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THE IMPACT OF ECONOMIC NEWS ON THE
CANADA-U.S. EXCHANGE RATE

by

Kee Jin Ngiam, B.Soc.Sc. (Honours), M.A.

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of
Doctor of Philosophy
Department of Economics

Carleton University
Ottawa, Ontario
October 1988

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submitted by

Kee Jin Ngiam, B.Soc.Sc. (Honours), M.A.

in partial fulfilment of the requirements
for the degree of Doctor of Philosophy.

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ABSTRACT

This thesis analyzes the response of the Canada-U.S. exchange rate to the announcements of a wide range of economic data in Canada and the United States. It begins by developing a model which shows that in an efficient market the exchange rate should react only to the unexpected content of an announcement (news) and that the response should be immediate. The model is then estimated using twice-daily exchange rate data over the period from March 1980 to February 1984.

The thesis then turns to the question of the measurement of expectations. It is argued that measures of news derived from either survey data or an ARIMA model are inaccurate because they do not incorporate the information available just before each announcement. To provide a more stringent test of market efficiency and the impact of news, this study adopts an innovative approach for measuring expectations that incorporates a broad range of variables announced at different frequencies (monthly, weekly and daily). To deal with these different frequencies, two methods are developed. The first method (Method I) includes in the information set only monthly and weekly data. The second method (Method II) augments the information set in Method I with daily data for measuring expectations of variables announced weekly.

Two major conclusions emerge from this study. First, of the ten announcements studied, only monetary news affect the Canada-U.S. exchange rate. Specifically, only news about

U.S. money supply, the U.S. Treasury bill rate and the Canadian bank rate (but not Canadian money supply) are significant. Second, the results for market efficiency are sensitive to the measurement of expectations: Market efficiency is rejected when Method I is used but supported when Method II is employed.

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CHAPTER I

INTRODUCTION

Considerable research has been done on the response of financial asset prices to the announcement or release of macroeconomic data. Most of the empirical work is devoted to the effects of announcements of data on U.S. economic variables on American stock prices and interest rates (e.g. Belongia and Sheehan, 1985; Hardouvelis, 1985; Pearce and Roley, 1983, 1985; and Urich and Wachtel, 1981, 1984). In recent years, however, there is a growing literature on the response of foreign exchange rates to announcements of the U.S. economic variables (e.g. Hakkio and Pearce, 1985; Hardouvelis, 1985; Ito and Roley, 1987; and Tandon and Urich, 1987). The announcements of non-U.S. economic variables are likely to be important but have been largely ignored.¹

The approach adopted in this thesis is different from that of the majority of existing studies. Instead of examining the impact of U.S. economic announcements on various exchange rates, the empirical work is conducted by an intensive examination of short-run responses of the Canada-U.S. exchange rate² to announcements of both U.S. and Canadian economic variables. It is well known that data for a wide range of economic variables are provided on a regular basis in both Canada and the United States. A subset of these variables will be considered, encompassing those variables that are relevant to asset market models of exchange rate determination.³

The basic issue in this area of research is the question of market efficiency. According to the efficient markets hypothesis, only "economic news" should cause the exchange rate to move. In this context, economic news refers to the unanticipated component of an announcement concerning an economic variable.⁴ In contrast, the anticipated part of the announcement should not influence the exchange rate; in an efficient market it has already been taken into account. Market efficiency also implies that the exchange rate should react almost instantaneously to economic news. Any delay in the response of the exchange rate means that systematic profits can be obtained. Empirical tests of this hypothesis have thus far yielded conflicting results.⁵

Research on market efficiency raises three other issues. The first concerns the type of economic news which would affect the exchange rate, with corresponding important implications for evaluating the various exchange rate models. Basically, if a particular economic variable is related to the exchange rate, news of that variable should have an effect. However, if the economic variable is not linked directly to the exchange rate, the announcement of that variable (whether anticipated or unanticipated) should not alter the exchange rate.

The second issue concerns the direction the exchange rate moves in response to economic news. This involves knowledge of how the foreign exchange market interprets the information it receives. Consider, for example, the announcement of an unexpectedly large increase in the U.S. money supply. According to the asset market view, this announcement will influence the exchange rate through two

channels: (a) the direct effect of the money supply on the exchange rate, and (b) the indirect effect of money supply announcement due to revised expectations about the future values of all economic variables. The way the market revises the expected future values of these economic variables has a profound effect on the behavior of the exchange rate.

The third issue concerns whether the same type of economic news originating in different countries has the same effect on the exchange rate. This requires an understanding of the economic conditions, financial market structure, foreign exchange intervention, and policy objectives in the countries. Because of dissimilar economic environments, it is conceivable that the same type of economic news (e.g. money supply changes) originating in different countries may not have the same effect on the exchange rate.

Previous studies on the effect of news on exchange rates suffer from a number of methodological problems which make it difficult to resolve these issues. Most of the studies examined U.S. economic news and ignored Canadian information, because survey data are available for U.S. but not Canadian variables. The omission of Canadian economic news was rationalized on the grounds that the U.S. economy is predominant and only U.S. economic data are studied by money traders. However, since Canadian and U.S. variables are relevant to the determination of the exchange rate, there is no strong justification for excluding Canadian economic data.⁶ This thesis introduces a methodology for

generating expectations which allows both Canadian and the U.S. news to be analyzed.

A second problem is that almost all the studies investigating the effects of announcements measure changes in the exchange rate over a 24-hour period. If the exchange rate reacts instantaneously to news, a 24-hour interval may be too long. It is recognized in the literature on announcement effects that it is desirable to take the shortest interval around potential news since over a given day other shocks may dilute the estimated impact. Exchange rate data are available with higher frequency but these are seldom used.⁷

A third concern is that the asset market efficiency literature uses survey data and ARIMA models to estimate expectations. These two measures are likely to be biased so that poor tests of market efficiency would result. While survey data are a convenient measure of market expectations, such data do not fully reflect all known information since they are collected many days (in certain cases, up to a week) before the actual announcements. Relevant information, available just before the announcements, is thus not incorporated. Using the ARIMA model, expectations of a variable are formed from past values of only that variable. A more appropriate procedure would recognize other factors playing an important role in the determination of that variable.

This study solves, or at least minimizes, the methodological problems inherent in empirical tests in this area of research. Three aspects have been improved. First, the range of economic news is widened to include both

Canadian and U.S. news. The list of news variables is not chosen arbitrarily, as in other studies, but is selected from consideration of the asset market model of exchange rate determination.

Second, a narrower time interval for the change in the exchange rate is used. Specifically, changes in the exchange rate between noon and 4:30 p.m. and between 4:30 p.m. and noon of the following business day are examined.

Third, a more efficient econometric estimation of expectations is used. Unlike previous approaches, the information set used for forecasting in this study includes a wide range of variables and incorporates data available at different frequencies (e.g. monthly, weekly and daily). To deal with the different frequencies, two methods for measuring expectations are developed. The first method (Method I) uses past values of variables announced at monthly and weekly intervals. The novelty of this method is that it is able to exploit both monthly and weekly data for generating expectations. The second method (Method II) augments the information set used in Method I with other relevant data available on a daily basis.

Two major conclusions emerge from this research. First, exchange rate behavior is consistent with the efficient asset market view that only news matters and that news about money supply and interest rate is of principal importance. Second, test results for market efficiency are sensitive to the measurement of expectations: the results reject market efficiency when the first method (the less appropriate method) for generating expectations is used but the evidence

supports market efficiency when expectations are formed by the second method (the appropriate method).

The organization of this thesis is as follows.

Chapter II develops the theoretical framework and derives an empirical model. Chapter III reviews the empirical literature and presents the research methodology for testing the empirical model. Chapter IV examines the data used in this study and analyzes the exchange rate behavior during the sample period from March 1980 to February 1984. Chapter V describes the two methods for measuring expectations. Chapter VI presents empirical results based on these two methods. Finally, Chapter VII presents the conclusions of this study and suggests areas for further research.

FOOTNOTES TO CHAPTER I

1. Exceptions include Apel (1986), Doukas (1985), Goodhart and Smith (1985), and Ngiam (1987).

2. The Canada-U.S. exchange rate is the price of a U.S. dollar in terms of Canadian dollars.

3. Other publicly announced information (such as an announced change in government policy, change of government, major foreign corporate takeover, natural calamities, and changes in oil prices) are not considered although they may affect the exchange rate. For a discussion of the impact of such information on the exchange rate, see Cosset and Doutriaux de la Rianderie (1985).

4. News, surprises, unanticipated or unexpected changes, innovations, new information and forecast errors are used interchangeably in this study.

5. This issue is explored further in Chapter IV and Chapter VI.

6. It should be pointed out that the Canada-U.S. exchange rate may also be affected by economic news of countries other than Canada and the United States. Suppose that the Canadian dollar depreciates against the Yen when Japan announces its intention to cease coal imports from Canada. Unless the Yen/U.S. dollar exchange rate changes, triangular arbitrage will ensure the weakening of the Canadian dollar against the U.S. dollar.

7. The paper by Hakkio and Pearce (1985) is a notable exception.

8. Since the foreign exchange market is most active from 8:30 a.m. to 4:30 p.m. Toronto time, the change in the exchange rate from 4:30 p.m. to noon of the next business day involves only three and a half hours of active trading time.

CHAPTER II

BASIC FRAMEWORK

This chapter is divided into two sections. Section I develops the theoretical model used in this study. Within this theoretical framework, the exact nature of the effects of economic news on the exchange rate is identified and analyzed. Section II derives the empirical model used to test the effect of economic news on the exchange rate. The results are presented in Chapter V.

I. Theoretical Model

Frenkel and Mussa (1980) and Dornbusch (1980) lay the groundwork for analyzing the impact of economic news on the exchange rates. Their work suggests that exchange rates are determined in a manner similar to other financial asset prices (or commodity prices determined in organized auction markets). Such an approach highlights the importance of expectations. Like other financial assets, spot exchange rates are influenced by both current and expected future values of economic variables. Exchange rates move in response to new information that changes the market's expectations of the future values of these economic variables. The view that the exchange rate should be regarded as an "asset price" may be represented by the following simple model of exchange rate determination:

$$S_t = \alpha Z_t + \beta (E S_{t+1} - S_t) \quad (2.1)$$

where s_t is the spot exchange rate at time t ; $z_t = [x_{1t}, x_{2t}, x_{3t}, \dots, x_{qt}]'$ is a vector of q economic variables that influence the spot exchange rate; $\alpha = [\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_q]$ is a vector of coefficients; B ($B > 0$) is a (scalar) parameter; and $E s_{t+1}$ is the expected exchange rate at time $t+1$ conditional on information available at t .

Frenkel and Mussa (1980) use this type of equation to show that the logarithm of the spot exchange rate (s_t) is determined by the current values of a set of economic variables (z_t) and the expected rate of change of the exchange rate ($E s_{t+1} - s_t$). B measures the sensitivity of the current spot rate to its expected rate of change. Equation (2.1) may be viewed as a general relationship that can be derived from a variety of asset market models of exchange rate determination. As an example, Appendix I derives an equation of this form from a model of the monetary approach.

If expectations are rational, equation (2.1) applies to all future periods, and by forward iteration

$$s_t = \frac{\alpha}{1+B} \sum_{j=0}^{\infty} \left(\frac{B}{1+B}\right)^j E z_{t+j} \quad (2.2)$$

The current spot rate thus depends on the discounted sum of current and expected future values of the economic variables. Any economic news that alters the expected future values of the economic variables can result in changes in the exchange rate.¹

Since the focus of this study is on the examination of short-run exchange rate responses to economic news, equation

(2.2) is transformed into the following rate-of-change form:²

$$s_t - {}_tE_1 s_t = \left\{ \frac{\alpha}{1+\beta} \sum_{j=0}^{\infty} \left(\frac{\beta}{1+\beta} \right)^j (E z_{t+j} - {}_tE_1 z_{t+j}) \right\} \quad (2.3)$$

Equation (2.3) shows that the unexpected change in the exchange rate ($s_t - {}_tE_1 s_t$) is a discounted sum of unanticipated changes in the present and future values of the economic variables ($E z_{t+j} - {}_tE_1 z_{t+j}$). In this context, the change in expectations about future z 's depends on the new information ($z_t - {}_tE_1 z_t$).

Since the announcement of a variable can influence expectations about the future values of variables in vector z_t , it is important to understand how such expectations are formed. Under rational expectations, expectations about the variables in vector z_t are formed on the basis of all the available information relating to the true or actual process governing the behavior of the vector z_t . Assume that the vector z_t follows the autoregressive process³

$$\delta(L) z_t = v_t \quad (2.4)$$

where L is the lag operator, $v_t = [v_1, v_2, v_3, \dots, v_q]'$ is a vector of innovations, $\delta(L)$ is a matrix of polynomials in L such that $\delta(L) = I - \delta_1 L - \delta_2 L^2 - \dots - \delta_q L^q$, and each δ_i is a $q \times q$ matrix of coefficients. As Hansen and Sargent (1980) have shown, equation (2.4) yields the following equations (see Appendix II for derivation):

$$\sum_{j=0}^{\infty} \theta^j E z_{t+j} = \frac{[\delta(L)^{-1} - L^{-1} \theta \delta(\theta)^{-1}] v_t}{(1 - \theta L^{-1})} \quad (2.5)$$

and

$$\sum_{j=0}^{\infty} \theta^j E_1 z_{t+j} = \frac{\{L^{-1}[\delta(L)^{-1} - \delta(\theta)^{-1}]\}}{(1 - \theta L^{-1})} v_{t-1} \quad (2.6)$$

where $\theta^{-1} = (\frac{\beta}{1+\beta})^{-1}$, $\delta(L)^{-1}$ is the inverse of $\delta(L)$ such that $\delta(L)^{-1}\delta(L) = I$, and $\delta(\theta)^{-1}$ is $\delta(L)^{-1}$ with θ substituting for L .

Equations (2.4), (2.5) and (2.6) imply that equation (2.3) can be written as:

$$s_t - E_1 s_t = (\frac{\alpha}{1+\beta}) \delta(\theta)^{-1} v_t \quad (2.7)$$

Two major implications arise from equation (2.7):

- (a) There is a linear relationship between the unexpected change in the exchange rate from $t-1$ to t and innovations in the elements of the z -vector during the corresponding period. Notice that the unexpected exchange rate change does not respond to news that occurred before $t-1$, or to anticipated changes in the variables.
- (b) The effect of innovations depends on the parameter vector β and on a complicated vector of coefficients involving the elements of β and δ and α . Studies assuming univariate autoregressive processes are restrictive cases of the more general model used in this study. Different types of relationships can be obtained depending on: (i) the direct effect of the new information ($z_t - E_1 z_t$) on the exchange rate, and (ii) the indirect effect of new information on the revision of expectations concerning the future values of the variables in vector z_t .

II. Empirical Model

The above theoretical model is based on the vector z_t , which contains all the economic variables that influence the exchange rate. For an empirical study, however, it is feasible to deal with only a limited number of variables. This study focuses on a list of variables included in the asset market models of Bilson (1978), Frenkel (1976), Mussa (1976), Dornbusch (1976), Frankel (1979), Hooper and Morton (1982) and Marwah (1985). The vector of variables used in this study is denoted by x_t , where x_t is a subset of vector z_t .

