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An Intraday Analysis of the Effectiveness of Foreign Exchange Intervention

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ABSTRACT

This paper assesses the effectiveness of Canada's official foreign exchange intervention in moderating intraday volatility of the Can$/US$ exchange rate, using a 2-1/2-year sample of 10-minute exchange rate data. The use of high frequency data (higher than daily frequency) should help in assessing the impact of intervention since the foreign exchange market is efficient and reacts rapidly to new information. The estimated equations explain volatility in terms of four major factors: intraday seasonal pattern; daily volatility persistence; macroeconomic news announcements; and the impact of central bank intervention. Rule-based (or expected) intervention apparently had no direct impact on the reduction of foreign exchange volatility, although the existence of a non-intervention band seemed to provide a small stabilizing influence. This result is interpreted to mean that the stabilizing effect of expected intervention came into play as the Canadian dollar approached the upper or lower limits of the band. When the dollar exceeded the band, actual intervention did not have any direct impact because it was expected. Moreover, the results show that discretionary (or unexpected) intervention might have been effective in stabilizing the Canadian dollar, although the impact of an intervention sequence diminished as it increased beyond a few days.

RÉSUMÉ

Les auteurs cherchent à établir si les interventions officielles du Canada sur le marché des changes réussissent à modérer la volatilité intrajournalière du taux de change du dollar canadien par rapport à la devise américaine. Pour étudier cette question, ils font appel aux cours cotés par le dollar toutes les dix minutes sur une période d'environ trente mois. L'utilisation de données de haute fréquence (c'est-à-dire intrajournalières) devrait aider à évaluer l'incidence des interventions puisque le marché des changes est efficient et qu'il réagit rapidement aux nouvelles informations. Les équations estimées par les auteurs lient la volatilité à quatre grands facteurs : le profil d'évolution de la volatilité durant une journée normale, la persistance de la volatilité d'une journée à l'autre, les annonces de données macroéconomiques et l'incidence des interventions de la banque centrale. Les interventions reposant sur une règle préétablie (ou anticipées) n'ont

apparemment pas eu d’effet direct sur la réduction de la volatilité des taux de change, même si l’existence d’une fourchette de non-intervention semble avoir eu une faible influence stabilisatrice. Ce résultat amène les auteurs à penser que l’influence stabilisatrice des interventions anticipées s’est fait sentir lorsque le dollar canadien s’est approché des limites inférieure ou supérieure de la fourchette. Quand le dollar est sorti de la fourchette, les interventions n’ont pas eu d’effet direct car elles étaient anticipées. De plus, les résultats montrent que les interventions discrétionnaires (ou imprévues) ont pu parvenir à stabiliser le dollar canadien, bien qu’une séquence d’interventions perde de son efficacité lorsqu’elle se prolonge au delà de quelques jours.

1. Introduction

The Bank of Canada, on behalf of the Government of Canada, conducts sterilized foreign exchange intervention to promote orderly markets for the Canadian dollar. The purpose is to slow movements in the exchange rate, working on the presumption that volatility in financial markets might adversely affect financial and economic conditions. Recent evidence, however, suggests that intervention might not be very successful at moderating fluctuations of the Canadian dollar. For example, Murray, Zelmer, and McManus (1996) report that intervention that is anticipated by the market fails to reduce significantly the implied volatility of the Can$/US$ exchange rate on the day after intervention; however, unexpectedly heavy intervention might be effective in stabilizing the dollar. The present study builds on their work by considering whether Canada's intervention affects currency volatility within each trading day.

Theory suggests at least four mechanisms by which sterilized intervention might affect the exchange rate: changing the composition of the outstanding stock of financial assets (the portfolio-balance approach); providing additional liquidity to the market during periods of market uncertainty (the liquidity approach); conveying information concerning future monetary policy (the signalling approach); or, altering the technical outlook for the currency (the noise-trading approach).

The portfolio-balance approach maintains that, if foreign and domestic securities are imperfect substitutes, intervention might influence the exchange rate *level* by altering the relative supply of foreign and domestic securities. However, as noted by Obstfeld (1989), the portfolio effect has received little empirical support, which is not surprising given the enormous stock of financial assets outstanding relative to the amount of official intervention.

