The role of exchange rate flexibility in the international transmission of inflation in long and shorter runs: Canada, 1953 to 1981

STANLEY L. WINER Carleton University

Abstract. This paper investigates the role of exchange rate flexibility in the transmission of inflation from the United States to Canada, using measures of linear feedback due to John Geweke. The results suggest exchange flexibility after 1972 was sufficient to insulate the secular rate of inflation in Canada against nominal shocks of U.S. origin. Methodologically, the paper illustrates the biases introduced in the present context by the failure to distinguish between real and nominal shocks and between long- and shorter-run transmission. The importance of treating the 1970 to 1972 period as a distinct exchange regime is also demonstrated.

Le rôle de la flexibilité du taux de change dans la transmission internationale de l'inflation en courte et en longue périodes: Canada (1953-81). Ce mémoire analyse le rôle de la flexibilité du taux de change dans la transmission de l'inflation des Etats-Unis vers le Canada en utilisant les mesures de rétroaction linéaire de John Geweke. Les résultats suggèrent que la flexibilité du taux de change après 1972 a été suffisante pour protéger le taux séculaire d'inflation au Canada contre les chocs enregistrés dans les agrégats nominaux de l'économie américaine. Sur le plan méthodologique, ce mémoire illustre les biais qu'on introduit dans l'analyse quand on ne distingue pas entre les chocs dans les agrégats nominaux et réels et entre le courte et la longue période. On montre aussi l'importance de traiter la période 1970-2 comme une période de régime de taux de change distinct.

The first draft of this paper was written while the author was on leave at Carnegie-Mellon University. The hospitality of the Graduate School of Industrial Administration and the financial support of a Social Sciences and Humanities Research Council of Canada leave fellowship are gratefully acknowledged. Helpful comments were provided by John Geweke, Michael Bordo, Ehsan Choudhri, Jean-Marie Dufour, Robert Hodrick, four referees for this journal, and participants in seminars at the Bank of Canada and Carleton, McMaster, and Queen's Universities. The author is responsible for all remaining errors and omissions.

Canadian Journal of Economics Revue canadienne d'Economique, XIX, No. 1
February février 1986. Printed in Canada Imprimé au Canada

0008-4085 / 86 / 62-86 $1.50 © Canadian Economics Association

INTRODUCTION

This paper uses recently developed measures of linear feedback, due to John Geweke (1982a, 1983a, 1984), to investigate the role of exchange rate flexibility in the transmission of inflation from the United States to Canada. The focus of attention is on the float of the 1970s, although the relationship between Canadian and U.S. rates of inflation during the float of the 1950s and during the fixed rate period of the 1960s will also be considered.

Recent evidence on the latest de jure floating rate experience in Canada (1970:2 to date) offered by Michael Bordo and Ehsan Choudhri (1982) and Choudhri (1983) suggests that exchange flexibility did not play a significant role in the determination of Canadian inflation in the 1970s. Bordo and Choudhri attribute this result to a policy by the Bank of Canada of moving short-term interest rates in the same direction as U.S. interest rates in order to avoid large fluctuations in the exchange rate.[1] This description of the Bank's behaviour accords with that of Thomas Courchene (1976a) for the earlier part of the decade, although there are indications that at least by 1976 the Bank's approach to monetary policy was more consistent with the theoretical rationale for flexible exchange rates (Courchene, 1976b).

The case for a flexible exchange regime rests to a large extent on its potential for blocking the transmission of foreign nominal disturbances (Friedman, 1953). For example, in the textbook 'monetary' model of exchange determination with complete price flexibility and efficient markets (such as in Bilson, 1978), a permanent foreign nominal shock causes an instantaneous and offsetting change in the domestic currency price of foreign exchange, thus insulating domestic prices.

A flexible rate cannot be expected to insulate an open economy against all external shocks even with full price flexibility, however, and any study of the role of the exchange rate in the international transmission of inflation must be at least as cognizant of the theoretical limitations of a flexible regime as of its virtues. It is well known that a flexible rate will not prevent transmission of real disturbances (Friedman, 1953; Mussa, 1976). For this reason it is important to seek the cause of inflation when studying the insulating properties of a flexible rate. Real shocks to the U.S. economy that influence the rate of inflation there may have similar consequences for real output and prices in Canada, regardless of exchange regime, because the output and capital markets of the two countries are highly integrated.

Moreover, exchange flexibility may not always prevent the transmission of

1 Such a policy might induce expectations of stable or, in effect, fixed exchange rates and hence permit U.S. prices to influence Canadian prices via the pricing of tradeable goods. Moreover, Bordo and Choudhri note that a policy of adjusting Canadian monetary growth to keep Canadian interest rates in line with those in the United States creates a direct link between monetary growth in the two countries (to the extent that changes in U.S. interest rates are the result of changes in U.S. monetary growth). On this last point, see also Knight and Mathieson (1983).

foreign nominal disturbances in the short run. Thus it is necessary to distinguish between long and shorter time horizons in order to reach conclusions about the insulation afforded the domestic economy by a flexible rate regime. Factors underlying the causes and nature of short-run transmission in recent analyses (reviewed, for example, by Mussa, 1979; Marston, 1983; and Krueger, 1983) include (1) the short-run foreign real consequences of unanticipated foreign nominal shocks; (2) the degree of domestic wage indexation; (3) the precise nature of short-run exchange rate expectations; and (4) the speed of adjustment of asset markets and the exchange rate relative to that of goods markets and the general price level. For example, even in the absence of exchange intervention by the Canadian authorities, an unexpected change in U.S. money growth may in the short run alter real U.S. interest rates, change real demands for U.S. and Canadian goods, and thereby influence U.S. and Canadian prices at more or less the same time.

This paper attempts to determine the role of exchange flexibility in the transmission of inflation *after* due allowance for the sources of inflation and the distinction between long-run and shorter-run transmission. The second section of the paper briefly introduces the measures of linear feedback used in this investigation and discusses their application in the present context. A complete development of the relevant statistical theory can be found in the work of Geweke cited above. The results themselves are discussed in the third section, and conclusions are summarized in a final section.

METHODOLOGY

Let us begin with some notation. Let $W = \{w_t, t \text{ integer}\}$ be a wide-sense stationary, multiple time series and suppose that w_t has been decomposed into subvectors x_t, y_t and z_t, $w_t = (x_t, y_t, z_t)$, reflecting an interest in relationships between $X = \{x_t, t \text{ integer}\}$, $Y = \{y_t, t \text{ integer}\}$, and $Z = \{z_t, t \text{ integer}\}$. Let $W_{t-1} = \{w_{t-s}, s = 1, 2, \ldots\}$ and adopt a similar notation for the subvectors. Under certain conditions the autoregressive representations for each subvector will exist.[2] Define then

$$\Sigma_1 = \text{var}(x_t|X_{t-1}),\ \Sigma_2 = \text{var}(x_t|X_{t-1}, Y_{t-1}),$$

$$T_1 = \text{var}(y_t|Y_{t-1}),\ T_2 = \text{var}(y_t|Y_{t-1}, X_{t-1}),$$

and

$$P = \text{var}(w_t^{+}|W_{t-1}^{+}),$$

where $W_t^{+} = (x_t, y_t)$.

Here, for example, Σ_1 is the variance of the innovation in the linear projection

2 The existence of these autoregressive representations is discussed in Geweke (1982a, 304).

$$x_t = \alpha + \sum_{s=1}^{\infty} E_{1s} x_{t-s} + u_{1t}, \tag{1}$$

$\Sigma_2 = \text{var}(u_{2t})$ in the linear projection

$$x_t = \beta_0 + \sum_{s=1}^{\infty} E_{2s} x_{t-s} + \sum_{s=1}^{\infty} F_{2s} y_{t-s} + u_{2t}, \tag{2}$$

P is the variance-covariance matrix of the vector autoregression of $w_t^{\,+}$ on $W_{t-1}^{\,+}$ (consisting of equation (2) and the projection of y_t on Y_{t-1} and X_{t-1}), and so on.

Measures of linear unconditional feedback from Y to X, from X to Y, and instantaneous feedback are defined as

$$F_{Y\to X} = \ln(\,|\Sigma_1|/|\Sigma_2|\,),$$
$$F_{X\to Y} = \ln(\,|T_1|/|T_2|\,) \text{ and } F_{X\cdot Y} = \ln(\,|\Sigma_2|\cdot|T_2|/|P|\,), \tag{3}$$

where $|\cdot|$ refers to the determinant of the indicated matrix. All these measures are non-negative and can be interpreted in terms of the proportionate decrease in the variance of one-step-ahead forecast errors. For example, $1 - \exp(-F_{Y\to X})$ is the proportionate reduction in the predictive variance of X that may be achieved using past Y *in addition* to past X (as in equation (2)) in prediction of current X. $F_{X\cdot Y}$ is a monotonic function of the proportionate reduction in forecast error that results when current values of Y are used in addition to lagged X and Y in forecasts of the current value of X.