Equation (2.7) suggests a testable equation of the form:

$$\begin{aligned}
 s_t - {}_{t-1}E_1 s_t = & a + \sum_{i=1}^m b_i (x_{it} - \hat{x}_{it}) & (2.8) \\
 & + \sum_{i=1}^m c_i (\hat{x}_{it} - x_{it-1}) \\
 & + \sum_{j=1}^n \sum_{i=1}^m d_{ij} (x_{it-j} - \hat{x}_{it-j}) + u_t
 \end{aligned}$$

where:

$s_t - {}_{t-1}E_1 s_t$ = unexpected change in the exchange rate
from $t-1$ to t

a, b_i, c_i, d_{ij} = parameters

$x_{it} - \hat{x}_{it}$ = unanticipated change in the economic
indicator x_i ($i = 1, 2, \dots, m$) announced
during the interval from $t-1$ to t

$\hat{x}_{1t} - x_{1t-1}$ = anticipated change in the economic indicator x_1 prior to its announcement

$x_{1t-j} - \hat{x}_{1t-j}$ = unanticipated change in the economic indicator x_1 occurring in the interval from $t-j-1$ to $t-j$ ($j = 1, 2, \dots, n$)

u_t = forecast error which arises because the empirical model uses only a subset of vector z_t .

In terms of equation (2.8), the following hypotheses are tested:

$$(H1) \quad b_1 \neq 0$$

$$(H2) \quad c_1 = 0$$

$$(H3) \quad d_{1j} = 0$$

The first hypothesis (H1) asserts that the unanticipated component of an announcement should affect the unexpected exchange rate change. As shown in the previous section, the sign of b_1 cannot be determined a priori without knowledge of β , δ , and α . Consequently, b_1 does not have a sign restriction. The second hypothesis (H2) is that the anticipated component of an announcement should not influence the unexpected exchange rate change (in an efficient market it is already taken into account before the announcement). The third hypothesis (H3) asserts that the

unexpected exchange rate change should respond immediately to new information.

Testing equation (2.8) requires data on the unexpected exchange rate change. Forward market data are available for the unexpected exchange rate change of one month or longer but not for the unexpected exchange rate change over such a short interval as half a day.⁶ For example, no data are available on s_t , the exchange rate at time t (say, 4:30 p.m.) expected at $t-1$ (noon of the same day). To solve this problem, this study uses the actual exchange rate change ($s_t - s_{t-1}$) as a proxy for the unexpected exchange rate change. Two reasons can be presented to justify this approach.

First, several studies have shown that only a small fraction (less than one-tenth) of actual monthly exchange rate changes can be predicted by forward exchange rate premiums or discounts, suggesting that exchange rate changes are dominated by the unexpected exchange rate movements (Mussa, 1979; Frenkel and Mussa, 1980; and Frenkel, 1981).⁷ Mussa (1979) puts it succinctly when he states:

Reliable data are not available for forward contracts with maturities of fewer than 30 days; however, data on interest differentials (which should approximate the relevant forward premia or discounts) indicate that an even larger fraction of day-to-day or week-to-week changes in exchange rates are attributed to unexpected rather than expected changes. (p.21).

Second, even if the expected exchange rate change may not be negligible over a period of one month, it should be insignificant over a much smaller interval. Since this

study measures the exchange rate change over an interval of only half a day, the expected exchange rate change component should be negligible.² This suggests that the actual exchange rate change may be used as the dependent variable in equation (2.8) instead of the unexpected exchange rate change.³

III. Conclusions

In this chapter, the theoretical framework and the empirical model of this study have been presented. The theoretical formulation involves three basic steps. First, the asset market approach to exchange rate determination posits that the current spot exchange rate is a function of the expected future spot rate and relevant economic variables. Using rational expectations, the current spot rate is specified as a function of the current and expected future values of the economic variables. Second, an equation is derived which shows that the unexpected change in the spot rate depends on (a) unanticipated changes in the economic variables, and (b) changes in the expected future values of the economic variables. Finally, the exchange rate behavior is shown to depend on the way the unanticipated changes in the economic variables alter people's expectations about these variables.

On this theoretical base, an empirical model is constructed. In this empirical model, the change in the Canada-U.S. exchange rate depends on a broad range of Canadian and U.S. economic news. If the market is

efficient, the exchange rate should react only to the unanticipated component of an announcement and the response should be immediate. These hypotheses will be tested later (Chapter VI) but first it is necessary to establish a proper research methodology for an investigation of the empirical model. This will be the task of the next chapter.

FOOTNOTES TO CHAPTER II

1. In this study, it is assumed that the release of economic statistics may lead to the revision of expectations about the future values of the economic variables. It should be stressed that this is not the only channel through which the expected future values of the economic variables can be altered. Statements by government leaders, changes in market psychology, natural disasters, wars, rumours and election results can also cause revisions in expectations and consequently exchange rate changes. These are beyond the scope of this study.

2. Taking expectations of equation (2.2) at time $t-1$ gives:

$${}_tE_1s_t = \frac{\alpha}{1+\beta} {}_tE_1z_t + \left(\frac{\alpha}{1+\beta}\right) \left(\frac{\beta}{1+\beta}\right) \sum_{j=0}^{\infty} \left(\frac{\beta}{1+\beta}\right)^j {}_tE_1z_{t+j+1}$$

Subtracting this from equation (2.2) yields:

$$\begin{aligned} s_t - {}_tE_1s_t &= \frac{\alpha}{1+\beta} (z_t - {}_tE_1z_t) \\ &\quad + \left(\frac{\alpha}{1+\beta}\right) \left(\frac{\beta}{1+\beta}\right) \sum_{j=0}^{\infty} \left(\frac{\beta}{1+\beta}\right)^j (Ez_{t+j+1} - {}_tE_1z_{t+j+1}) \end{aligned}$$

which is identical to equation (2.3).

3. Equation (2.7) is derived as follows:

$$\begin{aligned} s_t - {}_tE_1s_t &= \frac{\alpha}{1+\beta} \sum_{j=0}^{\infty} \theta^j (Ez_{t+j} - {}_tE_1z_{t+j}) \\ &= \frac{\alpha}{1+\beta} \left\{ \sum_{j=0}^{\infty} \theta^j Ez_{t+j} - \sum_{j=0}^{\infty} \theta^j {}_tE_1z_{t+j} \right\} \\ &= \frac{\alpha}{1+\beta} \left\{ \frac{\delta(L)^{-1} - \theta L^{-1} \delta(\theta)^{-1}}{(1 - \theta L^{-1})} \right\} v_t \\ &\quad - \frac{\alpha}{1+\beta} \left\{ \frac{L^{-1} [\delta(L)^{-1} - \delta(\theta)^{-1}]}{(1 - \theta L^{-1})} \right\} L v_t \\ &= \frac{\alpha}{1+\beta} \left\{ \frac{\delta(\theta)^{-1} - L^{-1} \theta \delta(\theta)^{-1}}{(1 - \theta L^{-1})} \right\} v_t \\ &= \frac{\alpha}{1+\beta} \left\{ \frac{\delta(\theta)^{-1} [1 - \theta L^{-1}]}{(1 - \theta L^{-1})} \right\} v_t \\ &= \frac{\alpha}{1+\beta} \delta(\theta)^{-1} v_t \end{aligned}$$

4. In a simple case where z_t contains only one element and is governed by a first-order autoregressive process:

$$z_t = az_{t-1} + v_t, \quad -1 < a < 1$$

It follows that $\delta(L) = (1 - aL)$ and $\delta(L)^{-1} = 1/(1 - aL)$. Consequently, $\delta(\theta)^{-1} = 1/(1 - a\theta) = (1 + \beta)/(1 + \beta - a\beta)$ using $\theta = \beta/(1 + \beta)$. Substituting into equation (2.7) gives

$$s_t - {}^E_{t-1}s_t = \frac{\alpha}{1 + \beta(1-a)} v_t$$

which shows that the unexpected exchange rate change is positively related to the forecast error v_t .

5. According to Urich (1982), the foreign exchange market may be viewed as a competitive Walrasian auction market. Consequently, the effect of, say, the money supply announcement on the exchange rate can be separated into three distinctive stages:

- i) an auction takes place in the foreign exchange market before the money supply announcement and the value of the exchange rate ${}^E_{t-1}s_t$ is determined;
- ii) money supply announcement at time t of the actual money supply realized nine days earlier; and
- iii) a second auction takes place immediately after the money supply announcement establishing a new exchange rate s_t which reflects the influence of both direct and indirect effects.

6. The forward rate is commonly used as a proxy for the expected exchange rate but data are only available for the forward rate of maturity of one month or longer.

7. Although the expected change in the exchange rate is not zero even in the absence of any surprises or innovations (given forward premium or discount), the high frequency of data used in this study means that such "drift" in the exchange rate will have a negligible effect on the results.

8. The actual exchange rate change may be decomposed into unexpected and expected components:

$$s_t - s_{t-1} = (s_t - {}^E_{t-1}s_t) + ({}^E_{t-1}s_t - s_{t-1})$$

If uncovered interest parity holds and 1-day interest rate differentials are very small at daily rates, then the unexpected exchange rate change for all practical purposes is equal to the actual exchange rate change.

9. If the expected exchange rate change is significant, which is most unlikely, using exchange rate change as the

dependent variable may yield biased results. Suppose the "true model" is:

$$s_t - {}_tE_1 s_t = a + b(x_t - \hat{x}_t) + c(\hat{x}_t - x_{t-1}) + u_t$$

where, for simplicity, x_t is assumed to be a single variable and lag terms are ignored. If ${}_tE_1 s_t \neq s_{t-1}$, the expected change in the exchange rate is not zero but is determined as:

$${}_tE_1 s_t = \alpha_0 + \alpha_1 s_{t-1} + \alpha_2 (\hat{x}_t - x_{t-1})$$

where α_0 captures the potential impact of news other than the announcements of x_t . Estimation of the announcement effect using $(s_t - s_{t-1})$ rather than $(s_t - {}_tE_1 s_t)$ as the dependent variable assumes $\alpha_0 = \alpha_2 = 0$ and $\alpha_1 = 1$. The anticipated change in x_t could have a nonzero effect even in an efficient market if: (a) $\alpha_2 \neq 0$ and (b) $(s_t - s_{t-1})$ is used as the dependent variable. This can be seen by substituting the expression for ${}_tE_1 s_t$ into the "true model" which yields:

$$\begin{aligned} s_t - \alpha_1 s_{t-1} &= (a + \alpha_0) + b(x_t - \hat{x}_t) \\ &+ (c + \alpha_2)(\hat{x}_t - x_{t-1}) + u_t \end{aligned}$$

Thus the significance of the anticipated change in x_t may be due to either market inefficiency (i.e. $c \neq 0$) or the use of $(s_t - s_{t-1})$ as the dependent variable, or both.

APPENDIX I: Construction of Equation (2.1) Using the Monetary Approach

Following Bordo and Choudhri (1982), and Batten and Hafer (1984), the demand functions for domestic and foreign money that incorporate currency substitution can be written as:

$$m_t^d - p_t = \beta_1 y_t - \beta_2 r_t - \beta_3 (\bar{e}_{t+1} - s_t) \quad (A1)$$

$$m_t^{d*} - p_t^* = \beta_1 y_t^* - \beta_2 r_t^* + \beta_3 (\bar{e}_{t+1} - s_t) \quad (A2)$$

where:

m_t^d = demand for real balances

p_t = price level

y_t = real income

r_t = nominal interest rate

s_t = spot exchange rate (price of foreign currency)

$\bar{e}_{t+1}$ = expected spot exchange rate at time $t+1$

conditional upon the information set at time t .

All variables except r are expressed in logarithms and foreign variables are indicated by asterisks.

Assuming $m_t = m_t^d$ and $m_t^* = m_t^{d*}$ (where m_t is money supply), (A1) and (A2) can be rearranged to give

$$p_t = m_t - \beta_1 y_t + \beta_2 r_t + \beta_3 (\bar{e}_{t+1} - s_t) \quad (A3)$$

$$p_t^* = m_t^* - \beta_1 y_t^* + \beta_2 r_t^* - \beta_3 (\bar{e}_{t+1} - s_t) \quad (A4)$$

If purchasing power parity holds,

$$s_t = p_t - p_t^* \quad (A5)$$

Substituting p_t and p_t^* from (A3) and (A4) into (A5) yields

$$s_t = m_t - m_t^* - \beta_1 y_t + \beta_1 y_t^* + \beta_2 r_t - \beta_2 r_t^* + (\beta_3 + \beta_3) (\bar{e}_{t+1} - s_t) \quad (A6)$$

which is the monetary version of equation (2.1).

APPENDIX II: Derivation of Equation (2.5)
and Equation (2.6)

Equation (2.4) can be expressed as

$$z_t = \delta(L)^{-1} v_t = \mu(L) v_t = \left[\sum_{k=0}^{\infty} \tilde{\epsilon}_{0\mu k} L^k \right] v_t \quad (A1)$$

The Weiner-Kolmogorov prediction formula is

$$\tilde{\epsilon} z_{t+j} = [\mu(L)/L^j]_+ v_t \quad (A2)$$

where $[\]_+$ is the annihilation operator that ignores negative powers of L . In other words,

$$\tilde{\epsilon} z_{t+j} = \left[\sum_{k=0}^{\infty} \tilde{\epsilon}_{j\mu k} L^{k-j} \right] v_t \quad (A3)$$

Then,

$$\begin{aligned} \sum_{j=0}^{\infty} \tilde{\epsilon}_{0\theta^j} \tilde{\epsilon} z_{t+j} &= \left[\sum_{j=0}^{\infty} \tilde{\epsilon}_{0\theta^j} \sum_{k=0}^{\infty} \tilde{\epsilon}_{j\mu k} L^{k-j} \right] v_t \\ &= \phi(L) v_t \end{aligned} \quad (A4)$$

where $\phi(L) = \sum_{j=0}^{\infty} \tilde{\epsilon}_{0\theta^j} \sum_{k=0}^{\infty} \tilde{\epsilon}_{j\mu k} L^{k-j}$.