The liquidity approach proposes that central bank intervention might have a direct impact on exchange rate *volatility*, but not on its level. If the amount of intervention is large relative to the market turnover within a brief period of time, intervention might have a short-term, flow-driven impact on the the value of the currency. Also, by providing liquidity, intervention might reduce the risk of making markets, thereby encouraging dealers to provide additional liquidity. Hence, the exchange rate adjustment should be more "orderly" than would otherwise be the case. While the impact of intervention on volatility is generally believed to be small with the use of daily data, the use of intraday data should help provide a more complete assessment of its effect.

The signalling approach relies on the assumption of asymmetric information. It assumes that the central bank possesses information superior to that of the market—either a more accurate economic forecast or "insider" information regarding future monetary policy. The monetary authority reveals this information through foreign exchange intervention in order to "put its money where its month is." As noted by Dominguez (1998), if intervention signals are fully credible and unambiguous, they should have one of two effects. Either they will have no influence on the variance of the exchange rates (but a one-time effect on the level of the currencies); or they should reduce volatility if they convey the message that the central bank is committed to reducing volatility. However, Klein and Rosengren (1991), Kaminsky and Lewis (1993), and Dominguez (1996) cast some doubts that intervention always conveys clear and credible signals about future monetary policy, at least for the G-3 nations. For example, over the 1977–93 period, Dominguez (1996) finds that fewer than 50 per cent of intervention signals are consistent with the observed direction of future monetary policy.

Hung (1997) proposes a noise-trading model within which the authorities might use different strategies that either increase or decrease volatility to manage the exchange rate level. Hung's model acknowledges that the presence of noise traders (e.g., technicians or chartists) can push asset prices away from their fundamental equilibrium value.[1] A central bank, familiar with the reaction function of these traders, can have a large influence on the overall supply and demand conditions for the currency by altering the technical indicators that they follow (i.e., causing or preventing the break of key levels). For example, if the currency is moving away from its fundamental value, the central bank might look "to lean with the wind" on short-term pullbacks of the trend, thereby enhancing short-term variance. However, if the exchange rate is moving towards its fundamental value, the central bank might "lean against the wind" to slow the movement of the currency so that volatility is minimized. Hung's model is consistent with her empirical observation that dollar/yen and dollar/DM volatilities *declined* during the 1985–86 period (the post-Plaza period when policy was used to slow the U.S. dollar's declining trend), but *increased* during the 1987–89 period (the post-Louvre period when intervention was designed to reduce one-way speculation against the U.S. dollar by introducing two-way risk into the market).

Empirical work completed to date indicates that impact of interventions on the level and volatility of the exchange rate is not robust.[2] This is not surprising, given the different channels through which intervention might affect the exchange rate plus the various objectives and strategies of central banks. For example, some recent studies such as Dominguez (1998) and Aguilar and Nydahl (1998), show that intervention might reduce volatility in certain episodes but might increase it in others. Earlier studies, like Bonser-Neal and Tanner (1996), found that intervention by the U.S. authority was positively associated with changes in implied DM/US$

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1. These actions should, in theory, provide profitable opportunities for fundamental traders. However, risk aversion or imperfect knowledge of the currency's equilibrium value might prevent them from opposing the short-term trend. As such, deviations of the currency from its equilibrium value might be persistent. Vigfusson (1996) and Murray, van Norden, and Vigfusson (1996) explore the role of technical trading on the Canadian dollar.

2. While numerous studies have quantified the empirical impact of intervention on the level and the volatility of the exchange rates, its theoretical and empirical effects on the higher moments of the exchange rate statistical distribution have received far less attention. Future work could use the methodology employed in Levin, McManus, and Watt (1998) to analyze the impact of intervention on the skewness and kurtosis of the exchange rate distribution.

volatility.[3] Baillie and Humpage (1992), Dominguez (1993), and Connolly and Taylor (1994) report similar outcomes using conditional volatility measures. In Canada, Phillips and Pippenger (1993) found that lagged values of Canada's official intervention were also associated with increased exchange rate volatility. Edison (1993) provides a good review of the empirical evidence from 1982 to 1993.