It is of interest to note that measures of feedback can be used to test for Granger-causality (Granger, 1969), although this is not of direct interest in this paper. The statement $F_{Y\to X} = 0$ is equivalent to the statement that Y does not Granger-cause X. Note also that the concept of feedback is consistent with situations in which feedback is bidirectional; it may be the case that both $F_{Y\to X} \neq 0$ and $F_{X\to Y} \neq 0$.

Measures of conditional feedback can be defined in a similar manner. (Geweke, 1984). Let Z_{t-1} be the information or conditioning set at time t. Then the conditional feedback analog to $F_{Y\to X}$ is

$$F_{Y\to X|Z_{t-1}} = \ln\{\,|\text{var}(x_t|X_{t-1}, Z_{t-1})\,|/|\text{var}(x_t|W_{t-1}^{\,+}, Z_{t-1})\,|\,\}$$
$$= F_{YZ\to X} - F_{Z\to X}. \tag{4}$$

The definitions of $F_{X\to Y|Z_{t-1}}$ and of $F_{X\cdot Y|Z_{t-1}}$ can be similarly formed from the definitions of $F_{X\to Y}$ and $F_{X\cdot Y}$ by the introduction of the conditioning set Z_{t-1} and will not be stated here. Like its unconditional counterpart, $F_{Y\to X|Z_{t-1}}$ can be interpreted in terms of the reduction in forecast error. If X is forecast one step ahead using the linear projection of x_t on X_{t-1} and Z_{t-1}, then when Y_{t-1} is added to the projection set the proportionate reduction in the generalized variance of the mean square forecast error is $1 - \exp(-F_{Y\to X|Z_{t-1}})$.

Decomposition of feedback by frequency

The decomposition of feedback by frequency permits a distinction to be made between the long-run and the short-run association of related time series. Assuming that the autoregressive representations for any subvector of W_t can be inverted, the following moving average representation of x_t (in the joint MA representation of x_t and y_t) can be shown to exist (Geweke, 1982a):

$$x_t = P(L)u_{2t} + Q(L)v_{3t}, \tag{5}$$

where $P(L)$ and $Q(L)$ are polynomials in the lag operator L, $\text{cov}(u_{2t}, v_{3t}) = 0$, and v_{3t} is the innovation in the linear projection of y_t on x_t, X_{t-1} and Y_{t-1}:

$$y_t = \delta + \sum_{s=0}^{\infty} H_{3s}x_{t-s} + \sum_{s=1}^{\infty} G_{3s}y_{t-s} + v_{3t};\ \text{var}(v_{3t}) = T_3. \tag{6}$$

In the $X - Y$ system of (2) and (6), and therefore in (5), v_{3t} may be unambiguously interpreted as new information entering this system at time t arising from Y rather than from X.

Using (5), the spectral density of x_t at frequency λ can be written as

$$S_x(\lambda) = \tilde{P}(\lambda)\Sigma_2\tilde{P}(\lambda)' + \tilde{Q}(\lambda)T_3\tilde{Q}(\lambda)', \tag{7}$$

where a tilde denotes a Fourier transform of the indicated lag operator. The measure of feedback from Y to X at frequency λ is then defined to be

$$f_{Y\rightarrow X}(\lambda) = \ln(\,|S_x(\lambda)\,|/|\tilde{P}(\lambda)\Sigma_2\tilde{P}(\lambda)'|\,). \tag{8}$$

This non-negative measure reflects the relative importance of the contributions of u_{2t} and v_{3t} to the variance in X at frequency λ. It approaches infinity at a given frequency as the relative contribution of the variance in the innovation in Y to the variance of X increases at that frequency. Furthermore, provided that $I - \Sigma_{s=0}^{\infty} G_{3s}L^s$ is invertible, a condition always met in the empirical work reported here, it can be shown that

$$F_{Y\rightarrow X} = (1/2\pi)\int_{-\pi}^{\pi} f_{Y\rightarrow X}(\lambda)d\lambda. \tag{9}$$

Hence $f_{Y\rightarrow X}(\lambda)$ provides a decomposition of feedback by frequency and indicates the relative importance of variance in v_{3t} at different frequencies in explaining feedback from Y to X.

It is also the case that

$$F_{Y\rightarrow X|Z_{t-1}} = (1/2\pi)\int_{-\pi}^{\pi} f_{Y\rightarrow X|Z_{t-1}}(\lambda)d\lambda, \tag{10}$$

so that the conditional feedback has a similar interpretation; $f_{Y\rightarrow X|Z_{t-1}}(\lambda)$ indicates the relative importance at frequency λ of variance in the innovation in Y in explaining feedback from Y to X, after the influence of Z_{t-1} on X has been 'appropriately' accounted for.[3] Similar remarks apply to the decomposition by frequency of $F_{X \rightarrow Y}$ and $F_{X \rightarrow Y|Z_{t-1}}$.

Feedback by frequency may be related analytically to the long and short runs of economic theory in the following sense (Geweke, 1983a). Suppose that realizations of W were replicated (in the same way that a model can be replicated) while constraining the innovations in X, Y, and Z to follow cosine waves of specified frequency but random phase and amplitude. The measures $f_{Y \rightarrow X}(\lambda)$ and $f_{Y \rightarrow X|Z_{t-1}}(\lambda)$ are monotonically increasing functions of the explained sum of squares in a regression equation explaining variation in X across replications by this random phase and amplitude. When this explained sum of squares is high at low (high) frequencies, we say that there is a strong long-run (short-run) relationship between innovations in Y and variations in X. The operational definition of 'long run' being used here corresponds to 'that which is permanent (cosine waves of low frequency) relative to that which is more temporary (cosine waves of high frequency).'

The feedback at zero frequency, or equivalently at infinite periodicity, is of particular interest: here the experiment corresponds to random assignment of means in the disturbance to Y (given Z_{t-1}). Thus, the outcome $f_{Y \rightarrow X}(0) = 0$ (or $f_{Y \rightarrow X|Z_{t-1}}(0) = 0$) is equivalent to the comparative static result that a change in the mean of Y produces no change in the mean of X (given Z_{t-1}). In other words, in the appropriate *long-run* reduced form for X, the coefficient on Y is zero (but see McCallum, 1984). The critical importance of feedback at zero frequency to investigation of the role of exchange flexibility in the transmission of inflation is discussed below.

Diagrammatic exposition

To complete the introduction to measures of feedback, figure 1 illustrates the meaning of F and f diagrammatically and in the more familiar time domain (Geweke, 1982c). This figure shows a situation involving 'weak' overall feedback from Y to X (i.e., $F_{Y \rightarrow X}$ is small), together with a 'strong' feedback at high frequencies (i.e., $f_{Y \rightarrow X}$ at high frequencies is large). In the diagrams, u_{2t} represents the direct shock to x_t (as in equation (2)), and v_{3t} is the direct shock to y_t which affects x_t indirectly through lagged values of y_t (as in equation (6)). These shocks are serially uncorrelated, hence their rough pattern. As indicated by the moving average representation of x_t, $x_t = P(L)u_{2t} + Q(L)v_{3t}$, the model smooths the shock u_{2t} and roughens the shock v_{3t}. Clearly longer swings in X are due to its own shock u_{2t}, so $F_{Y \rightarrow X}$ will be small. In other words, in this example it is evidently not very important to use the past history of Y to predict 'longer-run' swings in X. The past history of X alone will serve well for that purpose. But 'short-run' or high frequency movements in X are shown to be due to the shock to y_t. Hence $f_{Y \rightarrow X}$ at high frequencies will be substantial.

3 See Geweke (1984) for the exact meaning of 'appropriately' in this context. Note that it is not the case that $f_{Y \rightarrow X|Z_{t-1}}(\lambda) = f_{YZ \rightarrow X}(\lambda) - f_{Z \rightarrow X}(\lambda)$.