Interchanging orders of summation gives:

$$\begin{aligned} \phi(L) &= \sum_{k=0}^{\infty} \tilde{\epsilon}_{0\mu k} \sum_{j=0}^k \tilde{\epsilon}_{0\theta^j} L^k L^{-j} \\ &= \sum_{k=0}^{\infty} \tilde{\epsilon}_{0\mu k} L^k \sum_{j=0}^k \tilde{\epsilon}_{0\theta^j} L^{-j} \\ &= \sum_{k=0}^{\infty} \tilde{\epsilon}_{0\mu k} L^k \left[(1 - \theta^{k+1} L^{-k-1}) / (1 - \theta L^{-1}) \right] \\ &= \left(\sum_{k=0}^{\infty} \tilde{\epsilon}_{0\mu k} L^k - \theta L^{-1} \sum_{k=0}^{\infty} \tilde{\epsilon}_{0\mu k} \theta^k \right) / (1 - \theta L^{-1}) \\ &= [\mu(L) - \theta L^{-1} \mu(\theta)] / (1 - \theta L^{-1}) \end{aligned} \quad (A5)$$

Although the above expression for $\phi(L)$ contains positive and negative powers of L , the polynomial in the lag operator

$\phi(L)$ by construction contains only nonnegative powers of L .
In summary it has been shown that

$$\sum_{j=0}^{\infty} \theta^{-j} z_{t+j} = \frac{[\mu(L) - \theta L^{-1} \mu(\theta)]}{(1 - \theta L^{-1})} v_t \quad (A6)$$

Since $\mu(L) = \delta(L)^{-1}$ and $\mu(\theta) = \delta(\theta)^{-1}$ [from (A1)], (A6) can be expressed as

$$\sum_{j=0}^{\infty} \theta^{-j} z_{t+j} = \frac{[\delta(L)^{-1} - \theta L^{-1} \delta(\theta)^{-1}]}{(1 - \theta L^{-1})} v_t \quad (A7)$$

which is equation (2.5).

The derivation of equation (2.6) is straightforward.
Using (A7),

$$\sum_{j=0}^{\infty} \theta^{-j} z_{t+j-1} = \frac{[\delta(L)^{-1} - \theta L^{-1} \delta(\theta)^{-1}]}{(1 - \theta L^{-1})} v_{t-1} \quad (A8)$$

Since $\sum_{j=0}^{\infty} \theta^{-j} z_{t+j-1} = z_{t-1} + \theta \sum_{j=0}^{\infty} \theta^{-j} z_{t+j}$, and

$$z_{t-1} = \delta(L)^{-1} v_{t-1},$$

$$\begin{aligned} \sum_{j=0}^{\infty} \theta^{-j} z_{t+j-1} &= \frac{[\delta(L)^{-1} - \theta L^{-1} \delta(\theta)^{-1}]}{(1 - \theta L^{-1})} v_{t-1} \quad (A9) \\ &\quad - \theta^{-1} \delta(L)^{-1} v_{t-1} \\ &= \frac{L^{-1} [\delta(L)^{-1} - \delta(\theta)^{-1}]}{(1 - \theta L^{-1})} v_{t-1} \end{aligned}$$

which is equation (2.6).

CHAPTER III

EMPIRICAL TESTING: REVIEW OF LITERATURE AND RESEARCH METHODOLOGY

This chapter provides a review of the literature and establishes the research methodology for estimating the empirical model of Chapter II. In Section I, a representative sample of the relevant literature is discussed. In this survey, the focus is on studies which deal with the impact of economic news on the Canada-U.S. exchange rate. In Section II, the research methodology is discussed, while Section III concludes with a summary and commentary.

I. Review of Literature

The impact of economic announcements on the exchange rates depends crucially on the frequency of exchange rate data used. If exchange rate observations are close enough in time, before and after the announcement, it is likely that exchange rate changes are explained largely by the announcement. If, however, the time interval is too long, the exchange rate may be affected by other factors and not accurately reflect the impact of the economic announcement.

The existing studies may be grouped into the following categories according to the frequency of the exchange rate data used:

- (1) Monthly Exchange Rate Data,

(2) Daily Exchange Rate Data, and

(3) Intra-Daily Exchange Rate Data.

Each category is considered in detail below.

1. Monthly Exchange Rate Data

Studies using monthly exchange rate data (Longworth, 1979; Frenkel, 1981; Edwards, 1982, 1983) tend to pay more attention to the question of market efficiency than the announcement effect. This is, because month-to-month changes in the exchange rate cannot capture the immediate response of exchange rates to an announcement. As pointed out by Belongia and Sheehan (1987), an accurate assessment of the impact of an announcement depends on how well that announcement is isolated from other events. Since agents receive a continuous flow of information, measuring the exchange rate change over a period of one month may confuse the effect of that announcement with the reaction to other new information.

The most common test of market efficiency has been the estimation of the following equation:¹

$$e_t = a + b f_{t-1} + u_t \quad (3.1)$$

where e_t is the logarithm of the spot exchange rate at time t (the price of a foreign currency in U.S. dollars), f_{t-1} is the logarithm of the forward exchange rate at time $t-1$ of one-month maturity, and u_t is the error term.² The null hypothesis that the forward rate is an efficient predictor

of the future spot rate implies that $a = 0$, $b = 1$ and u_t is white noise. If these conditions hold, the market is said to exhibit "speculative efficiency".³ Empirical tests of this hypothesis for various foreign exchange markets yield mixed results, with several studies rejecting the null hypothesis (Hansen and Hodrick, 1980; Hakkio, 1981; Longworth, 1983; Baillie, Lippens and McMahon, 1983).

It should be stressed that rejection of the null hypothesis does not necessarily imply that the market is inefficient since the expected spot rate can differ from the forward rate because of risk premiums (which may be constant or time-varying).⁴ Consequently, rejection of the null hypothesis is actually the rejection of a joint hypothesis of market efficiency and no risk premiums.⁵ It is not possible to determine a priori whether the rejection of the null hypothesis is due to market inefficiency or the existence of time-varying risk premiums or both.

Frenkel (1981) argued that the divergence between the forward rate (as set at time $t-1$) and the actual spot rate at time t may be explained by the fact the spot rate at time t reflects news that was not available at time $t-1$. The spot rate should then reflect, in addition to previously formed expectations, all unanticipated events or news. Accordingly, equation (3.1) should be extended such that:⁶

$$e_t = a + b f_{t-1} + c \text{ "news" } + v_t \quad (3.2)$$

where news variables represent new information arriving in the market during the one-month interval from time $t-1$ to t ,

and v_t is the error term. Under the assumption that exchange markets are efficient, it is expected that in equation (3.2) $a = 0$, $b = 1$, $c = 0$ and v_t is white noise.

As pointed out by Frenkel (1981), "the key difficulty lies in identifying the variable which measures the news".⁷ Frenkel focused on news of the interest rate differential. Thus, equation (3.2) was written as:

$$e_t = a + b f_{t-1} + \delta \text{INN} + v_t \quad (3.3)$$

where:

$$\text{INN} = [(i_t - i_t^*) - \sum_{i=1}^n (i_t - i_t^*)]$$

= unexpected interest rate differential;

i_t = U.S. interest rate; and

i_t^* = foreign interest rate.

He tested equation (3.3) for the dollar/pound, dollar/franc and dollar/DM rate from June 1973 to July 1979. His principal conclusion is that the exchange rate behavior "... has been broadly consistent with the general implications of the efficient market hypothesis".⁸ Since the 1970's were characterized by inflation, δ is expected to be positive, reflecting news about inflationary expectations. Frenkel found δ to be positive in all cases, although in one case (the dollar/pound market), δ differed significantly from zero.

⁸Edwards (1982) tested equation (3.2) for the currencies studied by Frenkel, plus the dollar/lira rate, from July 1973 to September 1979. News about money supply, real income, and the interest rate of each country were examined.

Autoregressions of these variables were used to obtain the news. Using Zellner's seemingly unrelated regressions (SURE), he concluded that "...during the recent floating period exchange rates have behaved according to the market efficiency hypothesis".⁷ With respect to news, he reported positive and significant coefficients on unanticipated relative money supplies for two currencies, a positive and significant coefficient on unanticipated relative real incomes for one currency, and a negative and significant coefficient on unanticipated interest rate differentials for one currency. The above analysis was repeated in Edwards (1983) with news generated from vector autoregressions.

Longworth (1979)⁸ used an extended version of equation (3.2) to test the efficiency of the Canada-U.S. exchange market, with the estimation equation as:

$$s_t - s_{t-1} = a_0 + a_1 (f_{t-1} - s_{t-1}) + a_2 \Delta(f_t - s_t) + c \text{ NEWS} + u_t \quad (3.4)$$

where:

- $s_t - s_{t-1}$ = change in the logarithm of end-of-month spot exchange rate (Canadian dollars/U.S.dollars),
- $f_{t-1} - s_{t-1}$ = lagged forward premium, and
- $\Delta(f_t - s_t)$ = revision between time $t-1$ and time t of the expected exchange rate at time $t+1$.

He estimated equation (3.4) using monthly data from 1972 to 1978, with news generated from autoregressions. Two

interesting findings emerge from his tests. One is that news of interest rate changes, the merchandise trade balance and new foreign borrowing by Canadians were found to have significant impacts on the Canada-U.S. exchange rate. The other is that the coefficient on the lagged forward premium was significantly different from unity and thus inconsistent with the market efficiency hypothesis. As Longworth (1979) pointed out: "rejection of the unbiasedness of the forward premium does not necessarily mean that the exchange market was inefficient."¹⁰ Consequently, the role of risk premiums cannot be ruled out.

2. Daily Exchange Rate Data

Most studies investigating the effect of announcements measure changes in exchange rates over a 24-hour period (Cornell, 1982; Doukas, 1985; Engel and Frankel, 1984; Goodhart and Smith, 1985; Hardouvelis, 1984, 1985; Ngiam, 1987; Tandon and Urich, 1987). This should give more precise estimates than those obtained using data on monthly exchange rate changes. Table 3.1 summarizes the main features of these studies.

Certain facts stand out. First, most studies used survey data provided by the Money Market Services Inc. of San Francisco to measure expectations.¹¹ Second, since this company surveys only the major U.S. economic indicators, studies that used its data were forced to examine only U.S. economic news. Third, a few studies which examined the non-U.S. news used either the ARIMA model to generate

TABLE 3.1

MAIN FEATURES OF STUDIES USING
DAILY EXCHANGE RATE DATA

<u>Author</u>	<u>Sample Period</u>	<u>Measurement of Expectations^(a)</u>	<u>Economic News</u>
Cornell (1982)	11/10/78-12/12/81	Survey Data	U.S. money supply news
Doukas (1985)	01/01/76-01/02/78	ARIMA Model	U.S. and Canadian money supply news
Doukas and Melhem (1985)	01/01/74-09/21/77	ARIMA Model	U.S. money supply news
Doukas and Melhem (1986)	09/21/77-10/03/79	ARIMA Model	U.S. and Canadian money supply news
Engel and Frankel (1984)	10/01/79-08/01/81	Survey Data	U.S. money supply news
Goodhart Smith (1985)	01/01/77-12/31/83	Survey Data ^(b)	Several U.K. economic news
Hardouvelis (1985)	10/11/79-08/16/84	Survey Data	Several U.S. economic news
Ngiam (1987)	03/10/80-02/01/84	Survey Data ^(c)	Canadian bank rate
Tandon and Urich (1987)	10/06/79-12/31/82	Survey Data	U.S. money supply and inflation news

Notes: (a) Unless otherwise stated, survey data were obtained from the Money Market Service of San Francisco.

(b) Data from Messel and Company of London.

(c) Data from the Toronto Globe and Mail.

expectations (Doukas, 1985; Doukas and Melhem, 1985, 1986) or the expectational series from other sources (Goodhart and Smith, 1985; Ngiam, 1987). For example, Goodhart and Smith (1985) used the expectational series of a City of London broker, Messel and Co., for the major U.K. economic indicators.¹² Ngiam (1987) used the expectational series of the Toronto Globe and Mail for weekly bank rate changes.¹³

Since literature in this area is extensive, only the results about the impact of economic news on the Canada-U.S. exchange rate are presented. Common to these studies is the examination of the effect of U.S. money supply news, the first topic to be considered. Unlike equation (2.8) which employs a vector of economic news simultaneously, the studies in Table 3.1 (with one exception) employ a separate equation to test each type of economic news.¹⁴ To test the effect of weekly U.S. money supply announcements, the standard equation is:¹⁵

$$s_t - s_{t-1} = a + b(m_t^e - \hat{m}_t^e) + c(\hat{m}_t^e - m_{t-1}^e) + u_t \quad (3.5)$$

where: $(s_t - s_{t-1})$ is the logarithmic change in the exchange rate from Friday at 4:30 p.m. to Monday at 4:30 p.m. (before and after the U.S. money supply announcements); $(m_t^e - \hat{m}_t^e)$ and $(\hat{m}_t^e - m_{t-1}^e)$ are the unanticipated and anticipated change in U.S. money supply; and u_t is the error term. The market is considered to be efficient if $b \neq 0$ and $c = 0$.

Results about the impact of U.S. money supply news on the Canada-U.S. exchange rate are reported in Table 3.2. Only

TABLE 3.2

EMPIRICAL RESULTS OF THE WEEKLY U.S. MONEY SUPPLY
ANNOUNCEMENTS FOR STUDIES USING
DAILY EXCHANGE RATE DATA

<u>Study</u>	<u>Estimated Coefficients</u>		
	a	b	c
Cornell (1982) ⁺	-.047 (1.73)	-.051 (1.07)	N.R.
Doukas (1985)	.0003 (1.57)	.051 (2.15)	N.R.
Hardouvelis (1985) ⁺	-.007 (0.01)	-.038 (.032)	N.R.
Doukas and Melhem (1985) ⁺	N.R.	-.071 (2.16)	N.R.
Doukas and Melhem (1986) ⁺	-.0004 (1.86)	-.071 (2.03)	-.003 (1.12)
Tandon and Urich (1987) ⁺	-8.86 (4.14)	-.890 (0.93)	-4.27 (3.11)
	-2.16 (.92)	-.990 (0.72)	-2.10 (1.22)

Note: The model is $s_t - s_{t-1} = a + b(m_t^* - m_{t-1}^*)$

$$+ c(\hat{m}_t^* - m_{t-1}^*) + u_t$$

The absolute values in parenthesis are t-statistics.

N.R. means the particular coefficient is either not estimated or not reported.

⁺ means that the particular study defines the exchange rate as the price of a Canadian dollar in U.S. dollars.

studies by Doukaš (Doukas, 1985; Doukas and Melhem, 1985; Doukas and Melhem, 1986) reported a significant reaction of the Canada-U.S. exchange rate to announcements of U.S. money supply (using the ARIMA model to generate expected values). Studies which reported the Canada-U.S. exchange rate did not respond to the announcement of U.S. money supply used survey data (Cornell, 1982; Hardouvelis, 1985; Tandon and Urich, 1987). These results are surprising since Urich and Wachtel (1981) found that forecasts of U.S. money supply from market surveys and the ARIMA model are almost identical. Their findings led them to conclude that "by this time, the ARIMA model can be treated as a standard methodology for proxying expectations".¹⁴

Those that reported significant effects found that an unanticipated increase (decrease) in the U.S. money supply causes an immediate appreciation (depreciation) of the U.S. dollar against the Canadian dollar.¹⁵ The estimated coefficient implies that a 1 percent unanticipated weekly increase (decrease) in the U.S. money supply (approximately 5 billion U.S. dollars) leads to an immediate appreciation of the U.S. dollar against the Canadian dollar of about 0.07 percent.