This paper investigates the relationship between Canada's intervention and the volatility of the Canadian exchange rate using a 2 1/2-year sample of 10-minute exchange rate and intervention statistics. The use of high-frequency data (higher than daily frequency) should help in assessing the impact of intervention, since foreign exchange rates respond quickly to incoming information. A recent study by Chang and Taylor (1998) shows that intervention by the Bank of Japan has the most significant (albeit positive) impact on JPY/US$ volatility at high frequencies (5- and 10-minute intervals), but a less evident impact at lower frequencies.[4] This suggests that using a 10-minute interval might also be appropriate for the current study to better capture the effect of intervention on volatility. Moreover, as will be discussed in Section 2, the data set makes it possible to distinguish the effects of two types of intervention. One intervention is mechanistic, used to promote orderly markets. The other—more discretionary—is used for signalling purposes. The objectives of these two types of intervention are different. However, the Bank of Canada appeared to use relatively consistent strategies in implementing intervention during the sample period. Thus, it would appear that both types were aimed at reducing foreign exchange volatility. The functional form of the estimated equations, based largely on a framework developed by Andersen and Bollerslev (1996; 1997), also captures the intraday volatility pattern, the effect of changes in the operating band for the overnight rate and other macroeconomic news announcements, and the persistent daily volatility dependencies found in foreign exchange data.

Section 2 of the paper describes Canada's intervention program and provides some statistics concerning intervention. Section 3 reviews the properties of intraday mouvements in the exchange rate and discusses relevant specification issues. Section 4 presents the estimated equations and discusses the results, and Section 5 concludes.

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3. The positive correlation between exchange rate volatility and foreign exchange intervention could also be explained by a positive simultaneity bias since intervention possibly occurs during periods of high volatility. We will return to this issue later in the paper.

4. We are familiar with only a few studies that analyze central bank intervention within the context of intraday data: Goodhart and Hesse (1993); Peiers (1997); and Chang and Taylor (1998). In many respects, the current study is similar to Chang and Taylor's, although they examine the effect of intervention by the Bank of Japan using Reuter's intervention reports, not actual amounts of intervention as in this study.

2. Canada's foreign exchange intervention

The intervention program, in effect between April 1995 and September 1998, had two components, one mechanical and the other discretionary.[5] The estimation results in Section 4 make a distinction between mechanical (or expected) and discretionary (or unexpected) intervention episodes. While the authorities have never revealed the exact details of the intervention program, this distinction is based on the assumption that market participants have good knowledge of the practices.

Canada's mechanical intervention program was designed to promote orderly markets by leaning against the prevailing exchange rate trend, thus reducing foreign exchange volatility. Under the program, a non-intervention band was established at the end of each business day. If the exchange rate deviated during the following day from the non-intervention band, intervention was conducted. The stated goal of the program was not to keep the exchange rate within the band, but rather to slow rapid movements of the dollar.

Discretionary intervention provides greater flexibility to intervene when conditions warrant, sooner (or later) and with greater (or lesser) intensity than would otherwise have been the case. On those days, the band was re-set to make intervention more (or less) likely in one direction. The impact on volatility of discretionary intervention depended critically on the market's interpretation of the Bank's signal. If intervention was interpreted as a warning that a continued deterioration in foreign exchange market will provoke a monetary policy response, then its impact would have been to moderate movements in the exchange rate. Thus, within a regression equation, one would anticipate ex ante a negative impact of discretionary intervention on foreign exchange volatility. However, if the signal was confusing or lacked credibility, intervention might have had no impact on volatility and might, in some circumstances, have enhanced volatility by encouraging speculators to trade against the central bank operations.

Table 1 summarizes daily and 10-minute absolute intervention statistics within two samples: the base sample from 12 April 1995 to 30 September 1997; and a more recent period from 1 October 1997 to 30 January 1998 that coincided with the beginning of the Asian crisis. The figures include all interventions conducted between 7 a.m. to 5 p.m (Eastern time).

During the base sample, the Bank of Canada intervened over 56 days, or in 168 ten-minute intervals. Thus, the Bank intervened on 9 per cent of all business days, compared with almost 50 per cent under the old, pre-April 1995 regime. Of the 56 days of intervention, there were nine occasions where the Bank used discretionary intervention. All these occasions occurred in periods of a depreciating Canadian dollar that required the selling of U.S. dollars. Overall, however,

5. Murray, Zelmer, and McManus (1996) discuss the old, pre-April 1995 intervention program.

upward and downward market pressures on the Canadian dollar were distributed approximately evenly, with the Bank selling U.S. dollars on 30 days and buying on the remaining 26 days.