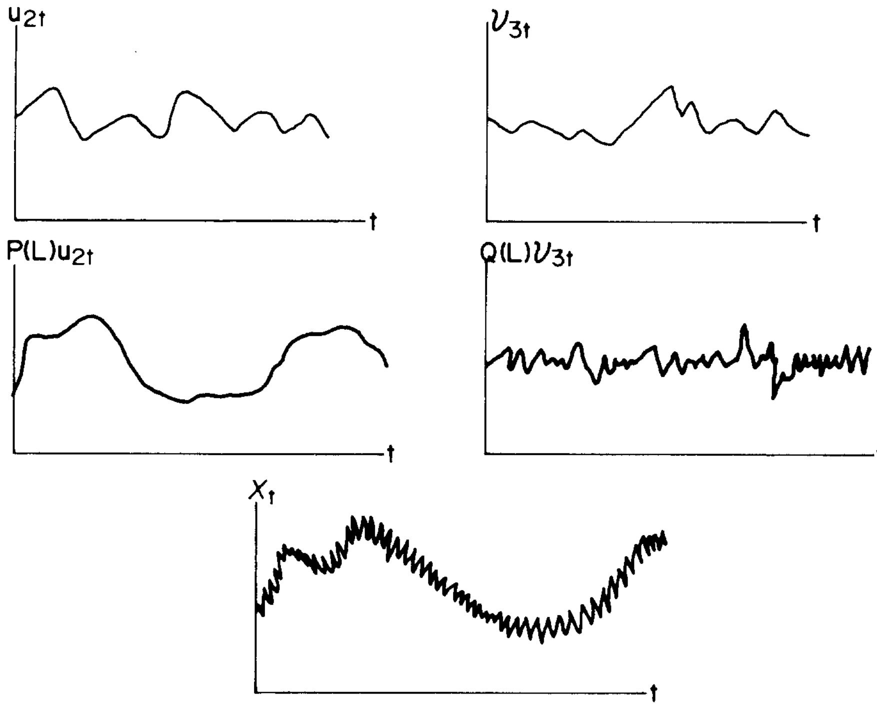

FIGURE 1. Time domain representation

Application to the study of the international transmission of inflation
This paper presents new evidence on the transmission of inflation from the United States to Canada based on estimation of $F_{P \to P^*}$ and $F_{P \to P^* | Y,Y^*}$ and their decomposition by frequency, where P^* and P are respectively the first differences in logs of the U.S. and Canadian GNE deflators and Y^* and Y are, respectively, the first differences in logs of U.S. and Canadian real GNP. The untransformed data are seasonally adjusted, quarterly series.[4]

In keeping with the philosophy underlying the use of feedback measures, no a priori assumptions about the strength of feedback from P to P^* are imposed on the estimates, even though this feedback is expected to be small, and estimates of feedback from Canadian to U.S. prices are also reported in some of the tables.

4 All data are from the CANSIM or the CITIBASE data bases circa June 1982. The data are available from the author on request. Sources are: P – CANSIM D40625; P^* – CITIBASE GD; Y – CANSIM D40593; Y^* – CITIBASE GNP72. Other data referred to in the text below include U.S. M1 – CITIBASE FMS/FMIB after 1958; and Canadian dollars per \$U.S. – CITIBASE EXRCAN.

The use of GNE deflators rather than wholesale or consumer price indexes follows Kravis and Lipsey (1978). The choice of the quarterly time period reflects a balance between the need for degrees of freedom on the one hand, and, on the other, a desire to avoid the necessity of coping with the limitations of monthly CPIs and industrial production indexes.

A comparison of $F_{P^* \to P}$ and $F_{P^* \to P|Y,Y^*}$ over all and across frequencies will illustrate the importance of controlling for the source of inflation when studying its transmission under flexible rates. As argued above, it is important to hold constant, or condition on, foreign real activity, since a flexible exchange rate will, at most, block transmission of foreign nominal disturbances. Domestic real activity must also appear in the conditioning set (under flexible rates), since changes in Y may either reinforce or offset the domestic inflationary consequences of foreign nominal shocks. Moreover, for a similar reason, both Y and Y^* must be in the conditioning set under fixed rates: for example, positive transmission of nominal disturbances under fixed rates could be hidden under the effects of simultaneously occurring real shocks. Indeed, it turns out that not conditioning on Y and Y^* leads to a substantial underestimate of the influence of U.S. on Canadian prices during the fixed rate period of the 1960s.

Note that foreign nominal shocks are represented here by P^* given Y^* rather than by M^* (the first difference in logs of the U.S. money stock) given Y^*. Use of M^* does not capture the effects on U.S. prices of structural shifts or errors in portfolio choice equations including the demand for money. In any case, the conclusions stated below appear to remain essentially the same whichever variable is used.[5]

The decomposition by frequency permits a distinction to be made between the short run and the long run in the feedback from P^* to P. As was previously argued, this is essential to the study of the insulation afforded by a flexible rate, because there are several theoretical reasons why flexibility can not be expected to block completely transmission of foreign nominal shocks in the short run. The crucial test of the insulating property of a flexible rate regime is whether or not it has succeeded in blocking transmission in the long run. Thus estimation of conditional feedback at the zero frequency, $f_{P^* \to P|Y,Y^*}(0)$, is critical to consideration of the insulating property of flexible rates. The statement that this feedback is zero is equivalent to the statement that, given real activity in both the United States and Canada, changes in the mean or long-run rate of inflation in the United States do not help to predict changes in the mean or long-run rate of inflation in Canada.[6] This is a result we should observe if a flexible rate does what it is supposed to in the long run, regardless of the strength of feedback at non-zero frequencies.

ESTIMATION PERIODS, LAG LENGTH, COMPUTATION, AND RESULTS

The basic classification of exchange regimes used in the empirical work

5 This statement is based on an investigation using a lag length of four quarters, which is the most general lag structure (i.e., the longest lag) the data reasonably permit.

6 It should be noted that the absence of feedback at the zero frequency is not equivalent to the statement that the coefficients on lagged U.S. prices are, as a group, insignificant in an explanation of current Canadian prices. Rather, it is analogous to the statement that the sum of these coefficients is zero in the long-run reduced form for Canadian prices.

reported below is 1953:2 to 1962:1 – a flexible period; 1962:3 to 1970:1 – a fixed rate period; and 1973:1 to 1981:4 – a flexible period.[7] The quarters in which there was a de jure change in exchange regime between 1953 and 1981 have been omitted. Since there is some doubt as to whether or not the first few years of the de jure float that began in 1970:2 should also be considered de facto flexible, the period beginning in 1973:1 is chosen to represent the most recent floating rate experience in Canada. The influence on feedback of adding observations for 1970 to 1972 will be considered at length below.

Estimates of feedback are based on estimation of vector autoregressions of subvectors of W which have been truncated at lag length q. This estimation uses observations entirely from within each of the exchange regimes listed above. That is, observations on the variable with the earliest date, $t - q$, in the vector autoregressions begin with the first quarter of each exchange regime. Since the purpose of the paper is to compare distinct regimes, it is not desirable to conduct estimation in such a way that estimates for one regime depend, via lag structure, on observations generated while another regime was in force.

The approach to the specification of lag length used here is to choose a value of q thought to be large enough to include most relevant lags subject to degrees of freedom considerations. The value of q is then allowed to vary and the sensitivity of the results to this variation is considered. The tables below are based on $q = 4$; thus current P is assumed in these tables to be influenced by P^* from one to four quarters in the past. Some results for $q = 2$ are also reported. A sensitivity analysis indicates that the conclusions stated below concerning comparisons across exchange regimes of overall feedback and the corresponding feedback at the infinite periodicity are robust for lag lengths from two to four quarters. Values of q greater than 4 have not been systematically considered, because they lead to much wider confidence intervals due to degrees of freedom problems.