The effect of the other economic news has been considered in a few studies. Hardouvelis (1985) and Tandon and Urich (1987) examined the reaction of the Canada-U.S. exchange rate to a range of U.S. macroeconomic announcements: the U.S. index of industrial production, the U.S. consumer price index, the U.S. merchandise trade balance, the U.S. discount rate, and several other monthly U.S. macroeconomic series. Tandon and

Urich (1987) found the Canada-U.S. exchange rate reacted to news about the U.S. producer price index but not the U.S. consumer price index. Hardouvelis (1985) reported the Canada-U.S. exchange rate responded only to changes in the U.S. discount rate. Since both studies employed daily exchange rate data and survey data as proxies for expectations, differences in their results could be due to the longer sample period employed in Hardouvelis (1985).

Only a few studies (Doukas, 1985; Doukas and Melhem, 1986; Ngiam, 1987) investigated reactions of the Canada-U.S. exchange rate to economic news originating in Canada.¹⁰ Doukas (1985) and Doukas and Melhem (1986) found the Canada-U.S. exchange rate did not react to Canadian money supply news. Ngiam (1987) reported that, an unexpected increase (decrease) in bank rate appeared to cause an immediate appreciation (depreciation) of the Canadian dollar against the U.S. dollar, but an expected change in bank rate did not affect the exchange rate.

3. Intra-Daily Exchange Rate Data

Two studies examined intra-daily movements in the exchange rates in the context of economic news (Hakkio and Pearce, 1985; Ito and Roley, 1987). Hakkio and Pearce (1985) examined the impact of U.S. economic news on the exchange rates at 9:00 a.m., 12:00 noon and 4:30 p.m. each business day (changes in the exchange rates are: 9:00 a.m. to noon on the same day, noon to 4:30 p.m. on the same day, and 4:30 p.m. to 9:00 a.m. the next business day). Ito and Roley (1987) used twice-daily

data on the Yen/U.S. dollar exchange rate and examined its reaction to a wide range of economic news in both the United States and Japan.¹⁷

Using thrice-daily exchange rate data, Hakkio and Pearce (1985) obtained results which are different from those reported by studies using daily exchange rate data. In common with these studies, Hakkio and Pearce (1985) used survey data as proxies for expectations but reported a significant reaction of the Canada-U.S. exchange rate to the announcement of the U.S. money supply. Their results for the impact of other U.S. economic news also differed from those obtained by Hardouvelis (1985) and Tandon and Urich (1987). Contrary to the findings of these two studies, Hakkio and Pearce (1985) found the Canada-U.S. exchange rate reacted immediately to unexpected changes in the U.S. index of industrial index but responded slowly to an unexpected change in the U.S. consumer price index. This shows that the results are sensitive to the measurement of exchange rate changes.

II. Research Methodology

This section presents the research methodology for estimating equation (2.8) in a fashion that avoids — or at least minimizes — the specification errors found in other studies. By using improved methodology, this study provides a more stringent test of the efficient markets hypothesis. Although there are many possible ways of estimating equation (2.8), the following considerations are important:

- (1) Measurement of Expectations;
- (2) Specification of Economic news;
- (3) Frequency of Exchange Rate Data; and
- (4) Treatment of Intervals with No Announcements.

(1) Measurement of Expectations

As discussed in the previous section, the existing empirical work on the announcement effects measured expectations either from market surveys or the ARIMA model. This poses two problems.

The first problem is that survey data are available only for U.S. variables so that studies using this data are forced to examine only U.S. economic news. To study the impact of Canadian money supply news, Doukas (1985) used the ARIMA model to generate expectations. To examine the impact of bank rate changes, Ngiam (1987) employed an expectation series derived from Toronto Globe and Mail reports.

The second problem is that survey data and expectations data generated from the ARIMA model may be biased by omitting certain relevant information. Survey data are not up-to-date since these are gathered many days (and in certain cases up to a week) before the actual announcement. For example, the survey on the expected change in the U.S. money supply is not taken on the day of the announcement (Friday) but three days before (Tuesday).²⁰ The ARIMA model has been criticised for being too narrow in scope since it uses only past values of the variable considered to generate the expected values. It is widely recognized that expectations of any variable are

determined not only by its own past values but also by past values of other variables. For example, any attempt to measure anticipated money growth using only a money supply series is not likely to be accurate.

To overcome these problems, this study develops econometric measures of expectations that attempt to incorporate all relevant available information. Unlike previous studies, the information set used in this study includes a wide range of variables announced at different frequencies (e.g. monthly, weekly and daily). To deal with these different frequencies, two methods for measuring expectations are developed. The first method (Method I) uses past values of those variables that are announced at monthly and weekly intervals. The novelty of this method is that it is able to exploit both monthly and weekly data for generating expectations. The second method (Method II) augments the information set used in Method I with relevant data available on a daily basis. These two methods for measuring expectations will be discussed in detail in Chapter V.

(2) Specification of Economic News

The theoretical analysis in Chapter II suggests that types of economic news should not be chosen arbitrarily but should be relevant to asset market models of exchange rate determination. The following models have been chosen in this regard:

- (a) the "flexible-price" monetary model (Bilson, 1978; Frenkel, 1976; Mussa, 1976),

- (b) the "sticky-price" monetary model (Dornbusch, 1976; Frankel, 1979), and
- (c) the Hooper-Morton model (Hooper and Morton, 1982).²¹

The key assumption underlying the flexible-price monetary model is that purchasing power parity (PPP) holds continuously, in the short run as well as in the long run. If this assumption is combined with money demand functions of the two countries, the exchange rate can be expressed as a function of relative money supplies, relative incomes, and the interest rate differential. The interest rate differential can be replaced by differences in expected inflation rates if uncovered interest parity is assumed to hold.

The sticky-price monetary model has the same long-run properties as the flexible-price monetary model, but allows for sluggish price adjustment leading to short-run deviations from purchasing power parity.²²

The Hooper-Morton model extends the two monetary models by considering changes in the real exchange rate. As proxies for real exchange rate changes, this model uses unexpected changes in the current account balance and the trade balance.

The basic variables of these models are money supply, interest rate, real income, inflation rate and the trade balance.²³ They are incorporated as elements in the vector x of equation (2.8), and their significance tested. Moreover, since in this study the exchange rate is defined as the relative price of Canadian and U.S. currencies, the same determinants from both Canada and the United States will be considered.

(3) Frequency of Exchange Rate Data

In estimating equation (2.8), the change in the exchange rate ($s_t - s_{t-1}$) should be measured over as short an interval as possible. There are two reasons. First, as Hardouvelis (1985) and others have noted, using exchange rate data from longer intervals adds "noise" to the measurement of the dependent variable. Since agents receive a continuous flow of information, measuring the change in the exchange rate over a period of one day or more confuses the announcement effect with the impact of other (new) information. Second, if the authorities respond to the exchange rate movements within the time interval from $t-1$ to t , estimates of equation (2.8) may suffer from simultaneity bias.²⁴ It would then be difficult to infer about the impact of economic news. The shorter the interval, the less severe is the bias.

To isolate the announcement effect from other factors, this study employs the narrowest window through which the change in the exchange rate has yet been measured: from noon to 4:30 p.m. on the same day and from 4:30 p.m. to noon the following business day. These data are discussed in detail in Chapter IV.

(4) Treatment of Intervals With No announcements

In this study, the change in exchange rate is measured over a time interval of less than one day: from noon to 4:30 p.m. on the same day and from 4:30 p.m. to noon the following business day. Theoretically, if all variables were announced

twice-daily and expectations formed with the same frequency, each interval would contain the values resulting from news ($x_{1t} - \hat{x}_{1t}$) of the variables. The effect would be zero if the actual announcement (x_{1t}) equalled that predicted ($\hat{x}_{1t}$). That the variables are not announced twice-daily poses two problems.

The first problem involves the assignment of values to intervals that have no announcements. If the economic indicator x_{1t} is announced once a week, then news for that variable is only available for every tenth interval: $t-1$ to t , $t-11$ to $t-10$, $t-21$ to $t-20$ etc. To overcome this problem, the intervening intervals which have no announcements are assigned zeros. These zeros must not be confused with zeros for announcements with no surprises.

The second problem concerns the choice of observations used for estimating equation (2.8). Hakkio and Pearce (1985) and Hardouvelis (1985) used all the observations but claimed their results were unchanged by excluding intervals for which none of the economic indicators are announced.²⁵ However, as shown in Appendix I, the coefficients will be the same only if the mean of the exchange rate change is zero.¹¹ It is also shown that even if the coefficients are the same, the standard errors will be different. Apart from differences in results, the procedure adopted by these authors introduces a measurement error problem by equating no news due to no announcements with no news due to actual announcements equal to predicted announcements. To try to eliminate this measurement error problem, the estimation of equation (2.8) excludes intervals with no announcements.²⁶

III. Summary and Commentary

In this chapter, a review of the literature dealing with the impact of economic news on the exchange rates is presented. The studies are classified into three groups according to the frequency of exchange rate data used. The first group uses month-to-month changes in exchange rates to examine the impact of economic news. With monthly exchange rate changes, the immediate response of exchange rates to announcements is not measured. As recognized in the literature on the response of asset prices to economic announcements, it is desirable to take the shortest interval possible around potential news since over a longer period other shocks may occur to dilute the estimated effect.

The second group employs daily exchange rate data to study the impact of news. This should give more precise estimates than those obtained with monthly exchange rate changes. Even so, these studies are still not completely satisfactory for two reasons. First, since the exchange rate may react almost immediately to news, using exchange rate data with a 24-hour interval may not accurately capture the impact of the news. Second, almost all these studies have examined only U.S. news because survey data on a broad range of U.S. economic indicators are readily available. However, since the exchange rate is the relative price of two currencies, it should be affected not only by U.S. news but also by the news of the other country.

In an attempt to incorporate the impact of Canadian news on the Canada-U.S. exchange rate, Doukas (1985) used the ARIMA

model to generate expectations for the Canadian money supply. Ngiam (1987) studied the impact of the bank rate announcements using expectations data on the bank rate changes provided by the Toronto Globe and Mail.

The third group (Hakkio and Pearce, 1985; Ito and Roley, 1987) used intra-daily exchange rate data to examine the impact of economic news. Compared to daily data, intra-daily data should enable a more stringent test of the impact of economic news if news affects the exchange rate quickly. Unfortunately, Canadian economic news were not considered in the studies: Hakkio and Pearce (1985) examined the impact of U.S. economic news on seven bilateral exchange rates, while Ito and Roley (1987) studied the impact of U.S. and Japanese economic news on the yen/dollar exchange rate.

From the review of empirical evidence, it is clear that the results are sensitive to the measurement of exchange rate changes and expectations. As a result, it is important to use high frequency exchange rate data and measure expectations accurately to produce a powerful test of market efficiency. For example, the U.S. money supply news appears to affect the Canada-U.S. exchange rate only when the exchange rate is measured over a time interval of less than one day or when the ARIMA model is used to measure expectations.

This study uses a research methodology that improves on the methodological problems of previous studies, by using (a) short-term intervals between exchange rate observations, (b) a wide range of Canadian and U.S. economic data, and (c) more accurate measurement of expectations. This study should produce a more powerful test of market efficiency and provide

a rigorous test of the impact of different types of economic news (e.g. monetary vs nonmonetary news or Canadian vs U.S. news). The remaining chapters are devoted to a development of this analysis.

FOOTNOTES TO CHAPTER III

1. Other types of tests of market efficiency can be found in Longworth, Boothe and Clinton (1983).

2. Here there is a change of notation. A unit increase in the subscript t now stands for 1 month. Similar change in notation will be made when daily data are used.

3. This is the terminology of Bilson (1981).

4. For example, Fama (1984) found strong evidence of time-varying premiums for a number of currencies.

5. Transactions costs for trading in heavily-traded currencies, embodied in their bid-ask spreads, are found to be negligible. See Longworth, Boothe and Clinton (1983) for estimates of these costs.

6. Failure to take news into consideration would produce less efficient estimates of a and b in equation (3.1).

7. Frenkel (1981), pp. 687.

8. Frenkel (1981), pp. 672.

9. Edwards (1982), pp. 382.

10. Longworth, pp. 12.

11. Each week, this company asks some 60 market participants about their expectations of the major U.S. economic statistics to be released in the following seven days. Prior to February 8, 1980, surveys were conducted twice weekly on Tuesday and Thursday. Since then surveys have been conducted only once a week (Tuesday). Twelve economic indicators are surveyed (the money supply, unemployment rate, producer price index, consumer price index, consumer installment credit, retail sales, industrial production index, personal income, housing starts, manufacturers' orders for durable goods, trade balance, and the composite index of leading indicators). Since money supply figures are announced on a weekly basis, the survey on M1 is done once a week. The indicators announced on a monthly basis are surveyed at a monthly interval. The medians of the surveys are normally used to represent the expected values.

12. The United Kingdom is the only country outside the United States where expectational series are available on a regular basis for major economic indicators prior to the announcements but this series is not derived from a market survey and is not widely used. See Goodhart and Smith (1985) for a discussion of these data.

13. The Thursday edition of the Toronto Globe and Mail often has an article predicting the change in the bank rate to be announced that afternoon. In Ngiam's (1987) study, all the Thursday reports were scrutinized but only those that made specific and definitive statements about the expected change in the bank rate were selected for the empirical analysis.

14. An exception is Hardouvelis (1985) who simultaneously tests different types of U.S. economic news in a single equation.

15. As seen in Table 3.2, some studies omitted the expected money supply term by estimating the following equation:

$$s_t - s_{t-1} = a' + b' (m_t^* - \hat{m}_t^*) + u_t$$

Since $(m_t^* - \hat{m}_t^*)$ and $(\hat{m}_t^* - m_{t-1}^*)$ are orthogonal, estimates of b and b' should differ only slightly. See Peel and Pope (1987) for a discussion of this topic.

16. Urlich and Wachtel (1981), pp. 1065.

17. This finding supports the so-called "policy anticipation effect" which suggests that agents expect the Federal Reserve to respond to a positive (negative) money shock by tightening (loosening) up future money supply. See Urlich and Wachtel (1981), Cornell (1983), and Roley and Walsh (1985) for a discussion of this effect.

18. London (1981) used a different methodology, the "residual analysis", to examine the impact of Canadian bank rate changes from 1971 to 1979 on the Canada-U.S. exchange rate.

19. Ito and Roley (1987) used survey data to derive the U.S. economic news but the ARIMA model to obtain the Japanese economic news.

20. Recent studies (Brocato, 1987; Deaves, Melino and Pesando, 1987) have shown that the U.S. money stock as determined from survey respondents is a biased predictor of the actual money stock subsequently announced by the Federal Reserve.

21. These three models are also used by Meese and Rogoff (1983) for forecasting exchange rates.

22. Frenkel (1983) gives an excellent account of the differences between the two models.

23. An analysis of the trade balance instead of the current account balance was chosen for two reasons. First, Hooper and Morton (1982) found that "unexpected changes in the current account and the trade balance serve equally well as indicators of the real shocks requiring adjustments in the real exchange rate" (pp. 49). Second, the trade balance figures are released on a monthly basis in Canada and the United States. In contrast, the current account figures only appear

quarterly.