The Bank was much more active in foreign exchange markets in the more recent period (from 1 October 1997 to 30 January 1998), with intervention occurring on 27 days in only four months (or about once every three business days). The higher frequency of intervention was largely attributable to the weakness of the Canadian dollar that followed the beginning of the Asian crisis, the associated decline in commodity prices, and a flight-to-quality to U.S. financial markets. The majority of interventions during the more recent period were discretionary.

2.1 The effect of the non-intervention zone

While many studies have explored the relationship between intervention and volatility, the theory and empirical impact of a non-intervention zone on exchange rate behaviour has received no attention. However, with the recent experience of the exchange rate mechanism (ERM), there is a great deal of literature concerning the impact of target zones. Target zones are clearly different in many respects from the non-intervention band of the Canadian program. However, the two do share some important characteristics that might allow some of the conclusions found in the literature to be applied to the Canadian situation.

Krugman (1991) develops a simple model that demonstrates how the expectation of central bank intervention affects exchange rate behaviour within the target zone. The assumption in this model is that the monetary authority is credible and has the ability to defend the band if the currency comes under attack. Krugman notes that, in the top half of the zone, the expected *rate of change* of the spot exchange rate must be negative as potential appreciation is limited by the monetary authority’s expected defence of the band. As Figure 1 shows, the resulting relationship between the spot exchange rate and velocity shocks is an S-shaped curve, with its tails tangent to the target band. The effect of the target zone then is to stabilize the exchange rate, even in the absence of actual central bank intervention.

While Canada’s intervention was not designed to keep the exchange rate within a zone,we assumed that the effect noted by Krugman should still appear in the behaviour of the Canadian dollar if the mechanical intervention is well known and credible. This is because the actual and the expected changes of the exchange rate should be smaller when the dollar approached the top or the bottom of the band since market participants knew that the Bank would be entering the market to resist the prevailing exchange rate trend. The regressions will evaluate this effect using a “position” variable, defined as the absolute difference between the current level of the exchange rate and the closest target band. Thus, the position variable became smaller when the Canadian dollar approached the non-intervention band. It should also be positively related to the volatility of the currency (i.e., smaller value of the position variable should be associated with lower future volatility). Moreover, as will be discussed further in Section 4, the relationship between the position variable and the volatility of the exchange rate will be modelled by a non-linear function.

3. Description of the exchange rate data and specification issues

The data set consists of 10-minute data on the Can$/US$ exchange rate from 12 April 1995 to January 30, 1998. Foreign exchange quotes were collected from the Reuters Instrument Code (RIC) System 24 hours a day, seven days a week.[6] However, there exist a number of missing data points in the exchange rate series. The length of the gaps varies from only one 10-minute interval to periods as long as one month. Periods with missing data have been excluded from the sample; this resulted in a loss of 21 observations of 10-minute intervention points.

The empirical analysis focuses on a set of data that excludes weekends and weekdays that are holidays in both the United States and Canada, such as Christmas Day. Moreover, unlike other studies of intraday exchange rates that model the 24-hour foreign exchange market, this study focuses on the business hours during which the Bank's foreign exchange desk conducts most of its intervention activity, between 7 a.m. to 5 p.m. (Eastern time), Monday to Friday.[7] There are several reasons for this:

- The variables of interest—official intervention and Canadian and U.S. macroeconomic news releases—occur mainly during these hours.[8]

- Unlike the U.S. dollar, which is liquid in around-the-clock trading, the Canadian dollar does experience periods of very low quote activity in the hours between the close and the opening in North America.

- Asia does not switch to daylight saving time, which complicates the modelling of the intraday volatility pattern. As will be shown in the following section, volatility rises and falls in a relatively predictable pattern in response to the opening and closing of regional foreign exchange markets. During the summer months, there is a small spike in activity when the Japanese market opens at 7 p.m. EST; however, the upsurge in volatility appears at 6 p.m. during

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6. Note that these are not transacted prices, but rather are only indicative of the rates at which dealers would be willing to trade. Much has been made in the literature of the difference between indicative quotes and hard transaction prices. For example, the negative first-order autocorrelation commonly observed in high-frequency foreign exchange returns is thought to occur because market makers skew the bid-ask spread in a particular direction in order to smooth order imbalances (Bollerslev and Domowitz (1993), among others). However, Goodhart et al. (1996) note that the time paths of mid-market indicative and actual quotes are extremely close. As such, little or no bias should be imparted to the study from our use of indicative quotes.