Once the infinite-dimensional vector autoregressions have been truncated, point estimates of linear feedback and their decomposition by frequency are computed after replacing the population coefficients in the autoregressions with their point estimates. Tests of the null hypothesis that these measures are zero are not reported, since the asymptotic distribution theory involved, in the case of conditional feedback at least, is extremely difficult, and because one suspects that such theory may not be very reliable in any case given the non-linearity in autoregression coefficients of expressions like (8) and the length of available time series (Geweke, 1983a, 34). Instead, estimates corrected for small sample bias and confidence intervals are computed using a parametric bootstrap procedure (Efron, 1982; Geweke, 1984, 911). This

7 The start of the sample period reflects the public availability of quarterly Canadian money stock data, which were part of my initial investigations. Similarly, the latest observation in the sample period reflects the availability of data when most of the statistical work was completed. Some results using 1982 data and lag length of two quarters are reported in the text below.

procedure involves the generation of artificial data using the point estimates of autoregression coefficients instead of population values and error terms drawn from a normal distribution with zero mean and variance – covariance matrix determined by initial estimation of the vector autoregressions, and the re-computation of the feedback measures. A substantial number of replications of this experiment are performed, the results of which as a whole can be used to approximate the small sample bias of the final estimates and form confidence intervals for these estimates.[8,9]

Results

The discussion of results will focus on estimates of $F_{P \to P}*$ (in tables 1A to 1C) and $F_{P* \to P|Y,Y*}$ (in tables 2A to 2C) which are given in the first row of the top panel in the tables, and on the frequency decompositions of $F_{P* \to P|Y,Y*}$, which are given in the second panel of tables 2A to 2C. Estimated measures of conditional feedback from P to P^* and its decomposition are also reported in tables 2A to 2C, but only to demonstrate that these estimates are generally consistent with the expectation that P^* is exogenous with respect to P.[10]

In the tables the 'Estimate' column indicates the point estimates of measures of feedback, and the 'Adjusted estimate' column provides the estimates adjusted for small sample bias as described above based on the number of replications of synthetic data indicated at the bottom of the table. Both the raw estimates and the adjusted estimates support the same general conclusions concerning comparisons across exchange regimes, and subsequent discussion of the results will refer to the adjusted estimates only. The figures in parentheses

8 All computations were performed using the MTSM program (Geweke, 1983b). This program is CPU intensive, and computing costs were the primary determinant of the number of replications performed. Twenty-five replications, used in generating tables 2A and 2C, are not enough to eliminate variation across alternative sets of (twenty-five) replications, although the pattern of results *across* exchange regimes seems to be robust. The estimation of vector autoregressions uses an algorithim due to Whittle (1963); see Geweke (1984, 910-11) for discussion. The small sample properties of this procedure, which produces estimates only asymptotically equivalent to OLS, are not well known. The small sample properties of measures of feedback also remain to be investigated. A reviewer has quite properly emphasized that our lack of knowledge about this property of the estimators should be borne in mind when assessing the results.

9 If $\hat{F}$ is the original point estimate of feedback, and $\bar{F}$ is the mean estimate across replications, the bias-adjusted point estimate reported in the tables below is $\hat{\hat{F}} = \hat{F} \cdot \hat{F}/\bar{F}$; it is assumed that the bias in the estimator $\hat{F}$ is uniform as a percentage of F. Note that the point estimates are not corrected for degrees of freedom, to ensure that measures of conditional linear feedback (which depend on the log of ratios of variances) are always non-negative, and because there is no asymptotic distribution theory to serve as a basis for such a correction. This most probably imparts an upward bias to estimates of feedback. It is assumed that the bootstrap adjustment for bias will incorporate an adjustment for degrees of freedom.

10 $F_{P \to P*,Y,Y*}$ in tables 2B and 2C is small relative to feedback in the opposite direction. It is not so in table 2A. One referee has suggested such feedback may be attributed to the fact that Canada is a producer of raw materials, whose prices tend to record shocks to supply and demand before U.S. (predominantly manufactured goods) prices. Feedback from P to P^* during the 1950s largely disappears when three lags are used instead of four.

TABLE 1A

Estimated measures of linear feedback

Quarterly data, 1953:2 – 1962:1				
	4 lags, 36 observations. Dummy variables: Constant			
	X vector: P	Y vector: P^*		
	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X)$	0.063 (6.1%)	0.022 (2.1%)	0.014	0.030
			50 replications	

TABLE 1B

Estimated measures of linear feedback

Quarterly data, 1962:3 – 1970:1				
	4 lags, 31 observations. Dummy variables: Constant			
	X vector: P	Y vector: P^*		
	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X)$	0.243 (21.5%)	0.165 (15.2%)	0.085	0.244
			50 replications	

TABLE 1C

Estimated measures of linear feedback

Quarterly data, 1973:1 – 1981:4				
	4 lags, 36 observations. Dummy variables: Constant			
	X vector: P	Y vector: P^*		
	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X)$	0.229 (20.5%)	0.166 (15.3%)	0.118	0.218
			50 replications	

indicate the percentage of variance explained corresponding to the estimated measure of feedback. The last two columns indicate the lower and upper quartile for the adjusted estimates, based on the replications of synthetic data. For example, in table 2A the adjusted point estimate of the measure of conditional feedback from P^* to P is 0.001; this corresponds to a 0.1 per cent reduction in the one-step-ahead mean square forecast error for P when four lagged values of P^* are added to four lagged values of P over the flexible rate period 1953:2 to 1962:1. The lower and upper quartiles for the adjusted estimate are 0.0 to 0.002, respectively. In the decomposition by frequency of this estimated measure of feedback, at the infinite periodicity (zero frequency), for example, the adjusted point estimate ascribes 0.0 per cent of the variance in P (i.e., of the spectral density of P evaluated at the frequency $\lambda = 0$) to the innovation in P^* (i.e., to the conditional feedback analog of $\tilde{Q}(\lambda)T_3\tilde{Q}(\lambda)'$ in (7)). Note that in the tables decomposition of feedback by frequency is

TABLE 2A

Estimated measures of conditional linear feedback

Quarterly data, 1953:2 – 1962:1

4 lags, 36 observations. Dummy variables: Constant

X vector: *P* *Y* vector: P^*

Z vector: *Y*, Y^*

	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X\|Z-)$	0.011 (1.0%)	0.001 (0.1%)	0.000	0.002
$F(X \text{ to } Y\|Z-)$	0.090 (8.6%)	0.043 (4.2%)	0.019	0.065
$F(X \cdot Y\|Z-)$	0.008 (0.8%)	0.001 (0.1%)	0.000	0.001
$f(Y \text{ to } X\|Z-)$				
Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.003 (0.3%)	0.000 (0.0%)	0.000	0.000
40.000	0.003 (0.3%)	0.000 (0.0%)	0.000	0.000
30.000	0.004 (0.4%)	0.000 (0.0%)	0.000	0.000
20.000	0.004 (0.4%)	0.000 (0.0%)	0.000	0.000
10.000	0.007 (0.7%)	0.001 (0.1%)	0.000	0.001
9.000	0.008 (0.8%)	0.001 (0.1%)	0.000	0.001
8.000	0.009 (0.9%)	0.001 (0.1%)	0.000	0.001
7.000	0.010 (1.0%)	0.001 (0.1%)	0.001	0.001
6.000	0.012 (1.2%)	0.001 (0.1%)	0.001	0.002
5.000	0.015 (1.5%)	0.002 (0.2%)	0.001	0.003
4.000	0.022 (2.2%)	0.004 (0.4%)	0.001	0.007
3.000	0.017 (1.7%)	0.003 (0.3%)	0.001	0.005
2.000	0.001 (0.1%)	0.000 (0.0%)	0.000	0.000
$f(X \text{ to } Y\|Z-)$				
Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.187 (17.0%)	0.169 (15.6%)	0.047	0.224
40.000	0.182 (16.6%)	0.163 (15.0%)	0.051	0.214
30.000	0.178 (16.3%)	0.158 (14.6%)	0.048	0.205
20.000	0.169 (15.5%)	0.146 (13.6%)	0.041	0.182
10.000	0.132 (12.4%)	0.098 (9.4%)	0.024	0.135
9.000	0.124 (11.6%)	0.088 (8.4%)	0.025	0.120
8.000	0.114 (10.8%)	0.076 (7.3%)	0.027	0.104
7.000	0.102 (9.7%)	0.062 (6.0%)	0.028	0.081
6.000	0.087 (8.3%)	0.045 (4.4%)	0.021	0.062
5.000	0.067 (6.5%)	0.027 (2.7%)	0.008	0.034
4.000	0.039 (3.8%)	0.008 (0.8%)	0.002	0.012
3.000	0.035 (3.4%)	0.007 (0.7%)	0.002	0.013
2.000	0.187 (17.0%)	0.105 (10.0%)	0.011	0.216

25 replications

reported by periodicity ($= 2\pi/\lambda$), and the symbol '$Z-$' refers to the conditioning set Z_{t-1}.