24. See Hardouvelis (1985) for a discussion of this topic.

25. Pearce (1984) and Hardouvelis (1986), personal communications.

26. Using all the observations did not affect the conclusions but changed the coefficients and t-statistics slightly. Since the correct procedure is to exclude those intervals during which none of the ten series is announced, only these results are presented (Chapter VI).

APPENDIX I: Estimates Using All Intervals and
Using Only Announcement Intervals

Let equation (2.8) be represented as follows:

$$y = XB + u \quad (A1)$$

where y = the vector of the regressand

X = the matrix of the regressors

B = the vector of the unknown parameters

u = the vector of the disturbance terms

Suppose that the intercept term a in equation (2.8) is a priori zero and thus the rows of X corresponding to the time period with no announcements are set to zero in (A1).

Case I: All observations are used (including intervals with no announcements)

From equation (A1), B can be estimated as:

$$\hat{B} = (X'X)^{-1}X'y \quad (A2)$$

The variance-covariance matrix of $\hat{B}$ is estimated as:

$$\text{Est. cov}(\hat{B}) = \hat{\sigma}^2(X'X)^{-1} \quad (A3)$$

where $\hat{\sigma}^2 = (y'y - \hat{B}'X'y)/T$ and T is the number of observations.

Case II: Observations with zero X 's are excluded

Suppose for simplicity that every fourth observation in the original data comes with nonzero X 's. Using only these

nonzero X 's, the number of observations (n) is now $T/4$. The estimator of β in this case is:

$$\hat{\beta} = (X'X)^{-1}X'y \quad (A4)$$

$$= (X_1'X_1)^{-1}X_1'y_1.$$

where subscript 1 refers to the subset of data with nonzero X 's. Note that the estimator $\hat{\beta}$ in equation (A2) and equation (A4) are the same because $(X'X) = (X_1'X_1)$, and $(X'y) = (X_1'y_1)$. The rows with zero's in the X matrix do not change the moment matrix.

The estimated variance-covariance matrix of $\hat{\beta}$ in this case is:

$$\text{Est. cov}(\hat{\beta}) = \hat{\sigma}^2 (X_1'X_1)^{-1} \quad (A5)$$

where $\hat{\sigma}^2 = (y_1'y_1 - \hat{\beta}'X_1'y_1)/n$.

Note that there is a difference between equation (A5) and equation (A3) due to the difference between $\hat{\sigma}$ and $\hat{\sigma}$, since $(y'y) \neq (y_1'y_1)$ although $\hat{\beta}'X_1'y_1 = \hat{\beta}'X'y$.

CHAPTER IV

DATA AND RECENT EXCHANGE RATE BEHAVIOR

The empirical model developed in Chapter II suggests that the Canada-U.S. exchange rate may react to economic news about money supply, interest rate, income, inflation rate, and trade balance for Canada and the United States. To test this empirical model, data for these variables are required. Section I describes the data employed while Section II examines the behavior of the exchange rate during the sample period from March 1980 to February 1984.

I. The Data

In this section the exchange rate data are described briefly. Data for other economic variables are then considered with a summary description of the data provided in Table 4.1.

Exchange Rate

Data for the Canada-U.S. exchange rate are the daily noon rate and the closing rate (i.e. at 4:30 p.m.) from the interbank market in Toronto, as recorded by the Canadian Bankers' Association. The noon rate is a weighted average of transactions just before and after noon. The end of the day rate is the mid-point between the buying and selling

TABLE 4.1

SUMMARY OF DATA

<u>Variables</u>	<u>Frequency</u>	<u>Day</u>	<u>Time</u>	<u>Units</u>	<u>Source</u>
Canada-U.S. exchange rate*	twice-daily	N.A.	noon and 4:30 p.m.	N.A.	Bank of Canada
Canadian money supply (M1)	weekly	Thursday	5:00 p.m.	C\$millions	Bank of Canada
U.S. money supply (M1)	weekly	Friday	4:10 p.m. / 4:15 p.m.	U.S.\$millions	Federal Reserve
Canadian bank rate	weekly	Thursday	2:00 p.m.	percent	Bank of Canada
U.S. Treasury bill rate	weekly	Monday	4:30 p.m.	percent	U.S. Treasury
Canadian index of industrial production	monthly	vary	5:00 p.m.	N.A.	Statistics Canada
U.S. index of industrial production	monthly	vary	9:30 p.m.	N.A.	Federal Reserve
Canadian consumer price index	monthly	vary	1:00 p.m.	N.A.	Statistics Canada
U.S. consumer price index	monthly	vary	8:30 a.m. / 9:00 a.m.	N.A.	U.S. Dept. of Labour
Canadian merchandise trade balance	monthly	vary	1:00 p.m.	C\$millions	Statistics Canada
U.S. merchandise trade balance	monthly	vary	2:00 p.m.	U.S.\$billions	U.S. Dept. of Commerce

Note: * The exchange rate is not announced but it is readily available twice-daily: noon and 4:30 p.m.

N.A. means not applicable.

rates when trading closed. These unpublished data have been provided by the Bank of Canada.

Canadian Money Supply

Data on the Canadian money supply are announced weekly for narrowly defined money stock M1 (currency in public circulation and demand deposits). The announcement is made Thursday at 5:00 p.m. of the money stock on Wednesday of the week before. These data are obtained from the Bank of Canada's Weekly Financial Statistics and are not seasonally adjusted.¹

U.S. Money Supply

Data on the U.S. money supply are the narrowly defined money stock M1, reported weekly in the Federal Reserve's H.6 releases. The announcements are for the level of M1 in the statement week ending Wednesday of the previous calendar week. During the period from March 1980 to October 1982, the announcements were made Friday at 4:10 p.m. From November 1982 to February 1984, the releases occurred Friday at 4:15 p.m.² While seasonally adjusted and unadjusted data are reported in the releases, only the seasonally adjusted data are used in this study since these are closely watched by financial experts and highlighted every week by the press.

Canadian Bank Rate

The proxy for Canadian interest rates is the bank rate, which is the rate charged by the Bank of Canada for advances to chartered banks. Beginning March 10, 1980, the bank rate was set one quarter of one percentage point above the average rate established in the weekly auction for the 91-day treasury bill issued by the Government of Canada. The Bank of Canada acts as the agent and announces the new bank rate at 2:00 p.m. each Thursday immediately following the tender. There are two reasons for using the bank rate as a proxy for interest rates in Canada. First, it sets the trend for other short-term interest rates in Canada. Second, changes in the bank rate are believed to transmit information about the Bank of Canada's monetary policy.

U.S. Treasury bill rate

The U.S. Treasury bill rate, the average yield on 13-week U.S. Treasury bills at the weekly auction, is used as a proxy for short-term interest rates in the United States. The Treasury bill auction is held every Monday. By 1:30 p.m. on Monday, bids must be presented at Federal Reserve Banks or their branches acting as agents for the Treasury. Bids may be made on a competitive or noncompetitive basis: for a competitive bid, the investor states the quantity of the bills desired and the price he is willing to pay; for a noncompetitive bid, the investor indicates the quantity of bills desired and agrees to pay the average price of

accepted competitive bids. The average yield of the accepted competitive bids is announced at 4:30 p.m. on the day of the auction.

The Treasury bill rate, not the discount rate, is chosen for two reasons. First, the announcement effect of discount rate changes has already been examined.⁴ Second, like the Canadian bank rate, the Treasury bill rate is announced once a week. This contrasts with the discount rate which changes irregularly and infrequently making it extremely difficult to measure expectations of its behavior. As a result, all studies of the announcement effect of discount rate changes assumed that actual changes in the discount rate were unanticipated.

Canadian Index of Industrial Production

The Canadian index of industrial production is used as the proxy for Canadian real income. This index is selected as a summary indicator of economic activity rather than GNP because it is published once a month while GNP is estimated only quarterly. Data on this index are obtained from various releases of Statistics Canada.

U.S. Index of Industrial Production

The U.S. index of industrial production is used as a proxy for U.S. real income. As in Canada, this index is a useful barometer of changes in overall business activity.

Data on this index are found in the Federal Reserve Bulletin.

Canadian Consumer Price Index

The Canadian consumer price index measures the percentage change through time in the cost of a constant "basket" of goods and services purchased by urban households. It is the most commonly used measure of inflation in Canada. Data on this index are collected from the releases of Statistics Canada.

U.S. Consumer Price Index

In the United States, the consumer price index is one of the three most widely used measures of price movements, the others being the GNP price deflator and the producer price index. Since January 1978, the Bureau of Labor Statistics has published two indexes: the traditional index for urban wage earners and clerical workers (CPI-W) and a new index for all urban consumers (CPI-U), with seasonally adjusted and unadjusted figures for each. The data used in this study are the seasonally adjusted CPI-W which is widely publicized in the media.

Canadian Merchandise Trade Balance

Data on Canadian merchandise trade balance come from Statistics Canada releases. The figures are on a

"seasonally adjusted balance-of-payments basis". For a description of "balance-of payments basis", refer to the monthly Summary of Canadian International Trade (Statistics Canada).

U.S. Merchandise Trade Balance

The date and hour for the official announcement of the monthly U.S. merchandise trade balance are supplied by the U.S. Department of Commerce. The trade balances are based on the f.a.s. (free alongside ship) value of exports and the c.i.f. (cost, insurance, freight) value of imports. The data are published in the monthly Summary of U.S. Export and Import Merchandise Trade (Department of Commerce).

II. Recent Exchange Rate Behavior

The twice-daily movement of the Canada-U.S. exchange rate during the sample period from March 1980 to February 1984 is depicted in Figure 4.1. It can be seen that the Canada-U.S. exchange rate was volatile with movements coming in "waves". This kind of alternating pattern of volatility is a common feature of exchange rate movements. A closer examination of the chart reveals that the exchange rate was more volatile during the first subperiod (March 1980 to October 1982) than during the second subperiod (November 1982 to February 1984). The first subperiod coincides with the period of monetary targeting by the Bank of Canada and the Federal Reserve. The second subperiod corresponds to

FIGURE 4.1
Twice-Daily Movement
in the Canada-U.S. Exchange Rate*

March 1980 to February 1984

* Source: Bank of Canada, recorded at noon and 4 30 pm

the period during which monetary targeting appears to have been abandoned or de-emphasized in Canada and the United States.⁶ It would be interesting to find out whether a structural change has occurred after October 1982. However, Chow tests could not reject structural stability.⁷ Accordingly, estimation results will be shown for the whole sample period.

In the course of the first subperiod, the exchange rate fluctuated over a broad range, touching a high for the Canadian dollar of C\$1.1414/U.S.\$ (U.S.\$0.8761/C\$) on July 4, 1980 and a low of C\$1.3000/U.S.\$ (U.S.\$0.7690/C\$) on June 21, 1982. The exchange rate was very stable in the second subperiod, trading in a narrow range between C\$1.2200/U.S.\$ (U.S.\$0.8200/C\$) and C\$1.2500/U.S.\$ (U.S.\$0.8000/C\$).

The relative volatility of the exchange rate can be studied by counting the number of large exchange rate changes in the two subperiods. Table 4.2 lists the number of intervals in each subperiod when the Canada-U.S. exchange rate jumped by more than 0.5 Canadian cent. As the table shows, all but one of the large jumps occurred during the first subperiod. It would be interesting to find out what explanations were given for these changes, and in this regard relevant issues of the Toronto Globe and Mail were consulted. The findings are found in Appendix I.

Of the forty-one large jumps that had at least one explanation, twenty were linked to changes in the U.S. interest rates which were extremely volatile from 1980 to 1982 (corresponding to the period of monetary targeting by the Federal Reserve).⁸ The remaining twenty-one large jumps

TABLE 4.2LARGE CHANGES IN THE CANADA-U.S. EXCHANGE RATENumber of Intervals with more than
50 Points Absolute Change

<u>Interval from</u> <u>4:30 p.m. to Noon</u> <u>the Next Day</u>	<u>Interval from</u> <u>Noon to 4:30 p.m.</u> <u>the Same Day</u>
---	---

First sub-period (March 10, 1980 to November 30, 1982)	30	16
--	----	----

Second sub-period (December 1, 1982 to February 10, 1984)	1	0
---	---	---

Whole sample period (March 10, 1980 to February 10, 1984)	31	16
---	----	----

were attributed to a variety of other pieces of economic or political news."

The identification of changes in U.S. interest rates as the major cause of changes in the exchange rate is consistent with the study of Cornell and Shapiro (1985), who found that there was a significant relationship between the daily changes in the Canada-U.S. interest rate differential and daily changes in the exchange rate from January 1977 to December 1981. In fact, in response to changes in U.S. interest rates, the Bank of Canada has publicly declared that it "followed a course of action lying between the extremes available to it, some of the impact fell on Canadian interest rates and some on the exchange rate."

A closer look at other variables cited in the press as possible causes of exchange rate changes reveals that no single variable stands out. Various types of economic and political news were suggested, ranging from the decline in Canadian stock prices to the energy agreement between Ottawa and the Alberta government.

There is a widespread belief in newspaper accounts that large changes in the exchange rate will be partially offset in the subsequent trading period, with the subsequent adjustment of the exchange rate described as "market correction". This "market correction" phenomenon was tested using the following equation:¹¹

$$(\text{Change in the subsequent interval}) = a + b(\text{Jump}) + e, \quad b < 0$$

where a and b are the coefficients and e is the error term.

The empirical results for the forty-six intervals with large jumps are reported below (t-statistics in parentheses).

$$\begin{aligned} \text{(Change in the} \\ \text{subsequent interval)} &= -0.185 - 0.165 \text{ (Jump)} \\ &\quad (.462) \quad (2.431) \end{aligned}$$

$$\bar{R} = -.006, D.W. = 2.21, S.E.R. = 2.69$$

These results support the "market correction" phenomenon. For example, a positive jump of 0.5 Canadian cent during one interval led to a fall of about 0.08 Canadian cent during the next interval. In an efficient market, it is difficult to rationalize such behavior because the market does not seem to be making use of existing information to make profits. In particular, it appears agents can profit from a strategy of buying (selling) the Canadian dollars when there is a positive (negative) jump of 0.5 Canadian cent or more during an interval.

Can one necessarily conclude that the Canada-U.S. exchange rate is inefficient simply on the basis that some people do earn profits during these most unusual intervals? The answer is no. There may be other reasons for profits by speculators during periods of extreme exchange rate volatility. Speculators may require a premium to compensate them for the risk they incur during turbulent times. If so, earning unusual profits during such times may reflect the fact that the market "pays" this risk premium. Nonetheless, this finding suggests there might be a problem for market efficiency in the case of the Canada-U.S. exchange rate. This issue is explored further in Chapter VI.

FOOTNOTES TO CHAPTER IV

1. The Bank of Canada does not report seasonally adjusted weekly M1 figures.

2. Since February 16, 1984, the day of the release has changed to Thursdays, with the time of release remaining unchanged.

3. The Bank of Canada itself bids regularly at the weekly auction. For example, if it wishes to resist a rise in the bank rate, it can buy up as much of the issue as necessary.