7. The results related to the effects of intervention on foreign exchange volatility were basically unchanged if a 24-hour model was used.

8. In addition, difficulties pinpointing the exact time of overnight intervention rendered the data useless for purposes of this paper.

the winter months. Thus, the use of daylight saving time in North America shifts the Asian volatility pattern back one hour.

Because so many quotes are entered into the Reuters system, the probability of keying error by a dealer is non-trivial. Therefore, a simple algorithm, based on a procedure used by Dacorogna et al. (1993), is used to eliminate potential "bad" quotes. This is done in many studies that use high-frequency data. A quote is bad if the change in the exchange rate is greater than 19 points (4 times the standard deviation of the series between 7 a.m. to 5 p.m.), and at least 80 per cent of the initial change is subsequently reversed in the following 10-minute interval. This method identifies 37 quotes that should be filtered (eliminating 74 observations from our sample). This number is reasonable when compared to other study's estimates. For example, Dacorogna et al. (1994) estimate that such an error occurs about once in every 400 entries, which would represent about 90 quotes in this paper's sample.

The choice of an exchange rate volatility measure is not straightforward. Statistics concerning six different measures of 10-minute exchange rate volatility, and their definitions, are presented in Table 2. The six volatility measures can be divided into two categories: those with a correction for the long-term (i.e., daily) trend in volatility (numbers 4 to 6) and those without a correction (numbers 1 to 3). Analysis is focused on the three "de-trended" measures. The need for intraday volatility to be "de-trended" is discussed in more detail in Section 3.2. It is sufficient to say that the correction is made by dividing the 10-minute absolute returns, squared returns, and logarithmic returns by a daily GARCH volatility forecast, denoted $\hat{\sigma}^2_{daily}$. The absolute normalized return represents the ratio of the absolute 10-minute returns to the daily GARCH volatility forecast. The squared normalized return and the logarithmic normalized return represent, respectively, the squared values and the log values of the absolute normalized return.

It is is not immediately apparent which criteria should be used to determine which of the three normalized measures is the "most appropriate" for this purpose. Andersen and Bollerslev (1996) justify their selection of the logarithmic normalized return on the basis that its characteristics are close to a normal distribution. Table 2 shows that this is also the case for the Can$/US$ exchange rate, as the excess kurtosis and skewness are considerably less pronounced for the logarithmic normalized returns than for the absolute or squared normalized returns. However, in our opinion, it is not clear why a volatility measure should, a priori, be close to a normal distribution. Moreover, while the log transformation can smooth the large postive shocks, it can also create large negative outliers with the very small changes in the exchange rate (which, effectively, are close to zero). A constant adjustment is made to the raw data before the calculations of the log series to avoid the presence of zeros in the data set (see the note at the bottom of Table 2), following the suggestion of Andersen and Bollerslev (1996). However, the preliminary analysis shows that the estimation results are not invariant to the size of the constant adjustment. Overall, given the difficulty of choosing the most appropriate measure of volatility, estimation results for the three normalized series are presented in Section 4.

3.1 Intraday seasonal patterns

Figure 2 displays the autocorrelation function of the three normalized foreign exchange series over a 5-day horizon (using a 24-hour day). A partial analysis suggests that the first three lags of autocorrelation pattern are the most important. Moreover, the autocorrelations display a regular hump pattern at the 24-hour horizon, indicating the presence of persistent intraday volatility. This seasonal pattern is related to trading activity, information arrival, and the opening and closing of regional foreign exchange markets around the globe.

Figures 3 to 5 depict the average volatility in the exchange rate from 7 a.m. to 5 p.m. The bars represent observed volatility, while the thick lines are the fitted values from our models. This will be discussed further in Section 4. Volatility trends upward right from 7 a.m., peaking in the 10-minute interval from 8:30–8:40, the time at which most the major Canadian and U.S. macroeconomic news announcements are released. After 8:30, volatility spikes again in the interval from 9:00–9:10, which is the period immediately following the time at which most changes in the operating band have been announced by the Bank of Canada. Volatility decays unevenly throughout the rest of the morning, declining to approximately one-half of its morning peak during the lunch hours. After lunchtime, there is a small increase in currency volatility in the middle of the afternoon and a small upswing towards the end of the North American trading session. One can infer from those figures how misleading it would be to assess the effectiveness of intervention without accounting for the seasonal pattern. Due to the decline in volatility after the morning spikes, post-intervention volatility is likely to be lower than pre-intervention volatility, regardless of whether intervention is effective or not. Controlling for the seasonal pattern is thus of the utmost importance if these results are to be valid.