To begin the analysis of results, consider first the importance of controlling for real shocks when studying the role of exchange flexibility in the transmission of inflation. This importance is clearly revealed by a comparison

TABLE 2B

Estimated measures of conditional linear feedback

Quarterly data, 1962:3 – 1970:1

4 lags, 31 observations. Dummy variables: Constant

X vector: P Y vector: P^*

Z vector: Y, Y^*

	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X\|Z-)$	0.445 (35.9%)	0.402 (33.1%)	0.206	0.507
$F(X \text{ to } Y\|Z-)$	0.005 (0.5%)	0.000 (0.0%)	0.000	0.000
$F(X \cdot Y\|Z-)$	0.035 (3.4%)	0.013 (1.2%)	0.000	0.023

$f(Y \text{ to } X|Z-)$

Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	1.056 (65.2%)	0.792 (54.7%)	0.338	1.069
40.000	0.915 (59.9%)	0.793 (54.7%)	0.424	1.105
30.000	0.826 (56.2%)	0.704 (50.5%)	0.379	0.997
20.000	0.637 (47.1%)	0.488 (38.6%)	0.249	0.689
10.000	0.226 (20.3%)	0.109 (10.3%)	0.040	0.155
9.000	0.175 (16.0%)	0.074 (7.1%)	0.028	0.104
8.000	0.126 (11.9%)	0.045 (4.4%)	0.016	0.061
7.000	0.087 (8.3%)	0.026 (2.6%)	0.009	0.032
6.000	0.067 (6.5%)	0.019 (1.9%)	0.007	0.022
5.000	0.094 (8.9%)	0.039 (3.9%)	0.017	0.040
4.000	0.260 (22.9%)	0.208 (18.8%)	0.072	0.358
3.000	0.939 (60.9%)	0.985 (62.7%)	0.298	1.591
2.000	0.157 (14.5%)	0.274 (24.0%)	0.074	0.460

$f(X \text{ to } Y|Z-)$

Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.002 (0.2%)	0.000 (0.0%)	0.000	0.000
40.000	0.002 (0.2%)	0.000 (0.0%)	0.000	0.000
30.000	0.002 (0.2%)	0.000 (0.0%)	0.000	0.000
20.000	0.002 (0.2%)	0.000 (0.0%)	0.000	0.000
10.000	0.001 (0.1%)	0.000 (0.0%)	0.000	0.000
9.000	0.001 (0.1%)	0.000 (0.0%)	0.000	0.000
8.000	0.001 (0.1%)	0.000 (0.0%)	0.000	0.000
7.000	0.001 (0.1%)	0.000 (0.0%)	0.000	0.000
6.000	0.001 (0.1%)	0.000 (0.0%)	0.000	0.000
5.000	0.003 (0.3%)	0.000 (0.0%)	0.000	0.000
4.000	0.015 (1.5%)	0.001 (0.1%)	0.000	0.001
3.000	0.006 (0.6%)	0.000 (0.0%)	0.000	0.001
2.000	0.007 (0.7%)	0.000 (0.0%)	0.000	0.000

25 replications

of $F_{P^* \to P}$ in tables 1 and $F_{P^* \to P|Y,Y^*}$ in tables 2 for the same sample period. For the flexible period 1973:1 to 1981:4 unconditional feedback in table 1C is about three times larger than the conditional feedback for the same period in table 2C. In table 1B, for the fixed rate period of the 1960s unconditional feedback is less than one half as large as the conditional feedback for the same period in table 2B. That is, the estimate of feedback under fixed rates *increases*

TABLE 2C

Estimated measures of conditional linear feedback

Quarterly data, 1973:1 – 1981:4

4 lags, 36 observations. Dummy variables: Constant

X vector: *P* *Y* vector: P^*

Z vector: *Y*, Y^*

	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X \mid Z-)$	0.079 (7.6%)	0.052 (5.0%)	0.027	0.065
$F(X \text{ to } Y \mid Z-)$	0.057 (5.5%)	0.021 (2.1%)	0.009	0.027
$F(X \cdot Y \mid Z-)$	0.088 (8.5%)	0.038 (3.7%)	0.004	0.052
$f(Y \text{ to } X \mid Z-)$ Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.046 (4.5%)	0.018 (1.7%)	0.004	0.021
40.000	0.049 (4.8%)	0.020 (2.0%)	0.004	0.026
30.000	0.052 (5.1%)	0.022 (2.2%)	0.004	0.031
20.000	0.062 (6.0%)	0.028 (2.8%)	0.005	0.043
10.000	0.125 (11.8%)	0.095 (9.1%)	0.017	0.170
9.000	0.145 (13.5%)	0.125 (11.8%)	0.025	0.196
8.000	0.167 (15.4%)	0.158 (14.6%)	0.033	0.206
7.000	0.179 (16.4%)	0.200 (18.1%)	0.054	0.243
6.000	0.163 (15.1%)	0.215 (19.4%)	0.069	0.284
5.000	0.122 (11.5%)	0.140 (13.1%)	0.038	0.176
4.000	0.081 (7.8%)	0.065 (6.3%)	0.017	0.079
3.000	0.053 (5.1%)	0.024 (2.3%)	0.007	0.034
2.000	0.029 (2.9%)	0.010 (1.0%)	0.002	0.014
$f(X \text{ to } Y \mid Z-)$ Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.004 (0.4%)	0.000 (0.0%)	0.000	0.000
40.000	0.004 (0.4%)	0.000 (0.0%)	0.000	0.000
30.000	0.004 (0.4%)	0.000 (0.0%)	0.000	0.000
20.000	0.006 (0.6%)	0.000 (0.0%)	0.000	0.000
10.000	0.017 (1.7%)	0.002 (0.2%)	0.000	0.002
9.000	0.023 (2.2%)	0.003 (0.3%)	0.000	0.004
8.000	0.032 (3.2%)	0.006 (0.6%)	0.001	0.010
7.000	0.047 (4.6%)	0.012 (1.2%)	0.002	0.020
6.000	0.061 (5.9%)	0.021 (2.1%)	0.006	0.036
5.000	0.060 (5.9%)	0.027 (2.7%)	0.009	0.033
4.000	0.054 (5.3%)	0.026 (2.6%)	0.010	0.028
3.000	0.066 (6.4%)	0.029 (2.9%)	0.009	0.039
2.000	0.108 (10.2%)	0.056 (5.4%)	0.007	0.099

25 replications

substantially when real shocks are duly allowed for. A comparison of tables 1A and 2A also suggests that investigating the role of the exchange rate without adequate regard to the source of inflation may be misleading. Conditional feedback during the float of the 1950s in table 2A is about one twentieth the size of the corresponding unconditional feedback in table 1A, although the absolute size of the feedback in both of these tables is small in comparison with that in the tables referred to above.

The results which bear most directly on the role of exchange flexibility are the estimates of $F_{P^* \rightarrow P|Y,Y^*}$ and its decomposition given in tables 2A to 2C. Consider first a comparison of tables 2A and 2B. Overall feedback during the fixed rate regime of the 1960s (table 2B) is about 400 times larger than during the earlier floating rate period (table 2A), as is the contribution of P^* to overall variance in P unexplained by the conditioning factors Y and Y^*. At the infinite periodicity (zero frequency), feedback from U.S. prices accounts for less than 1 per cent of the variance in Canadian prices during the early flexible regime, but for over 54 per cent of this variance during the fixed rate period. Moreover, the confidence intervals (in the last two columns of the tables) for estimates of these long-run feedbacks are well separated. Finally, note that the contributions to variance of feedback at all periodicities are much lower in table 2A than in table 2B.

It is apparent from these results, therefore, that relative to the fixed rate experience of the 1960s, the period 1953 to 1962 can be considered one in which flexible exchange rates successfully inhibited the transmission of inflation from the United States to Canada.

Can the same conclusion be reached regarding the de jure float of the 1970s? At least for the period 1973:1 to 1981:4, the answer is a qualified yes. Overall feedback in table 2C is similar to that for the early flexible period, but this similarity covers a substantially different decomposition by periodicity. At very short-run periodicities of one to four quarters and at long-run periodicities of at least ten quarters, table 2C reveals that the contribution of U.S. prices to variance in Canadian prices is very small relative to that under fixed rates, as in table 2A. At 'contract length' periodicities of five to ten quarters, however, feedback is substantially more important during the latest flexible rate period than it was during the float of the 1950s and is in fact greater than feedback at the same periodicities during the fixed rate regime of the 1960s. This last result illustrates the importance of distinguishing between long and shorter runs when investigating the role of exchange flexibility in the international transmission of inflation.