4. See, for example, Hardouvelis (1985), and Hakkio and Pearce (1986).

5. See, for example, Mussa (1979).

6. For a discussion of the change in the operating regime in Canada, see the two speeches by the Governor of the Bank of Canada in Bank of Canada Review (December 1982). An indication of the change in strategy in the United States may be discerned by reading the summary of the FOMC meeting held on October 5, 1982 which is published in the Federal Reserve Bulletin (December 1982).

7. This finding is consistent with that in Hardouvelis (1985) and Smirlock (1986).

8. From October 6, 1979 to October 1982, the Federal Reserve controlled the growth of the monetary aggregate M1 using nonborrowed bank reserves. It is widely believed that this operating procedure contributed to increased interest rate volatility. The Federal Reserve has since placed less emphasis on the short-run behavior of M1, aiming instead for longer-run monetary and credit aggregate objectives. This policy has been implemented in the short run through a "flexible nonborrowed-reserve path." As a result of this procedural change, interest rate variability declined. For a discussion of these two operating procedures and their implications for interest rate variability, see Clarida and Friedman (1984), Rasche (1985), Mehra (1987), and Spindt and Taffan (1987).

9. No explanation was given in the press for five of the forty-six large jumps that occurred. A check with relevant issues of the Wall Street Journal confirmed there was no explanation for these five large jumps.

10. Bank of Canada, Annual Report, 1980, pp. 9.

11. Ito and Roley (1987) used the same equation to analyze the behavior of the Yen/U.S. dollar exchange rate.

APPENDIX I: Explanations For Large Changes
in the Canada-U.S. Exchange Rate

<u>Date</u>	<u>Change</u> (in Canadian Cents)*	<u>Explanations Given in the</u> <u>Globe and Mail</u>
<u>1980</u>		
3/10 (M)	+.660	Canadian stock prices suffered a record daily drop.
3/17 (A)	-.580	Rising interest rates in Canada.
4/2 (M)	-.870	Reaction to better-than-expected Canadian trade balance.
4/25 (M)	+.560	U.S. interest rates moved upward in financial markets.
5/21 (M)	-.980	News of the federalist victory in Quebec.
7/28 (M)	+.560	Breakdown of talks between Ottawa and Alberta over oil pricing
10/3 (A)	-.520	Reaction to figures of record Canadian trade surplus in September
<u>1981</u>		
4/7 (M)	-.570	U.S. interest rates fell.
7/20 (A)	+.550	Disappointing inflation figures in Canada. Rising trend in U.S. interest rates.
7/27 (M)	+.730	?
7/30 (A)	+.770	A much smaller-than-expected rise in the bank rate.
8/3 (A)	+.590	Predictions that a huge U.S. Treasury funding program would cause a capital inflow into the United States.
8/5 (A)	-.610	Heavy central bank intervention in Europe forced the U.S. dollar lower.

8/11 (M)	-.560	Fears of a rise in the West German Lombard facility rate.
8/17 (M)	-.570	A larger-than-expected increase in the U.S. money supply failed to cause U.S. short-term interest rates to rise.
8/25 (M)	+.520	Higher U.S. interest rates.
8/27 (A)	-.570	Hopes for success in talks between the federal and Alberta governments over energy pricing
9/2 (M)	-.729	Energy agreement between the federal and Alberta governments.
9/9 (M)	+.510	?
9/10 (A)	+.680	Large cut in the bank rate. Rumours that the U.S. plans to retaliate over Canada's energy policy.
11/18 (M)	-.580	Free fall in U.S. interest rates.
<u>1982</u>		
2/1 (A)	+.550	Rising U.S. interest rates.
2/26 (M)	+.530	Rising U.S. interest rates.
5/12 (M)	+.780	Rising U.S. interest rates.
5/21 (M)	+.510	A large increase in U.S. weekly money supply figures.
6/1 (M)	+.500	Rising U.S. interest rates.
6/14 (M)	+.840	Fears that U.S. interest rates surge during the next few weeks.
6/17 (M)	+.520	Rising U.S. interest rates.
6/21 (M)	+.750	Rising U.S. interest rates.
6/23 (A)	+1.690	Speculation against Canadian dollar.
6/28 (M)	+.830	?
6/28 (A)	-1.130	?

6/29 (M)	+1.200	Negative reactions to federal budget deficit in Canada.
6/29 (A)	-.750	Fall in U.S. interest rates.
7/5 (M)	+.690	Traders reacted negatively to news that Canadian Government borrowed \$2.35 billion last month to defend the falling Canadian dollar.
7/7 (A)	-.850	Lower U.S. interest rates.
7/9 (M)	-.820	Fall in U.S. interest rates.
7/9 (A)	-.580	Decline in weekly U.S. money supply was double the expected drop.
8/12 (A)	-.650	Fall in U.S. interest rates.
8/17 (M)	-.850	Although Canadian interest rates showed large drops, U.S. interest rates are dropping much faster.
8/19 (A)	-.530	Smaller-than-expected decline of the bank rate. Rumours that Mexico would default on its huge foreign debt.
8/24 (M)	-.500	U.S. interest rates slipped.
9/3 (M)	+.560	?
9/8 (A)	-.540	An unusually large order for Canadian dollar.
10/7 (M)	-.580	Lower U.S. interest rates.
10/12 (M)	-.600	U.S. interest rates fall more quickly than in Canada.

Note: * A positive (negative) figure means a depreciation (appreciation) of the Canadian dollar against the U.S. dollar.

(M) means the interval from closing of the day before to noon of the date shown.

(A) means the interval from noon to closing of the date shown.

? means no reason is given in the newspapers for the large change in the exchange rate.

CHAPTER V

MEASUREMENT OF EXPECTATIONS

To examine the impact of announcements of money supply, interest rate, income, inflation rate and trade balance in Canada and the United States, it is necessary to isolate unexpected from expected changes in these economic variables. For this purpose, it is important to have a good measure of expectations lest poor tests of market efficiency result.

The rational expectation of a variable uses all relevant information. In the case of a variable x_{1t} ,

$$\hat{x}_{1t} = E(x_{1t} / \Omega_{t-1}) \quad (5.1)$$

where $\hat{x}_{1t}$ is the expected value of the variable x_1 at time t forecasted at time $t-1$; Ω_{t-1} is the relevant information set at time $t-1$ used in forecasting x_{1t} ; and E is the expected value operator. To estimate $\hat{x}_{1t}$, the information set included in Ω_{t-1} must be specified. In econometric estimation, it is impossible to use all the information available at time $t-1$, so researchers choose which information is relevant to be included in Ω_{t-1} .

As discussed previously, the two approaches used to measure expected values are (a) the survey data and (b) econometric estimation. Survey data are used more widely in the asset market efficiency literature, but estimates of x_{1t} using survey data may be biased since the information is gathered many days (in some cases, up to a week) before the

announcements, so they do not incorporate all the relevant information available just before the announcements.¹ The econometric approach in this area has largely used the ARIMA model to generate expectations. Using this model, forecasts of x_{1t} incorporate only past values of that same variable (i.e. $\Omega_{t-1} = \{x_{1t-1}, x_{1t-2}, \dots\}$ = set of all past values of x_1). A more appropriate procedure would recognize other variables since they may play an important role in determining x_{1t} .

This study also develops econometric measures of expectations. Unlike previous approaches, the information set Ω_{t-1} in this study includes a wide range of data and incorporates data available at different frequencies (e.g. monthly, weekly and daily). To deal with these different frequencies, two methods for measuring expectations are developed. The first method (Method I) uses past values of those variables that are announced at monthly and weekly intervals. The novelty of this method is that it is able to exploit both monthly and weekly data for generating expectations. The second method (Method II) augments the information set used in Method I with relevant data available on a daily basis. Both of these methods are discussed in turn.

I. Method I: Forecasts Using Monthly and Weekly Data

This section presents the details of the multivariate time-series model for forecasting that includes data announced both monthly and weekly in the information set.

The following procedures are adopted to choose the variables in Ω_{t-1} :

- (a) In forecasting each Canadian variable, the variables in Ω_{t-1} include all Canadian variables listed in Table 4.1 and the corresponding U.S. variable. For example, the expected value of the Canadian money supply is estimated by regressing on its own past values and on the past values of the other Canadian variables (consumer price index, index of industrial production, merchandise trade balance, and bank rate) as well as on the corresponding U.S. variable, which in this case is the U.S. money supply. Only one U.S. variable is included in order to keep the list of variables to a manageable size. The inclusion of the U.S. variable reflects the usual assumption that Canada is a small country affected by events in the United States.²
- (b) In forecasting each U.S. variable, the variables in Ω_{t-1} include only the U.S. variables listed in Table 4.1 because it is unlikely that Canadian variables will affect U.S. variables.

All variables are in log difference form except for the merchandise trade balance, the bank rate and the U.S. Treasury bill rate. The merchandise trade balance is expressed in level form while the bank rate and the U.S. Treasury bill rate are expressed in weekly changes.

Operationally, the estimation of $\hat{\Omega}_t$ would be a straightforward matter if all the variables were announced with the same frequency. The problem is that some of these variables (index of industrial production, consumer price

index and merchandise trade balance for both countries) are announced once a month, while others (Canadian and U.S. money supply, the Canadian bank rate and the U.S. Treasury bill rate) are announced once a week. The method developed in this study for forecasting these two kinds of variables is discussed below.

1. Forecasts of Variables Announced Once a Month

Let $(x_1, x_2, \dots, x_m)$ be the m variables announced monthly and $(x_{m+1}, x_{m+2}, \dots, x_{m+n})$ be the n variables announced weekly. Let w represents time with the unit of time being one week. The anticipated values of a monthly-announced variable are the values predicted from the following equation:

$$\begin{aligned} \tilde{x}_{i,w} = & c + \sum_{j=1}^m \sum_{k=1}^l \beta_{jk} (x_{j,w-k} - x_{j,w-k-1}) \quad (5.2) \\ & + \sum_{j=m+1}^{m+n} \sum_{k=1}^{4l} \delta_{jk} (x_{j,w-k} - x_{j,w-k-1}) \\ & + u_t \end{aligned}$$

where:

$\tilde{x}_{i,w} = (x_{i,w} - x_{i,w-1})$ and $i \leq m$,

c = the constant term,

l = the lag length, and

u_t = the error term.

It can be seen from equation (5.2) that estimates of x_1 are made once every four weeks (one-month-ahead forecasts). As a concrete example, Table 5.1 illustrates the estimation procedure for a simple case where only two variables are considered. In this case, let $m = 1$ and $n = 1$ so that x_1 is the variable announced monthly and x_2 the variable announced weekly. x_1 is defined as the Canadian consumer price index and x_2 the Canadian money supply. The figures in the table are the actual values of these two variables.

Models such as ARIMA for estimating $\hat{x}_1$ would use information at least four weeks old, but in this study estimates of x_1 make use of information available a week before announcement. For example, the estimate of x_1 for week 12 utilises its latest announced value of 4.766 (announced four weeks ago) and announced values of x_2 (10.321) up to week 11.

2. Forecasts of Variables Announced Once a week

In the case of a weekly-announced variable, its anticipated values are predicted from the following equation:

$$\begin{aligned} \hat{x}_{1,w} = & c + \sum_{j=1}^m \sum_{k=1}^1 \alpha_{jk} (x_{j,w-k} - x_{j,w-k-1}) \quad (5.3) \\ & + \sum_{j=m+1}^{m+n} \sum_{k=1}^1 \phi_{jk} (x_{j,w-k} - x_{j,w-k-1}) \\ & + u_w \end{aligned}$$

TABLE 5.1

A PORTION OF THE DATA SET USED FOR FORECASTING

<u>w (During the week ending)</u>	<u>x₁ (Announced value of Canadian consumer price index)*</u>	<u>x₂ (Announced value of Canadian money supply)*</u>
0 (May 27, 1983)	4.817	10.226
1 (June 3, 1983)	N.A.	10.216
2 (June 10, 1983)	N.A.	10.205
3 (June 17, 1983)	N.A.	10.271
4 (June 24, 1983)	4.754	10.298
5 (July 1, 1983)	N.A.	10.275
6 (July 8, 1983)	N.A.	10.331
7 (July 15, 1983)	N.A.	10.303
8 (July 22, 1983)	4.766	10.295
9 (July 29, 1983)	N.A.	10.286
10 (August 5, 1983)	N.A.	10.301
11 (August 12, 1983)	N.A.	10.321
12 (August 19, 1983)	4.770	10.324

Note: * means that the value is expressed in natural logarithm.

N.A. means there is no announcement for x_i during that week.

where $\tilde{x}_{i,t} = (x_{i,t} - x_{i,t-1})$ and $i > m$. All the other terms are as defined in equation (5.2).

Unlike equation (5.2), this equation shows that the estimates $\hat{x}_i$ are made every week (one-week-ahead forecasts). One problem with using equation (5.3) is that monthly variables are measured every four weeks. Consequently, values for these variables have to be imputed for those weeks where there are no announcements. This study uses a simple procedure which involves using the latest announced values for those weeks. In the example given in Table 5.1, the values of x_i for week 9 to week 11 are each assigned the value of 4.766, its latest announced value.³

Complete specification of equations (5.2) and (5.3) requires a choice of the lag length (value of l) for the independent variables. Rather than picking an arbitrary lag length, a formal statistical criterion was used to choose the lag length. The criterion used in this study is Theil's $\bar{R}^2$ (minimum standard error) criterion. According to this criterion (based on Abrams, Froyen and Waud (1979), but originally suggested by Schmidt and Waud (1973)), OLS should be applied to a number of different lag lengths. The lag length that yields the highest $\bar{R}^2$ is selected as the optimal lag length. Since it is too cumbersome to experiment with all the different lag lengths, only lags of four, eight, and twelve weeks were tried.⁴

The optimal lag length and the associated $\bar{R}^2$ for each of the forecasting equations are presented in Table 5.2. The highest $\bar{R}^2$ is obtained with twelve week lags for six equations and eight week lags for four equations. For

TABLE 5.2OPTIMAL LAG LENGTH FOR THE FORECASTING EQUATIONS
USING METHOD I

<u>Forecast Variable</u>	<u>Lags (in weeks) on the</u> <u>Independent Variables</u>	<u>$\bar{R}^2$</u>
Canadian money supply	12	.187
U.S. money supply	12	.249
Canadian bank rate	8	.277
U.S. Treasury bill rate	12	.242
Canadian index of industrial production	8	.277
U.S. index of industrial production	12	.692
Canadian consumer price index	8	.115
U.S. consumer price index	12	.817
Canadian merchandise trade balance	12	.526
U.S. merchandise trade balance	8	.735

example, the lag length which yields the highest R^2 of 0.187 for the Canadian money supply equation is twelve weeks. The predictions generated by this procedure will be used to measure R_i^2 .

II. Method II: Forecasts Using Monthly, Weekly and Daily Data

One problem with the above method is that the information included in the information set is at least one week old. Some financial data such as interest and exchange rates are readily available on a daily or twice-daily basis and should be included in the information set when relevant. Because financial markets are interrelated, these financial data should provide useful information for predicting the values of the following four financial variables announced weekly: (a) Canadian money supply, (b) U.S. money supply, (c) the Canadian bank rate, and (d) the U.S. Treasury bill rate.