How should seasonal volatility be modelled? The literature suggests three possibilities. The first, and most straightforward, is to use seasonal dummy variables, as in Baillie and Bollerslev (1991). For the current study, this would require estimating an additional 60 time-of-day parameters, if one dummy variable were created for each 10-minute interval. While grouping intraday periods into categories—such as morning, lunch, and afternoon—would reduce the number of variables required, it is unlikely to be effective in capturing the complexity of the seasonal pattern. Second, Dacorogna et al. (1993) propose an intraday time scale, dubbed ϑ time, to de-seasonalize high-frequency data. Their time scale conversion is accomplished by expanding periods with high average volatility and contracting those with low volatility, effectively smoothing the seasonal pattern. They define a market activity variable, the integral of which defines the market time scale.

A third method, and the one used in this study, is the flexible Fourier form developed by Andersen and Bollerslev.[9] Their regression uses several sinusoidal and quadratic parameters to fit the intraday volatility pattern. The formulation used is:

$$f(t, n) = \mu_1 \cdot \frac{n}{N_1} + \mu_2 \cdot \frac{n^2}{N_2} + \sum_{p=1}^{P} \left(\delta_{c,p} \cdot \cos\left(\frac{p2\pi}{N} n\right) + \delta_{s,p} \cdot \sin\left(\frac{p2\pi}{N} n\right) \right)$$

where n is the period of the day (i.e., n equals 61 at 5 p.m.) and N is the number of intervals per day. N_1 (equal to $[N+1]/2$) and N_2 (equal to $[N+1][N+2]/6$) are normalizing constants. Andersen and Bollerslev found this functional form to be successful in modelling both the 24-hour periodicity of the DM/US$ exchange rate and the 7-hour periodicity of the S&P 500 stock index futures. After limited experimentation, we found that a model with $p = 3$ (allowing for the possibility of three seasonal cycles within each day) provided a good fit to the seasonal pattern of the Can$/US$ exchange rate. This means that this study’s Fourier functional form contains eight parameters that need to be estimated, μ_1, μ_2, $\delta_{c,1}$, $\delta_{c,2}$, $\delta_{c,3}$, $\delta_{s,1}$, $\delta_{s,2}$, $\delta_{s,3}$. It is also worthwhile to mention that the estimation of the Fourier form over the business hours, instead of over a full 24-hour day, implicitly imposes a continuity on the seasonal intraday pattern between the closing of a business day (the 10-minute period from 4:50 p.m. to 5 p.m.) and the opening of the following business day (the 10-minute period from 6:50 a.m. to 7 a.m.). As shown in Figures 3 to 5, this assumption is not very strong. However, the regressions will include a dummy variable at the opening to allow for a possible discontinuity.[10]

Another often noted volatility pattern is day-of-the-week effects, primarily that returns on Thursdays and Fridays are more variable than the rest of the week. Evidence has shown these effects to be the result of macroeconomic news announcements, the majority of which are released on those two days (Harvey and Huang, 1991). Explicit control for these announcement effects, as discussed in Section 3.3, eliminates in this study the need for daily dummy variables.[11]

3.2 Daily volatility persistence

The intraday volatility of short-term foreign exchange returns is a dynamic, complex process composed of volatility trends with many time horizons. As discussed, the returns exhibit a

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9. Payne (1997) uses a similar method in his stochastic variance model of the DM/US$ exchange rate.

10. A specific dummy was included at the opening on Monday, but the dummy was not statistically significant.

11. Regular calendar effects are not limited to intraday or daily patterns. For example, Andersen and Bollerslev identify a “summer slow-down” period. We also tried to include such a variable in our equations, which was inferred (from daily variance) to be the first two full weeks of August. However, the variable was not significant, possibly because the summer effect is already captured by the estimate of daily volatility persistence. (See Section 3.2.)

pronounced intraday pattern and significant announcement effects in the short-term. Now, the low-frequency volatility embodied in high-frequency data needs to be modelled. Low-frequency volatility, due for example to political events or to currency crises, represents a common source of variation across intraday returns for which the model should account.

