 1195-1234.

Courchene, T.J. (1976). Money, Inflation, and the Bank of Canada, Vol. 1: An Analysis of Canadian Monetary Policy from 1970 to Early 1975, Montreal, C.D. Howe Research Institute.

Courchene, T.J. (1981). Monetary Inflation and the Bank of Canada, Vol. 2: An Analysis of Monetary Gradualism, 1975-80, Montreal, C.D. Howe Research Institute

Daniel, B.C. and H.O. Fried (1983). "Currency Substitution, Postal Strikes and Canadian Money Demand." Canadian Journal of Economics, vol. 16, no. 4, November, pp. 112-24.

Dicky, D.A. and Fuller, W.A. (1979). "Distribution for the Estimators for Autoregression Time Series with a Unit Root." Journal of the American Statistical Association, vol. 74, pp. 427-431.

Doan, T. and R. Litterman (1980). User's Manual Rats Version 4.v., VAR Econometrics.

Driskill, R.A. and S.M. Sheffrin (1985). "The 'Patman Effect' and Stabilization Policy." The Quarterly Journal of Economics, February pp. 149-163.

Fackler, J.S. (1985) "An Empirical Analysis of the Markets for Goods, Money, and Credit." Journal of Money, Credit and Banking, vol. 17, February, pp. 28-42.

Freedman, C. (1982), "The Effect of U.S. Policies on Foreign Countries: The Case of Canada." in Monetary Policy Issues in the 1980's, a symposium sponsored by the Federal Reserve Bank of Kansas City, pp. 97-118.

Freedman, C. (1983). "Financial Innovation in Canada: Causes and Consequences." American Economic Review, vol. 73, no. 2, May, pp. 101-106

Freeman, G. (1974). "International Inflation: Four Commentaries." Economic Perspectives, Federal Reserve Bank of Chicago, July.

Gordon, R.J. and S.R. King (1982). "The Output Cost of Disinflation in Traditional and Vector Autoregressive Models." Brookings Papers on Economic Activity, vol. 1, pp. 205-242.

Litterman, R.B. and L. Weiss (1983). "Money, Real Interest Rates, and Output: A Reinterpretation of Postwar U.S. Data." NBER Working Paper # 1077.

Longworth, D.; P.M. Boothe; and K. Clinton (1983). A Study of the Efficiency of Foreign Exchange Markets, Bank of Canada, Ottawa.

Longworth, D. (1985). "Exchange Market Efficiency." Economic Letters, 8, Nos. 2 & 3, pp. 247-249.

Masson, P. and A. Blundell-Wignall (1985). "Fiscal Policy and the Exchange Rate in the Big Seven: Transmission of U.S. Fiscal Shocks." European Economic Review, vol. 28, no. 1-2, pp. 11-42.

McKinnon, R.I. (1982). "Currency Substitution and Instability in the World Dollar Standard." American Economic Review, vol. 72, no. 3, pp. 320-33.

McKinnon, R.I. (1984). An International Standard for Monetary Stabilization. Institute for International Economics, Washington, D.C.

Miles, M.A. (1978). "Currency Substitution, Flexible Exchange Rates, and Monetary Independence." American Economic Review, vol. 68., no. 3, pp. 428-36.

Nelson, C.R. and H. Kang (1984). "Pitfalls in the Use of Time as an Explanatory Variable in Regression." Journal of Business and Economic Statistics, vol. 2, no. 1, pp. 73-82.

Nelson, C.R. and C.I. Plosser (1982). "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications." Journal of Monetary Economics, vol. 10, no. 2, pp. 139-162.

Offenbacher, E.K. and R.D. Porter (1983). "Empirical Comparisons of Credit and Monetary Aggregates Using Vector Autoregression Methods." Special Studies Paper No. 181, Federal Reserve Board, Washington.

Poloz, S. (1982). "Unstable Velocity, Volatile Exchange Rates, and Currency Substitution: The Demand for Money in a Multicurrency World." Unpublished doctoral thesis, University of Western Ontario.

Sims, C.A. (1980a). "Comparison of Interwar and Postwar Business Cycles: Monetarism Reconsidered." American Economic Review, vol. 70, no. 2, May, pp. 250-257.

Sims, C.A. (1980b). "Macroeconomics and Reality." Econometrica, vol. 48, no. 1, pp. 1-48.

Thiessen, G.G. (1982). "The Canadian Experience with Monetary Targeting." in Central Bank Views on Monetary Targeting, Federal Reserve Bank of New York, pp. 100-105.

Thornton, D.L. and D.S. Batten (1985). "Lag-Length Selection and Tests of Granger Causality Between Money and Income." Journal of Money, Credit and Banking, vol. 17, May, pp. 164-178.

Printed in Canada Imprimé au Canada