Parenthetically it is of interest to note the complementary nature of feedback across periodicities in tables 2B and 2C; feedback at a given periodicity tends to be high (relative to overall feedback) in table 2B when it is low in table 2C. This complementarity reinforces the conclusion based on comparing feedback at the infinite periodicity, that the de jure switch from fixed to flexible exchange rates in the 1970s did in fact represent a significant change in exchange regime.[11]

Summing up the above results as they bear on the transmission of inflation during the float of the 1970s, it may be concluded that the latest de jure float successfully blocked the transmission of inflation in the long run. But in comparison with the flexible rate regime of the 1950s, the 1970s float does not appear to have been as successful in insulating the domestic economy over shorter time horizons for which feedback in the 1950s was also small. One possible explanation for the latter result is that the Canadian economy experienced a more serious history of real shocks and U.S. monetary surprises in the 1970s than in the 1950s, so that shorter run transmission for the reasons discussed in the first section was more substantial during the floating rate period of the 1970s.

Another possibility, not mutually exclusive with the first, is that the Bank of Canada's behaviour was consistent with a clean float in the 1950s (see for example, Plumptre, 1970; Pippenger and Phillips, 1973; and Wonnacott, 1965) relative to its behaviour during the 1970s.[12] As noted earlier, there is evidence that the Bank sought to avoid large exchange rate fluctuations in the 1970s by manipulating the U.S.-Canada interest rate spread. Such exchange management could for some period of time induce behaviour that is more nearly consistent with a fixed rate than with a flexible one. Even though exchange rate management may not influence the long-run trend in the exchange rate, it may be 'strong' enough to induce a belief that over some finite time horizon exchange rate changes should be considered transitory, and thus should be disregarded in the adjustment of Canadian prices (Bordo and Choudhri, 1982). However, the evidence presented here suggests strongly that exchange rate management did not prevent exchange flexibility from insulating the Canadian economy against changes in the secular rate of U.S. inflation, at least after 1972.[13]

11 I have not been able to find a compelling explanation for the difference between the decomposition in tables 2B and 2C. One possibility is the following. Assume there exists a Phillips curve in the 1960s that is negatively sloped in the short run and vertical in the long run. In that case, Canadian prices will be highly correlated in the short run with Canadian real output, so that only in the long run will $P_{t-1}{}^*$ add substantially to the explanation of P over and above what is added by Y_{t-1} (and $Y_{t-1}{}^*$). This could explain the pattern observed in table 2B (ignoring the substantial feedback at two to four quarters) while an erosion in the stability of the short-run Phillips curve in the 1970s coupled with a substantial difference between the 1960s and the 1970s in the nature of real shocks might account for the difference in decompositions between 2B and 2C.

12 It should be remembered that the results reported above are based on reduced-form vector autoregressions, and therefore it is not possible to determine which structure actually generated these results. For example, it is not possible to determine whether non-zero feedback at high frequencies during the float of the 1970s is due to the behaviour of the Bank, or due to the turbulence of the era (which includes adjustment to the oil shocks of 1973 and 1979 which may have occurred in different ways in Canada and the United States). The results are consistent with both explanations. Of course, this feature of reduced forms is the source of their strength as well as their weakness.

13 A third possible explanation for the difference in the frequency decompositions in tables 2A and 2C that should be raised is that the use of the past history of real growth to represent real shocks may be more satisfactory in the 1950s than in the 1970s. If so, a more adequate representation of real shocks for the 1970s might eliminate the feedback at intermediate periodicities in table 2C.

TABLE 3

Estimated measures of conditional linear feedback

Quarterly data, 1970:3 – 1981:4

4 lags, 46 observations. Dummy variables: Constant

X vector: *P* *Y* vector: *P**

Z vector: *Y*, *Y**

	Estimate	Adjusted estimate	25.0%	75.0%
F(*Y* to *X*|*Z*−)	0.147 (13.7%)	0.112 (10.6%)	0.072	0.130
f(*Y* to *X*|*Z*−)				
Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.238 (21.1%)	0.198 (18.0%)	0.084	0.248
40.000	0.242 (21.5%)	0.021 (18.2%)	0.091	0.249
30.000	0.246 (21.8%)	0.203 (18.3%)	0.093	0.251
20.000	0.256 (22.6%)	0.207 (18.7%)	0.098	0.249
10.000	0.289 (25.1%)	0.207 (18.7%)	0.103	0.255
9.000	0.291 (25.3%)	0.206 (18.7%)	0.097	0.246
8.000	0.290 (25.2%)	0.209 (18.9%)	0.094	0.268
7.000	0.279 (24.3%)	0.219 (19.6%)	0.091	0.285
6.000	0.253 (22.3%)	0.223 (20.0%)	0.106	0.341
5.000	0.205 (18.6%)	0.197 (17.9%)	0.083	0.266
4.000	0.141 (13.1%)	0.133 (12.4%)	0.052	0.162
3.000	0.064 (6.2%)	0.040 (3.9%)	0.015	0.047
2.000	0.008 (0.8%)	0.001 (0.1%)	0.000	0.002

25 replications

Further results

In addition to descriptive studies of the Bank of Canada's behaviour, the extremely large change in foreign exchange reserves in the period 1970:2 to 1971:4 relative to that over the preceding fixed rate period suggests an attempt to manage the exchange rate in the early years of the de jure float.[14] Together, these pieces of evidence have motivated a choice of 1973:1 as the start of the de facto float considered in table 2C. Further results that confirm the distinct nature of the exchange regime in the early 1970s are reported in tables 3 and 4.

A comparison of (conditional) feedback over the period 1970:3 to 1981:4 in table 3 with that in table 2C is consistent with the existence of substantial

14 The average current-dollar change in Canadian foreign exchange reserves for the years 1970 and 1971 was about 1,280 million. The corresponding figure for the fixed rate period 1963 to 1969 was 106 million. A further reason for regarding the early years of the latest de jure float as a distinct exchange regime is that international monetary arrangements were extremely unsettled in the early 1970s following the suspension of gold convertibility in August 1971 and the Smithsonian conference in December 1971. It is reasonable to suspect the Bank of Canada delayed implementation of a fully flexible rate in the face of attempts by the United States which followed these events to 'patch up' the fixed rate Bretton Woods system.

TABLE 4

Vector autoregression Chow tests (using four lags)[a]

Sample periods	Test statistic	Marginal significance level
1. 53-2 to 62-1, 62-2 to 70-1, 70-2 to 81-4.	136.2	0.48
2. 53-2 to 62-1, 62-2 to 72-4, 73-1 to 81-4.	145.1	0.28
3. 62-3 to 70-1, 70-2 to 81-4.	69.1	0.44
4. 62-3 to 72-4, 73-1 to 81-4.	82.5	0.11

[a] The test statistic is a X_k^2 with k = no. of subsample periods less one times no. of parameters in the vector autoregression of $W = \{P, P^*, Y, Y^*\}$. This statistic is based on the difference between $(T/2) \log |\hat{\Sigma}|$ and $\sum_{i=1}^{n} (Ti/2) \log |\hat{\Sigma}_i|$, where $\hat{\Sigma}$ is the estimated variance of the innovations in W over the entire sample T, $\hat{\Sigma}_i$ is the variance of the innovations in W over the subsample of length T_i and n is the number of subsample periods.
1. $k = 136$; $T_1 = 36$, $T_2 = 32$, $T_3 = 47$
2. $k = 136$; $T_1 = 36$, $T_2 = 43$, $T_3 = 36$
3. $k = 68$; $T_1 = 31$, $T_2 = 47$
4. $k = 68$; $T_1 = 42$, $T_2 = 36$

exchange rate management in the early 1970s. Feedback from P^* to P in table 3 is, overall, twice that in table 2C and at the infinite periodicity feedback is about ten times larger in table 3 than in table 2C.[15] The vector autoregression Chow tests[16] reported in table 4 reinforce the conclusion that the degree of flexibility of the exchange rate increased significantly after the first few years of the de jure float which began in 1970:2. The test statistics are larger and more significant when 1973:1 rather than 1970:2 is used as the first quarter of the most recent exchange regime. Thus, it could well be that the studies cited earlier which fail to detect any role for the exchange rate in the transmission of U.S. prices to Canada during the 1970s are biased by their failure to treat the early years of the recent float as a distinct exchange regime. This is in addition to the bias in conclusions concerning the remaining years of the most recent floating rate period that might result from inadequate attention to the source of

15 For the period 1972:1 to 1981:4, $F_{P^* \to P|Y,Y^*} = 0.038$ (3.8 per cent) and $f_{P^* \to P|Y,Y^*}(0) = 0.014$ (1.4 per cent). These results are similar to the results for the period 1973:1 to 1981:4 given in table 2C and thus suggest that the period 1972:1 to 1981:4 could also be treated as one that is substantially different from the managed float of 1970:3 to 1971:4. However, I have not systematically explored this possibility for all feasible lag structures.