It is well known that foreign exchange returns exhibit significant volatility clustering or ARCH effects. Theoretically, these effects must be present in the form of persistent components of the intraday process as well. Otherwise, the temporal aggregation of high-frequency returns would not accommodate volatility clustering at lower frequencies. (See, for example, Drost and Nijman (1993) and Drost and Werker (1996)). Thus, the conditional heteroskedasticity familiar from studies of daily or weekly foreign exchange returns must necessarily be present as a latent factor at the intraday level.

However, Guillaume et al. (1995) demonstrated that GARCH models of high-frequency exchange rates (excluding Can$/US$) perform poorly in out-of-sample long-term forecasts of volatility, even when compared to a naive forecast of the historical volatility itself. In addition, the model's parameter estimates are not robust over different data frequencies. According to the authors, the presence of volatility components at many different time-horizons was a confounding factor in the identification of a conditional volatility model with high-frequency data.[12]

Following the suggestion of Andersen and Bollerslev (1996), regressions in this study will account for the long-term component of foreign exchange variability by dividing the intraday returns by a daily GARCH volatility forecast. Through a simple correlation analysis, Andersen and Bollerslev demonstrated that daily GARCH volatility predictions are strongly related to the sum of the absolute intraday changes in the exchange rate for the following day. In fact, they note that the correlation between the two is 0.672, or an R-squared of $(0.672)^2 = 45.2$ per cent. This suggests that the long-term component of intraday volatility can be partially captured by GARCH volatility forecasts using daily foreign exchange data.

In order to measure the daily volatility forecast, we estimated a GARCH(1,1) equation on daily data of Can$/US$ exchange rate returns over the period from April 1995 to January 1998. Note that the parameter estimates sum approximately to unity, suggesting a near integrated volatility process.[13] The daily GARCH model was then used to generate one-day-ahead volatility forecasts, noted $\hat{\sigma}^2_{daily}$. Andersen and Bollerslev note that $\hat{\sigma}^2_{daily}$, by providing a normalization with respect to strong overall movements in volatility, should enhance the efficiency of the OLS regression. The GARCH volatility estimate is shown graphically in Figure 6.

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12. Another study (Goodhart, Hall, et al. 1993) suggests that the standard GARCH parameters do not remain robust when announcement variables are included. These findings partially motivated our decision to model the conditional long-term volatility separately.

13. The estimated MA coefficient of the daily GARCH model is equal to 0.93, and the AR coefficient, to 0.06.

3.3 Macroeconomic news announcements

The increasing availability of high-frequency data has caused an explosion of studies that examine the relationship between volatility and scheduled news announcements (for example, Andersen and Bollerslev (1996; 1997), Edderington and Lee (1993; 1996), Goodhart et al. (1993), and Payne (1997)). The findings of these studies are consistent, indicating that the price adjustment is largely completed within one minute, with volatility remaining significantly elevated for 10-15 minutes after the release. Volatility might remain slightly higher for several hours following the announcement.

Our analysis focuses on a relatively small set of announcements that, based on our experience, have the largest impact on the volatility of the Canadian dollar exchange rate.[14] These announcements are (followed by release frequency, time of announcement):

Canada

- consumer price index (monthly, 7:00)
- labour force survey (monthly, 7:00)
- merchandise trade (monthly, 8:30)
- GDP at factor cost (monthly, 8:30)
- Bank of Canada operating band changes (irregular, 9:00)

United States

- employment report / non-farm payrolls (monthly, 8:30)
- durable goods orders (monthly, 8:30)
- FOMC meetings (irregular, 2:15)
- federal funds rate changes (irregular, 2:15)

For each of the announcements, a “news” variable is created, which measures the extent to which an announcement deviates from markets’ forecasts in absolute terms (the variable equals zero otherwise). Three lags of each news variable are included in the estimated equations. Changes to the Bank of Canada’s operating band for the overnight rate are captured by a simple binomial variable that takes the value of 1 when a change actually occurred and 0 otherwise. Thus, it is implicitly assumed that the Bank’s actions were not fully expected by financial markets. Note also

14. To the best of our knowledge, the only study to examine the effect of Canadian macroeconomic news announcements on the volatility of the Canadian dollar is that of Murray, Zelmer, and McManus (1996).

that the FOMC Meetings variable is a binomial dummy that includes all meetings, while a separate dummy variable is introduced on those dates when the federal funds rate was changed. During the sample, the FOMC met 16 times but changed its target for the federal funds rate on only four occasions. In contrast, the Bank of Canada altered the operating band for the overnight rate on 20 occasions.