The use of daily or twice-daily data on exchange and interest rates for forecasting variables announced weekly can be justified on both theoretical and practical grounds. On a theoretical level, Engel and Frankel (1984) pointed out that actual changes in money supplies affect future interest and exchange rates, so that changes in these variables should provide a good indication of monetary changes that have already occurred but are yet to be announced.

On the practical side, daily or twice-daily data on exchange and interest rates are widely used for forecasts of the variables announced weekly. For example, at the weekly Treasury bill auctions in both Canada and the United States,

market participants are widely known to make use of information on interest and exchange rates up to the last minute before the closing of the tender.⁵ "Fedwatchers" are reported to use the latest information on interest and exchange rates for forecasting the weekly U.S. money supply.⁶ Accordingly, many studies⁷ have suggested that survey data on the expected announced change in the weekly U.S. money supply need to be adjusted to take into account the fact that the survey is not taken on the day of the announcement (Friday), but three days before (Tuesday). These studies incorporated the change in the 91-day U.S. Treasury bill rate between Tuesday (the day the expectations are surveyed) and Friday (the announcement day) into the survey data to produce a more accurate measurement of expectations.

If forecasts of a weekly-announced variable include information available on a daily or twice-daily basis, the information set used in equation (5.3) should be expanded:⁸

$$\tilde{x}_{i,w,d} = K \quad (5.4)$$

$$+ \sum_{j=1}^q \sum_{k=0}^1 \mu_{jk} (y_{i,w-k,d-1} - y_{i,w-k-1,d-1})$$

$$+ u_t$$

where the variable $\tilde{x}_{i,w,d} = (x_{i,w,d} - x_{i,w-1,d})$ is defined as the change in the variable x_i for day d of week w ; K represents all the terms on the right-hand side of equation (5.3); and the second term on the right-hand side of this

equation includes a set of variables y_j ($j = 1, 2, \dots, q$) available on a daily basis. In the case of daily data, the first lagged term is the change in y_j from day $d-1$ of week w to day $d-1$ of week $w-1$.

It is evident from equation (5.4) that forecasts of those variables announced weekly make use of daily data available up to the day prior to their announcements. In this empirical work, the following daily data are used: the Canada-U.S. exchange rate, the 91-day Canadian Treasury bill rate and the 91-day U.S. Treasury bill rate.⁹ For example, consider forecasts of the Canadian money supply. Since the Canadian money supply is announced on Friday, the information used to predict the announced value of the Canadian money supply on the day before its announcement include: the Canada-U.S. exchange rate on Thursday at 4:30 p.m., the 91-day Canadian Treasury bill rate on Thursday at 3:30 p.m., and the 91-day U.S. Treasury bill rate on Thursday at 3:30 p.m.¹⁰

The final step in the specification of equation (5.4) involves the choice of the lag length of each independent variable. As in Method I, this choice is determined by varying the lag length. OLS is then applied to each lag length, with lags of four, eight and twelve weeks being considered. The lag length that yields the highest $\bar{R}^2$ (minimum standard error) is selected as the appropriate lag order. The optimal lag length and the associated $\bar{R}^2$ for each of the forecasting equations are presented in Table 5.3. The highest $\bar{R}^2$ for all equations is obtained with a lag of twelve weeks. The predictions generated by this procedure are used as an alternative measurement of expectations.

TABLE 5.3

OPTIMAL LAG LENGTH FOR THE FORECASTING EQUATIONS
USING METHOD II

<u>Forecast Variable</u>	<u>Lags (in Weeks) on the Independent Variables</u>	<u>$\bar{R}^2$</u>
Canadian money supply	12	.233
U.S. money supply	12	.255
Canadian bank rate	12	.766
U.S. Treasury bill rate	12	.590

III. Conclusions

To test the impact of economic announcements on the exchange rates, it is necessary to separate unexpected changes from expected changes in the economic variables. For this purpose, it is crucial to have good measures of expected changes.

Traditionally, research in this area has utilized predictions from survey data or the ARIMA model as proxies for expected changes but there are two main problems with these approaches. First, survey data are available only for U.S. economic variables; consequently, studies which used survey data were forced to examine only U.S. news. Second, the expectations series obtained from survey data or the ARIMA model does not take into account some relevant information. The survey data are not up-to-date since they are gathered days (and in certain cases, up to a week) before the actual announcement. The ARIMA model is too narrow in scope since it employs only past values of the variable concerned to generate the expected values.

In this chapter, an econometric estimation is used to generate expectations. Unlike the ARIMA model, the information set in this study includes not only a wide range of data but also incorporates data available at different frequencies (monthly, weekly and daily). To deal with these different frequencies, two methods have been employed. The first method (Method I) uses past values of variables announced at monthly and weekly intervals. The innovation of this method is that it is able to exploit both weekly and

monthly data for generating expectations. The second method (Method II) is developed for forecasting variables that are announced weekly. This method augments the information set used in the first method with daily data available the day before the announcements. The expectations series obtained from these two methods will be used in the next chapter to test the responses of the Canada-U.S. exchange rate to the economic announcements in Canada and the United States.

FOOTNOTES TO CHAPTER V

1. For example, the expected announced value of the variable x_2 formed just one day prior to its announcement may be expressed as

$${}_{t-1}\hat{x}_{2t} = \mu_1 {}_{t-j}\hat{x}_{2t} + \mu_2 (I_{t-1} - I_{t-j})$$

where ${}_{t-j}\hat{x}_{2t}$ is the expected announced value of the variable x_2 formed j ($j > 1$) days prior to the announcement, and $(I_{t-1} - I_{t-j})$ captures the potential impact of relevant information between the day expectations are taken ($t-j$) and the day before the announcement ($t-1$). Thus, the survey data gathered j days before the announcement would only be up-to-date if $\mu_1 = 1$ and $\mu_2 = 0$.

2. The influence of the U.S. variable on the same Canadian variable is well-documented. Batten and Ott (1985) found that the U.S. money growth has significantly influenced the Canadian money growth during the period 1974 to 1982. They argued that since the Canadian economy is very closely integrated with the U.S. economy, the result should not be a surprise. Joyce (1986) found that U.S. interest rates affect the Canadian bank rate.

3. Another approach is to replace N.A. in Table 5.1 with interpolated data. For instance, one could use the generated figures of x_1 from equation (5.2) to interpolate the values for N.A. This approach is not adopted because it involves too much computation.

4. It should be pointed out that predictions are made using data from the whole sample rather than using only data available to market participants. The former method is employed because the latter method would be computationally prohibitive, and the use of the former method seems reasonable in view of the findings by Urich and Wachtel (1981) that predictions from these two methods do not differ significantly.

5. See Sarpkaya (1984), Tucker (1985), and Cook and Rowe (1986).

6. See, for example, Bannon (1986).

7. Roley (1983), Belongia and Shuehan (1987), Deaves, Melino and Pesando (1987), and Peel and Pope (1987).

8. This procedure was not attempted for variables announced once a month for two reasons. First and foremost, it is extremely inconvenient to incorporate the information a day prior to their announcements because these variables are not announced on any specific day of the week. Second; expectations formed a week before their announcements are not

likely to be affected by any subsequent changes, say in interest and exchange rates. This is because changes in these variables have occurred several weeks before their expectations are taken. Any effects on interest and exchange rates would have been completed by the time their expectations are obtained.

9. The 91-day Canadian Treasury bill rate is not used to predict U.S. money supply and the U.S. Treasury bill (auction) rate because it is unlikely that changes in a Canadian variable can have an effect on the U.S. variables.

10. The daily closing rates of both the Canadian and the U.S. Treasury bills were collected from the secondary market by the Securities Department of the Bank of Canada.

CHAPTER VI

EMPIRICAL RESULTS

This chapter presents an empirical analysis of the reaction of the Canada-U.S. exchange rate to news about money supply, interest rate, income, inflation rate and trade balance in Canada and the United States from March 1980 to February 1984. Several important questions are posed. First, what type of economic news would affect the Canada-U.S. exchange rate? Second, do these results support the efficient markets hypothesis that only news matters and the impact of news is immediate? Third, are the test results for market efficiency sensitive to the two methods of measuring expectations developed in the previous chapter?

This study addresses the above questions using a research methodology that should provide a powerful test of market efficiency. Section I reports the results on tests of announcement effects using Method I to compute expectations. Section II presents the results of tests of announcement effects using Method II for measuring expectations of those variables announced weekly. Section III summarizes the empirical findings of this chapter.

I. Tests of Announcement Effects: Using Method I For Measuring Expectations

The estimation results of equation (2.8) using Method I for measuring expectations are shown in Table 6.1. The dependent variable, $(s_t - s_{t-1})$, is the change in the Canada-

TABLE 6.1

TESTS OF ANNOUNCEMENT EFFECTS:
USING METHOD I FOR MEASURING EXPECTATIONS

$$s_t - s_{t-1} = a + \sum_{i=1}^m b_i (x_{1t} - \hat{x}_{1t}) \\
+ \sum_{i=1}^m c_i (\hat{x}_{1t} - x_{1t-1}) \\
+ \sum_{i=1}^m d_i (x_{1t-1} - \hat{x}_{1t-1}) + u_t$$

Estimated Coefficients

<u>Economic Variable</u>	<u>b_i</u>	<u>c_i</u>	<u>d_i</u>
Canadian money supply	.00058 (.105)	-.00444 (.769)	-.00532 (.957)
U.S. money supply	.06560 (2.46)**	.04639 (1.80)*	-.04491 (1.77)*
Canadian bank rate	-.03064 (.719)	.08116 (1.77)*	-.00969 (.225)
U.S. Treasury bill rate	.01939 (.776)	.00243 (.092)	-.00492 (.197)
Canadian index of industrial production	.02466 (1.08)	-.01891 (1.12)	-.03260 (1.32)
U.S. index of industrial production	-.04519 (.717)	.00047 (.026)	.04110 (.653)
Canadian consumer price index	.03035 (.436)	-.01336 (.412)	-.01342 (.193)
U.S. consumer price index	-.00618 (.158)	.00558 (.662)	.01898 (.483)
Canadian merchandise trade balance	-.00004 (.056)	-.00005 (1.30)	-.00028 (.413)
U.S. merchandise trade balance	.00086 (.603)	-.00021 (1.13)	-.00107 (.768)

T = 1388 R² = .021 S.E. = .163 D.W. = 1.93

Note: Figures in parentheses are t-statistics.

** Statistically significant at the 5 percent level.

* Statistically significant at the 10 percent level.

U.S. exchange rate from either 4:30 p.m. to noon on the following day or from noon to 4:30 p.m. on a given business day.¹ To limit the number of independent variables to a manageable size, only one lagged value of the forecast error for each variable is included.² In cases where all the independent variables equaled zero (because the relevant series were not announced in that period), such observations were dropped from the regression. As a result, only 1387 of a total of 2050 observations are used in the estimation.

The results exhibit a number of interesting features. First, only U.S. money supply news is significant and its impact is immediate. This finding is consistent with that of Doukas (1985), Hakkio and Pearce (1985), and Doukas and Melhem (1986).

Secondly, anticipated changes of U.S. money supply and the Canadian bank rate are significant, implying a rejection of the efficient market hypothesis. Hakkio and Pearce (1985) and Tandon and Urich (1987) used survey data to measure expectations and found expected U.S. money supply significant. One possible reason for the rejection of market efficiency hypothesis in this section as well as in the findings of Hakkio and Pearce (1985) and Tandon and Urich (1987) is that forecasts using survey data and Method I do not use up-to-date information. It is interesting to note that Ngiam (1987) used more up-to-date expectations data and found only the unexpected (and not the expected) change in the Canadian bank rate was significant.³

Thirdly, lagged U.S. money supply news plays a significant role in determining the Canada-U.S. exchange rate. However, the sign of this coefficient differs from

that for the initial impact of the U.S. money supply news, indicating an offsetting effect on the Canada-U.S. exchange rate after the initial response to U.S. money supply news. This subsequent reversal of the exchange rate is known as the "market correction" phenomenon. Hakkio and Pearce (1985) also found this effect and commented that "this may reflect intervention by the Bank of Canada but we have no direct evidence to support this interpretation".⁴ This interpretation suggests that whenever a positive (negative) U.S. money supply news leads to depreciation (appreciation) of the Canadian dollar against the U.S. dollar from noon to 4:30 p.m. on Friday, the Bank of Canada would take action to support (lower) the value of the Canadian dollar from 4:30 p.m. on Friday to noon on Monday.⁵ It also suggests that the Bank of Canada has intervened more heavily from 4:30 p.m. on Friday to noon on Monday than during any other interval. However, this is not borne out by the available evidence: Selody and Rose (1983) found that intervention by the Bank of Canada was heaviest on Thursday.⁶ Again, an alternative explanation for the "market correction" phenomenon could simply be that the measure of U.S. money supply news is biased because Method I does not use up-to-date information for generating expectations.

Fourthly, none of the news based on Canadian and U.S. variables announced on a monthly basis has any impact on the Canada-U.S. exchange rate. These results are consistent with Hardouvelis (1985), who found that the Canada-U.S. exchange rate did not react to news of any U.S. variable announced monthly. The conclusion that news of Canadian variables

announced on a monthly basis have no significant impact is a new finding.

II. Tests of Announcement Effects:
Using Method II For Measuring Expectations
of Variables Announced Weekly

A surprising result that emerges from the estimations presented in Section I is the significance of expected changes in the Canadian bank rate and U.S. money supply, as well as the delayed effect of U.S. money supply news. Such a result is inconsistent with the efficient market hypothesis (only news matters and the impact of news is immediate). However, it may be argued that test results are sensitive to the measurement of expectations. Consequently, it is important to reexamine these results using Method II, which is based on a more complete set of information for measuring expectations. To conclude that the market is inefficient, it is necessary to show that the results hold even when more information is included in formulating expectations.

In this section, tests of announcement effects are carried out using a measure of expectations (Method II) which incorporates relevant daily data for measuring expectations of variables announced weekly. The test results presented in Table 6.2 are different from those in Table 6.1 in two important respects: First, the efficient market hypothesis is supported: none of the coefficients on expected changes in the economic variables is significant. Second, the Canada-U.S. exchange rate responds only to surprises in U.S. money supply, the U.S. Treasury bill rate and the Canadian bank rate.