16 The 'Chow test' is described in table 4.

foreign inflation or from failure to adequately distinguish long-run from shorter-run linkages.

The results in tables 2A to 2C are based on four lags and therefore involve the estimation of seventeen parameters including a constant term. The estimated decomposition by frequency is more interesting the longer the lag used, because a longer lag imposes fewer constraints on the functional form of this decomposition. However, it may be that estimating seventeen parameters using thirty-one to thirty-six observations leads to under-estimation of error variances.[17] This is not as serious a problem as it may seem at first glance, because the bootstrap procedure will, approximately, correct for bias in the estimation of error variances.[18] To guard further against bias which might result from degrees of freedom problems, measures of feedback based on a lag length of two and involving the estimation of only nine parameters were computed for the same sample periods as used in tables 2A and 2B, and for the period 1972:1 to 1982:4 (rather than 1973:1 to 1981:4 as in table 2C). The results (not tabulated here) yield adjusted measures of overall conditional feedback from P^* to P of 0.041 (4.0 per cent) for the flexible period of the 1950s, 0.295 (25.5 per cent) for the fixed rates of the 1960s, and 0.0 (0.0 per cent) for the flexible rate period 72:1 to 82:4. For feedback at the infinite periodicity the corresponding estimates are 0.132 (12.4 per cent), 1.488 (77.4 per cent) and 0.003 (0.3 per cent).

It is apparent from these results that the above conclusion concerning the recent float remains unaltered. And in general they suggest the same classification of exchange regimes as does a comparison of tables 2A to 2C.

The final set of results to be reported concerns the problem of studying differences in exchange regimes without actually estimating a model of exchange rate determination. The advantage of the robust estimation technique used here is that it bypasses the considerable difficulties one must face in constructing such a model, yet still permits the discovery of some interesting 'stylized facts' which may serve as a guide to exchange rate modeling. The importance of real shocks, the difference between long- and shorter-run transmission and the difference in the operation of the flexible rate regimes of the 1950s and the 1970s (including the peculiarity of the early 1970s) appear to be 'facts' that any structural model should be able to replicate if it is to explain fully the role of the exchange rate in the international transmission of inflation from the United States to Canada.

17 The number of observations here refers to the total length of time series for exchange rate episodes. The number of observations on the dependent variable in each autoregression is smaller than this number by the length of the lag structure assumed.

18 Assume, for example, that the variance of the regression residuals is only one-half of the true variance. In the bootstrap, synthetic variates are generated using this smaller variance, and they in turn will produce a variance of about 0.5 × 0.5 the size of the original, true variance. The bootstrap correction for bias will divide the original estimate of the variance by the downward bias (about 0.5) found from the synthetic variates, thus leading to an approximately unbiased estimator.

TABLE 5A

Estimated measures of conditional linear feedback

Quarterly data, 1953:2 – 1962:1

4 lags, 36 observations. Dummy variables: Constant

X vector: P/E Y vector: P^*

Z vector: Y, Y^*

	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X\|Z-)$	0.092 (8.8%)	0.057 (5.6%)	0.023	0.076
$F(X \text{ to } Y\|Z-)$	0.242 (21.5%)	0.270 (23.7%)	0.113	0.449
$F(X \cdot Y\|Z-)$	0.001 (0.1%)	0.000 (0.0%)	0.000	0.000

$f(Y \text{ to } X\|Z-)$ Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.012 (1.2%)	0.001 (0.1%)	0.000	0.002
40.000	0.014 (1.4%)	0.002 (0.2%)	0.000	0.003
30.000	0.016 (1.6%)	0.002 (0.2%)	0.000	0.004
20.000	0.021 (2.1%)	0.004 (0.4%)	0.001	0.007
10.000	0.043 (4.3%)	0.017 (1.7%)	0.006	0.023
9.000	0.050 (4.8%)	0.022 (2.1%)	0.007	0.027
8.000	0.058 (5.6%)	0.028 (2.8%)	0.009	0.033
7.000	0.069 (6.7%)	0.038 (3.7%)	0.013	0.040
6.000	0.087 (8.3%)	0.053 (5.2%)	0.020	0.059
5.000	0.115 (10.9%)	0.078 (7.5%)	0.028	0.114
4.000	0.167 (15.4%)	0.131 (12.3%)	0.042	0.186
3.000	0.195 (17.7%)	0.193 (17.6%)	0.033	0.348
2.000	0.003 (0.3%)	0.000 (0.0%)	0.000	0.000

25 replications

However, concerning the nature of the exchange regime in the 1970s, the results in tables 2 still leave open the possibility that different inflation performances between Canada and the United States do not reflect the successful long-run insulation of a flexible exchange rate, as has been suggested above. Rather, the relatively (to fixed rates) low feedback at the infinite periodicity in the 1970s could possibly be attributed to factors such as Canadian energy or fiscal policies, or income controls which happened to move the underlying rate of inflation in Canada differently from that in the United States for some period of time, even though the exchange rate was (de facto) fixed.[19]

As one test of such a possibility, conditional feedback from U.S. to exchange-rate-adjusted Canadian prices, $F_{P^* \to (P/E)|Y,Y^*}$ was computed for the flexible exchange regimes of the 1950s and the 1970s. The exchange rate, E (the Canadian price of one U.S. dollar), used to adjust Canadian prices is the simple

19 This point has been raised by one of the referees.

TABLE 5C

Estimated measures of conditional linear feedback

Quarterly data, 1973:1 – 1981:4

4 lags, 36 observations. Dummy variables: Constant

X vector: P/E Y vector: P^*

Z vector: Y, Y^*

	Estimate	Adjusted estimate	25.0%	75.0%
$F(Y \text{ to } X \mid Z-)$	0.164 (15.2%)	0.118 (11.1%)	0.061	0.143
$F(X \text{ to } Y \mid Z-)$	0.006 (0.6%)	0.000 (0.0%)	0.000	0.000
$F(X \cdot Y \mid Z-)$	0.039 (3.8%)	0.024 (2.4%)	0.005	0.039

$f(Y \text{ to } X \mid Z-)$ Period	Estimate	Adjusted estimate	25.0%	75.0%
Infinite	0.177 (16.2%)	0.080 (7.7%)	0.022	0.156
40.000	0.187 (17.0%)	0.900 (8.6%)	0.028	0.170
30.000	0.195 (17.7%)	0.098 (9.3%)	0.032	0.181
20.000	0.218 (19.6%)	0.124 (11.6%)	0.038	0.200
10.000	0.333 (28.3%)	0.309 (26.6%)	0.081	0.494
9.000	0.348 (29.4%)	0.362 (30.4%)	0.101	0.568
8.000	0.349 (29.4%)	0.410 (33.6%)	0.141	0.608
7.000	0.320 (27.4%)	0.416 (34.0%)	0.187	0.587
6.000	0.262 (23.0%)	0.346 (29.3%)	0.211	0.461
5.000	0.195 (17.7%)	0.226 (20.2%)	0.111	0.300
4.000	0.145 (13.5%)	0.134 (12.6%)	0.081	0.161
3.000	0.116 (10.9%)	0.066 (6.4%)	0.022	0.109
2.000	0.019 (1.9%)	0.002 (0.2%)	0.000	0.003

25 replications

quarterly average of noon spot rates. The results are given in tables 5A and 5C, for comparison with tables 2A and 2C.

While overall conditional feedback from P^* to P for the 1950s in table 2A is 0.001 (0.1 per cent), it is 0.057 (5.6 per cent) in table 5A. Thus the use of exchange-rate-adjusted prices increases overall feedback in the 1950s by about sixty times (although both estimates are small). For the 1970s, the use of exchange-rate-adjusted prices raises overall feedback from 0.052 (5.0 per cent) in table 2C to 0.118 (11.1 per cent) in table 5C, that is, by a factor of about two. At the infinite periodicity, the point estimate of feedback is essentially the same in table 5A as in 2A. For the 1970s, in contrast, at the infinite periodicity, feedback rises by a factor of about four from 0.018 (1.7 per cent) in table 2C to 0.080 (7.7 per cent) in table 5C, and the confidence intervals do not overlap. It is also of interest to note the substantial increase in feedback in both tables 5A and 5C over that in tables 2A and 2C at short and intermediate periodicities.

It is not clear what differences between tables 2 and tables 5 should be expected when the exchange rate is completely flexible, in part because it is not obvious that E is the appropriate exchange rate with which to adjust P (the quarterly, seasonally adjusted GNE deflator). However, the above discussion of tables 5 suggests that exchange rate movements did play an active role in insulating the Canadian economy in the 1973 to 1981 period.

CONCLUSIONS

Recent theoretical work bearing on the role of de facto exchange flexibility in the international transmission of inflation, following Friedman (1953), has stressed the importance of controlling for the source of inflation. This research, as well as consideration of the possible influence of managed floating on shorter-run exchange rate expectations, also emphasizes the importance of distinguishing between transmission in the long run and international linkages over shorter time horizons. The evidence on the transmission of U.S. inflation to Canada presented here confirms the wisdom of this advice. It has been demonstrated that failure to control adequately for the existence of real shocks which have inflationary consequences in both the United States and Canada can lead to an unwarranted pessimism about the degree of insulation from U.S. inflation afforded the Canadian economy by a flexible exchange rate regime, and to overoptimistic views concerning the transmission of inflation under fixed rates. The results also suggest that there is a substantial difference, at least in the 1970s, between the long-run insulation provided by exchange flexibility and the insulation from foreign nominal disturbances that it provides over shorter time horizons.

Estimation of measures of conditional linear feedback across various periodicities that controls for real shocks and distinguishes between long-run and shorter-run linkages clearly reveals the long-run insulation afforded the Canadian economy by the flexible exchange rate regime of the 1950s and, correspondingly, the high degree of linkage created by the fixed rate system of the 1960s.

The plausibility of these results supports the application of the linear feedback technique to the more recent flexible rate episode. Estimates of linear feedback for the 1970 to 1981 period are consistent with the view that the de facto exchange flexibility which existed after 1972 was sufficient to insulate the secular rate of inflation in Canada against changes in the secular rate of inflation in the United States. It is by no means clear that the de jure float which began in 1970:2 was a de facto float in any sense, and some recent research has in fact concluded that exchange flexibility played no role in determining the Canadian rate of inflation in the 1970s. That exchange rate management resulted in a de facto fixed exchange rate in the early 1970s seems likely. However, the evidence presented here suggests that the long-run rate of inflation in Canada in the 1973 to 1981 floating rate period was made in Canada rather than in the United States.[20]

20 For evidence using time-series techniques that tends to support this conclusion, see Burbidge and Harrison (1985). For time-series evidence that does not appear to support this conclusion, see Pearce (1983). It is of interest to note that Pearce (276) still reaches the same conclusion as I do below concerning the need for further investigation of the determinants of monetary policy.

This last conclusion is consistent with Mundell's (1976, 1983) view of the relationship between exchange rate flexibility and the nature of monetary policy in open economies. Mundell has opposed flexible exchange rates on the grounds that they will be inflationary, because once the relevant authorities are freed from the balance-of-payments constraint imposed by fixed rates, they will tend to follow more expansionary policies.[21] Mundell's argument and the results presented above together suggest that empirical research on the determinants of monetary policy under alternative exchange regimes ought to be on the agenda.[22]

REFERENCES

Bilson, John F.O. (1978) 'Rational expectations and the exchange rate.' In J.A. Frenkel and H.G. Johnson, eds, *The Economics of Exchange Rates* (New York: Addison-Wesley)

Bordo, M. and E.U. Choudhri (1981) 'The link between money and prices in the open economy: the Canadian evidence from 1971 to 1980.' *Fed. of St. Louis Review* 64, 13-23

Burbidge, John and Alan Harrison (1985) '(Innovation) accounting for the impact of fluctuations in U.S. variables on the Canadian economy.' This JOURNAL 18, 784-98

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* 2, 167-78

Courchene, T.J. (1976a) *Money, Inflation, and the Bank of Canada* (Montreal: C.D. Howe Institute)

— (1976b), *Monetarism and Controls: The Inflation Fighters*, (Montreal: C.D. Howe Institute)

Daniel, B.C. (1981) 'The international transmission of economic disturbances under flexible exchange rates.' *International Economic Review* 22, 491-507

Dornbusch, Rudiger (1976) 'Expectations and exchange rate dynamics.' *Journal of Political Economy* 84, 1161-76

Efron, Bradley (1982) *The Jackknife, the Bootstrap and Other Resampling Plans* (Philadelphia: SIAM)

Flood, R.P. (1979), 'Capital mobility and choice of exchange rate system.' *International Economic Review* 20, 405-16

Frenkel, J.A. (1981) 'The collapse of purchasing power parities in the 1970s.' *European Economic Review* 16, 145-65

Friedman, Milton (1953) 'The case for flexible exchange rates.' In Friedman, *Essays in Positive Economics* (Chicago: University of Chicago Press)

Geweke, John (1982a) 'Measurement of linear dependence and feedback between multiple time series.' *Journal of the American Statistical Association* 77, 304-24

21 This description of Mundell's position is due to Douglas Purvis (1977, 208). It should be noted that while Purvis appears to view Mundell's position sympathetically, he concludes that inflation in Canada during the 1970s was imported from the United States via an essentially fixed exchange rate regime.

22 For an attempt in this direction, see Winer (1986).

— (1982b) 'Feedback between monetary policy, labour market activity and wage inflation, 1955-78.' In M.N. Baily, ed, *Workers, Jobs, and Inflation* (Washington DC: The Brookings Institution)

— (1982c) 'The neutrality of money in the United States, 1872-1980: an interpretation of the evidence.' Paper delivered to Econometric Society, Cornell University, June

— (1983a) 'The superneutrality of money in the United States: an interpretation of the evidence.' GSIA Working Paper No. 70-82-83, Carnegie-Mellon University, Pittsburgh, May

— (1983b) MTSM (Multiple Time Series Manipulator)

— (1984) 'Measures of conditional linear dependence and feedback between time series.' *Journal of the American Statistical Association* 79, 907-15

Granger, C.W.J. (1969) 'Investigating causal relations by econometric models and cross-spectral methods.' *Econometrica* 37, 424-38

Knight, Malcolm D. and Donald J. Mathieson (1983) 'Economic change and policy response in Canada under fixed and flexible exchange rates.' In J.S. Bhandari and B.H. Putnam, eds, *Economic Interdependence and Flexible Exchange Rates* (Cambridge, MA: MIT Press)

Krueger, A.D. (1983) *Exchange Rate Determination* (Cambridge: Cambridge University Press)

Kravis, I.B. and R.E. Lipsey (1978) 'Price behaviour in the light of balance of payments theories.' *Journal of International Economics* 8, 193-246

McCallum, Bennett T. (1984) 'On low-frequency estimates of "long-run relationships in macro-economics."' *Journal of Monetary Economics* 14, July

Marston, Richard C. (1983) 'Stabilization policies in open economies.' National Bureau of Economic Research, Working Paper No. 1117, forthcoming in R. Jones and P. Kenen, eds, *Handbook of International Economics* (Amsterdam: North-Holland)

Mundell, Robert A. (1976) 'Can flexible exchange rates stop imported inflation.' Paper given to McMaster University Conference on Inflation in Open Economies, Hamilton, Ontario, 5 March

— (1983) 'International monetary reform: the optimal mix in big countries.' In James Tobin, ed, *Macroeconomic Prices and Quantities* (Washington, DC: The Brookings Institution)

Mussa, M. (1976) 'The exchange rate, the balance of payments, and monetary and fiscal policy under a regime of controlled floating.' *Scandanavian Journal of Economics* 78, 229-48. Reprinted in J.A. Frenkel and H.G. Johnson, eds, *The Economics of Exchange Rates* (New York: Addison-Wesley), 1978

— (1979) 'Macroeconomic interdependence and the exchange rate regime.' In R. Dornbusch and J. Frenkel, eds, *International Economic Policy* (The Johns Hopkins University Press)

Pearce, Douglas K. (1983) 'The transmission of inflation between the United States and Canada: an empirical analysis.' *Journal of Macroeconomics* 5, 265-79

Pippenger, J.E. and L. Phillips (1973) 'Stabilization and the Canadian dollar: 1952-1960.' *Econometrica* 41, 797-815

Plumptre, A.F.W. (1970) 'Exchange-rate policy: experience with Canada's floating rate.' Princeton University, *Essays in International Finance* 81, June

Purvis, Douglas D. (1977) 'The exchange rate regime and economic policy in theory and practice.' *Canadian Public Policy* 3, 205-18

Whittle, P. (1963) 'On the fitting of multivariate autoregressions, and the approximate canonical factorization of a spectral density matrix.' *Biometrika* 50, 129-34

Winer, Stanley L. (1986) 'Money and choice in a small open economy.' *Public Choice,* forthcoming
Wonnacott, Paul (1965) *The Canadian Dollar 1948-62* (Toronto: University of Toronto Press)