TABLE 6.2

TESTS OF ANNOUNCEMENT EFFECTS:
USING METHOD II FOR MEASURING EXPECTATIONS
OF VARIABLES ANNOUNCED WEEKLY

$$s_t - s_{t-1} = a + \sum_{i=1}^m b_i (x_{it} - \hat{x}_{it}) \\ + \sum_{i=1}^m c_i (\hat{x}_{it} - x_{it-1}) \\ + \sum_{i=1}^m d_i (x_{it-1} - \hat{x}_{it-1}) + u_t$$

<u>Economic Variable</u>	<u>Estimated Coefficients</u>		
	<u>b_i</u>	<u>c_i</u>	<u>d_i</u>
Canadian money supply	-.00195 (.379)	.00477 (.799)	-.00733 (1.43)
U.S. money supply	.07247 (3.04)**	.02560 (.913)	-.03757 (1.59)
Canadian bank rate	-.02520 (.347)	.03164 (.918)	-.15107 (2.08)**
U.S. Treasury bill rate	.06282 (1.93)*	-.00570 (.335)	-.01772 (.546)
Canadian index of industrial production	.02890 (1.18)	-.01828 (1.09)	-.03074 (1.25)
U.S. index of industrial production	-.04712 (.750)	-.00276 (.152)	.04738 (.757)
Canadian consumer price index	.03141 (.452)	-.01001 (.309)	-.01266 (.182)
U.S. consumer price index*	-.00468 (.121)	.00568 (.675)	.02339 (.596)
Canadian merchandise trade balance	-.00007 (.107)	-.00005 (1.38)	-.00029 (.422)
U.S. merchandise trade balance	.00089 (.628)	-.00020 (1.07)	-.00081 (.585)
T = 1388 R ² = .026 S.E. = .162 D.W. = 1.92			

Note: Figures in parentheses are t-statistics.

** Statistically significant at the 5 percent level.

* Statistically significant at the 10 percent level.

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Test results of the four variables announced weekly using Method II for generating expectations are discussed in detail below.

U.S. Money Supply

The results indicate that U.S. money supply news has an immediate impact on the Canada-U.S. exchange rate. The estimated coefficient implies that a 1 percent unanticipated increase (decrease) in the U.S. money supply (which is approximately 5 billion U.S. dollars) leads to an immediate appreciation (depreciation) of the U.S. dollar against the Canadian dollar of about 0.7 percent. Such an impact is remarkably similar to the finding in Section I and the results of Hakkio and Pearce (1985) and Doukas and Melhem (1986).

The anticipated change in U.S. money supply and lagged U.S. money supply news do not have any impact on the exchange rate. These results are contrary to those reported in Section I and to the evidence in Hakkio and Pearce (1985) and Tandon and Urich (1987). It would thus appear that results rejecting market efficiency reported in Section I and other studies could be due to the imprecise measurement of expectations.

U.S. Treasury Bill Rate

While U.S. Treasury bill rate news has no effect when Method I is used, its impact is immediate with Method II.

The estimated coefficient suggests that an unanticipated increase (decrease) in the U.S. Treasury bill rate by 1 percent causes an immediate appreciation (depreciation) of the U.S. dollar against the Canadian dollar by 0.062 percent. Interestingly, the response of the Canada-U.S. exchange rate to news of the U.S. Treasury bill rate is qualitatively the same as to the announcement of a change in the discount rate. For example, Batten and Thornton (1985) found that when the U.S. discount rate increases (decreases) by 1 percent, the U.S. dollar appreciates (depreciates) against the Canadian dollar by 0.11 percent.

Canadian Money Supply

Canadian money supply news has no effect on the Canada-U.S. exchange rate regardless of whether Method I or Method II is used. This result is not surprising since market participants pay scant attention to the release of Canadian money supply data. Thursday's announcement of the Canadian money supply is overshadowed by the much-publicized Canadian bank rate announcement three hours earlier. While changes in the Canadian bank rate receive prominent coverage in newspapers, reports on changes in the Canadian money supply are usually given little attention. It is probable that the market knows in advance what the Canadian money supply will be so that the exchange rate is not likely to respond to the announcement. This finding that Canadian money supply has no announcement effect is consistent with the results of Doukas (1985), and Doukas and Melhem (1986).

Canadian Bank Rate

While the findings in Section I show that the expected Canadian bank rate change is significant, the results in this section indicate that Canadian bank rate news is significant with a lag. Since the Canadian bank rate is announced at 2:00 p.m. each Thursday, the effect is felt between 4:30 p.m. on Thursday and noon on Friday.⁷ Ngiam (1987) studied the impact of Canadian bank rate news but found no lagged response (his use of daily exchange rate observations may have reduced the statistical power of his econometric analysis).

One would be tempted to interpret this lagged response as evidence of market inefficiency since traders can earn a profit using a trading strategy based on observed exchange rate behavior. However, tests of this kind are joint tests for market efficiency and the absence of time-varying risk premiums or both. It is therefore impossible to determine whether this finding is due to market inefficiency or variable risk premiums or both. The first interpretation implies that traders are irrational for not making use of all available information. The second interpretation suggests that agents are risk averse and hence may not take advantage of the available information because of the risk involved in taking an open position. There are two possible reasons why the lagged Canadian bank rate news may indicate the effect of variable risk premiums.

The first reason is that the Bank of Canada is known to intervene regularly but erratically in the foreign exchange market.⁸ The policy of leaning against the wind has been

evident since the breakdown of the Bretton Woods System, but the manner of implementation has changed over time. Rose (1983) divided the period from June 1970 to December 1980 into fourteen subperiods and found the intervention policy rule changed in the 1970's. Since, in addition, the extent of intervention by the Bank of Canada is not made known to the public,⁹ taking a position involves a risk. In this case, the risk premium may be high enough to dissuade speculators from taking advantage of observed exchange rate behavior.¹⁰

The second reason is that traders may wish to reduce the risk by adopting a wait-and-see attitude until after the Canadian money supply figures are announced. (Canadian money supply figures are released three hours after the Canadian bank rate announcement.) Traders may want to use the latest Canadian money supply figures together with the Canadian bank rate news to judge the Bank of Canada's monetary policy. Suppose that the actual change in Canadian bank rate is higher than expected. Traders wish to know whether this information is random or signals a tightening of the Bank of Canada's monetary policy (which would cause the Canadian dollar to appreciate against the U.S. dollar). Before going "long" on the Canadian dollar, traders may wait three more hours to make sure that the announced Canadian money supply change is lower than expected. To explore whether a combination of Canadian money supply news and Canadian bank rate news provides traders with additional information, a term representing the interaction of these two news variables was added to the regression. The results show that the interaction term is significant.¹¹

III. Conclusions

This chapter has examined the impact on the Canada-U.S. exchange rate of the announcement of money supply, interest rate, income, inflation rate and trade balance in Canada and the United States. To express the new information provided by an announcement, two measurements of expectations are developed. The first method (Method I) uses weekly and monthly data to generate expectations. The second method (Method II) supplements the information set in Method I with daily data to generate expectations. Several interesting conclusions follow from this empirical investigation.

First, of the ten announcements studied, only monetary news affect the Canada-U.S. exchange rate. The finding that the Canada-U.S. exchange rate responds to U.S. monetary news is broadly consistent with the results of Hakkio and Pearce (1985), and Hardouvelis (1985). However, unlike Hardouvelis (1985) who found that only news about net free reserves and the discount rate in the United States were significant, the results in this study show that news about U.S. money supply and the U.S. Treasury bill rate are significant. The results for Canadian variables show that bank rate news is significant; this finding is interesting since this is the first time that a set of Canadian economic variables has been tested for announcement effects.

Second, test results for market efficiency are sensitive to the fashion in which expectations are measured. The results reject market efficiency when Method I (based on incomplete information) is used, but support market efficiency when Method II (based on up-to-date information)

is used to measure expectations. For example, anticipated changes in U.S. money supply and the Canadian bank rate as well as lagged U.S. money supply news are significant with Method I, but insignificant when Method II is used.

Third, it would appear that the effect of Canadian economic news is slower than the impact of U.S. economic news. While the Canada-U.S. exchange rate responds instantaneously to news about U.S. money supply and the U.S. Treasury bill rate, it reacts with a lag to Canadian bank rate news. There are two reasons why this may represent the effect of variable risk premiums. First, since the Bank of Canada has intervened regularly but erratically in the foreign exchange market, traders may not want to take an open position immediately after the announcement. The second reason is that traders may prefer to study Canadian money supply data available three hours later before acting decisively.

FOOTNOTES TO CHAPTER VI

1. To test whether the assumption of homoscedasticity is valid, an F-test is performed on the variances of the exchange rate change during the two intervals. The two variances are:

(a) noon to 4:30 p.m. on a given day = .00000037

(b) 4:30 p.m. to noon the following day = .00000041.

Since the ratio of these two variances is close to one, there is no reason to doubt the assumption of homoscedasticity.

2. A two-period lagged values for each variable were also estimated. The results were similar to those reported in Tables 6.1 and 6.2 except that U.S. trade balance news turned out to be significant after two lags.

3. Ngiam (1987) used expectations data on the Canadian bank rate supplied by the Toronto Globe and Mail on Thursday, the day of the announcement.

4. Hakkio and Pearce (1985), pp. 12.

5. The only way for lagged news to be significant in an efficient market is when the intervention is unpredictable, which may reduce the willingness of traders to take a position. If the intervention policy is known, traders would be able to make systematic profits by buying (selling) the Canadian dollars on Monday morning when they learn about a positive (negative) U.S. money supply surprise.

6. Selody and Rose (1983) studied the period from 1976 to 1980 and found that the largest and most significant intervention was on Thursdays, with a 1 percent depreciation of the Canadian dollar against the U.S. dollar leading to a decrease in the Bank of Canada's reserve position of U.S.\$ 211 million.

7. The estimated coefficient indicates that a one percent unanticipated increase (decrease) in the Canadian bank rate leads to 0.15 percent appreciation (depreciation) of the Canadian dollar against the U.S. dollar.

8. The United states virtually ceased intervention in the foreign exchange market from 1981 to 1985. Consequently, the value of the U.S. dollar rose during that period by 50 percent on a trade-weighted basis against other currencies.

9. Information on Canada's international reserve position is not available to the public on a daily basis (except with a two-year delay).

10. Peel and Pope (1987) demonstrated that unless the exchange rate follows a random walk, there can be a delayed response even if the market is efficient.

11. The following equation was estimated:

$$\begin{aligned}
 s_t - s_{t-1} = & a + \sum_{i=1}^m b_i (x_{1t} - \hat{x}_{1t}) \\
 & + \sum_{i=1}^m c_i (\hat{x}_{1t} - x_{1t-1}) \\
 & + \sum_{i=1}^m d_i (x_{1t-1} - \hat{x}_{1t-1}) \\
 & + \beta (r_{t-1} - \hat{r}_{t-1}) (\hat{m}_t - m_t) + u_t
 \end{aligned}$$

where $(r_{t-1} - \hat{r}_{t-1})$ is Canadian bank rate news, $(\hat{m}_t - m_t)$ is Canadian money supply news (multiplied by a negative sign), and all other terms are as defined in Table 6.2. If Canadian money supply news helps in interpreting the Canadian bank rate news released just hours earlier, then β should be significantly negative. Indeed, the estimated coefficient of β is -6.11 with the t-statistic of -1.84.

CHAPTER VII

SUMMARY AND CONCLUSIONS

This thesis has investigated the response of the Canada-U.S. exchange rate to announcements of money supply, interest rate, income, inflation and trade balance in Canada and the United States. In an efficient market, economic news (defined as the unanticipated part of an economic indicator) should have an immediate impact on the exchange rate, whereas the anticipated part of the economic indicator should not affect the exchange rate. Previous studies on the effect of economic announcements on the Canada-U.S. exchange rate draw conflicting conclusions, some supporting and others rejecting market efficiency. However, these studies suffer from a number of methodological problems which may have led to incorrect assertions about market efficiency.

First, most previous work concentrated exclusively on U.S. economic news. Only three studies — Doukas (1985), Doukas and Melhem (1986) and Ngiam (1987) — examined Canadian economic news. This is unsatisfactory since the exchange rate is the relative price of two currencies and therefore should be affected by the economic news of both countries.

Second, almost all the studies investigating the effects of announcements measured changes in the exchange rate over a 24-hour period. Unless the impact of economic news on the exchange rate persists for a day or more, tests based on more finely observed data are more powerful. If, for example, the

exchange rate reacts immediately to news, the change in exchange rate over a 24-hour (or longer) interval would fail to capture accurately the effect of news.

Third, all the studies used either survey data or the ARIMA model to measure anticipated changes in economic variables. While survey data are a convenient measure of market expectations, they are usually gathered many days before the actual announcements. Moreover, they are not available for Canadian economic indicators, so that studies of the impact of Canadian economic news had to resort to the ARIMA model to generate expectations. This model, however, is inadequate because expectations of a variable are formed from past values of only that variable.

In an attempt to provide a stringent test of market efficiency and the impact of different economic news, this thesis uses a research methodology that avoids the specification errors of other studies. Three aspects were improved. First, the range of economic variables is widened to incorporate both Canadian and U.S. news. The types of news were not chosen arbitrarily, but are suggested by the asset market models of exchange rate determination. This is the first time that a broad spectrum of Canadian and U.S. economic news has been tested for announcement effects.

Second, a narrower time interval for the change in the exchange rate is used. Specifically, changes in the Canada-U.S. exchange rate from noon and 4:30 p.m., and between 4:30 p.m. and noon of the following day, were examined. Using such high frequency data, this study is able to pinpoint the timing of the exchange rate response to economic news and provide a rigorous test of the efficient markets hypothesis.

Third, a more accurate econometric estimation of expectations is used. Unlike other approaches, the information set used for forecasting in this study incorporates a broad range of variables, data on which are available at different frequencies (monthly, weekly and daily). To deal with these different frequencies, two methods for measuring expectations are developed. The first method (Method I) combines monthly and weekly data for generating expectations. The second method (Method II) uses monthly, weekly and daily data for generating expectations of variables announced weekly.

The main conclusions from the empirical results are as follows. First, of the ten announcements studied, only monetary news affect the Canada-U.S. exchange rate. Second, test results concerning market efficiency were sensitive to the measurement of expectations: market efficiency was rejected when Method I was used, but supported when expectations were measured by Method II. Third, in the case of Canada, only the bank rate (and not money supply) had an announcement effect, which occurred after a lag. The lagged news concerning the Canadian bank rate may represent the effect of variable risk premiums which arise because of the unpredictable foreign exchange intervention by the Bank of Canada.

Several topics worthy of further research emerge from this thesis. First, it would be useful to test the robustness of the results on market efficiency by examining other kinds of news in Canada and the United States. Some work has been done on the impact of other U.S. economic news (e.g. housing starts, retail sales, the unemployment rate and

the composite leading indicator) using survey data to measure expectations. The forecasting technique developed in this thesis should be used because it provides more accurate measures of expectations than survey data and permits the examination of the impact of all kinds of news from Canada and the United States.

Another interesting research topic would be to extend the sample period of this study. The focus of market participants is on different variables at different times: in one period monetary news may take precedent, followed by trade balance news in the next. This study finds U.S. trade balance news had no impact on the exchange rate from 1980 to 1984. However, in the last two years the importance of trade balance figures has been emphasized by the mass media. Results for more recent data might suggest that this variable is now significant.

Finally, it would be fruitful to use the forecasting technique developed in this study to examine the reaction of Canadian stock prices to Canadian economic news, and U.S. stock prices to U.S. economic news. Pearce and Roley (1985) used survey data to examine the impact of U.S. economic news on U.S. stock prices but their results did not support the efficient markets hypothesis. A different conclusion might be reached with better measurement of expectations.

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