In our preliminary regressions, we investigated the pre- and post-announcement impact on volatility by including three leads and three lags of various announcements dummy variables. However, these variables are not included in the results presented in this paper. The post-announcement dummies were not significant after the "news" component of the announcements was included. Moreover, the pre-release impact of scheduled announcements was not significant. This result might reflect the different behaviour of foreign exchange dealers. On one hand, inventory re-balancing by some dealers, attempting to limit their exposure prior to an announcement, might lead to higher than normal volatility. On the other hand, some dealers might cease all activity until the content of the news release is known, engendering abnormally low volatility.

4. Estimation results

The estimated equations take the following form:

$$VOL_t = \beta_{0,r1} \bullet R1 + \beta_{0,r2} \bullet R2 + \sum_{i=1}^{3} \beta_{1,r1,i} \bullet VOL_{t-i} \bullet R1 + \sum_{i=1}^{3} \beta_{1,r2,i} \bullet VOL_{t-i} \bullet R2 +$$

$$\sum_{=1}^{n} \beta_{2,i} \bullet |Eint_{t-i}| + \sum_{i=1}^{n} \beta_{3,i} \bullet |Uint_{t-1}| + \beta_4 \bullet POS40_{t-1} + \beta_5 \bullet POS40^2_{t-1} +$$

$$3$$

$$f(t,n) + \beta_6 \bullet D0700 + \beta_7 \bullet DHOL_t + \sum_{k=1}^{D} \sum_{i=1}^{3} \lambda_{k,j} \bullet I_{k,t-i}$$

where:

- VOL_t is the volatility of the exchange rate in period *t*.
- *R1* is the constant term during the periods of non-intervention.
- *R2* is the constant term during the periods of intervention.
- $Eint_{t-i}$ is expected intervention conducted over the previous 10-minute interval.
- $Uint_{t-i}$ is unexpected intervention conducted over the previous 10-minute interval.

- $POS40_{t-1}$ is the absolute distance of the exchange rate from the closest non-intervention band. A multiplicative dummy variable (equal to 1 if the lagged position variable is below 40 points, and 0 otherwise) is attached to the position variable.
- $f(t, n)$ represents the flexible Fourier form.
- $I_{k,t-i}$ is the "news" component of announcement *k,* lagged *j* periods.
- $DHOL_t$ equals 1 if day *t* is a national holiday in either Canada or the United States, and 0 otherwise.

Results are given for three measures of foreign exchange volatility, *VOL*: the absolute normalized returns (referred henceforth as the ABS model); the squared normalized returns (the SQR model); and the logarithmic normalized returns (the LOG model). Remember that the returns of the exchange rate during the 10-minute period *t* are normalized by the daily GARCH volatility forecast for that day.

As mentioned before, there is a potential simultaneity bias between exchange rate volatility and foreign exchange intervention since intervention usually occurs during periods of high volatility.[15] To limit the consequences of this bias, the volatility of the exchange rate is modelled within two regimes—a regime of non-intervention (*R1*) and a regime of intervention (*R2*).[16] For example, if the Bank of Canada usually intervened in the foreign exchange market when exchange rate volatility increased; it is expected that, by taking into account the presence of a new regime in volatility, a better estimate of the "true" effect of intervention will be obtained. As shown in the equation below, it is assumed that the constant term ($\beta_{0,\,r1}$ and $\beta_{0,\,r2}$) and the autoregressive coefficients ($\beta_{1,\,r1}$ and $\beta_{1,\,r2}$) are different under the two regimes.[17] Note also that the estimated equations include three lags of the dependent variable under each regime. The choice of three lags was based on the autocorrelation pattern presented in Figure 2. However, the basic results related to the effect of macroeconomic announcements and intervention are robust across different lag specifications.

As explained in Section 2, the estimated equations make a distinction between mechanical/ expected (*Eint*) and discretionary/unexpected (*Uint*) interventions. For expected intervention, the

15. However, the results of a recent study by Chang and Taylor (1998) show that at the 10-minute frequency, the Bank of Japan's intervention is not caused by higher variances. This suggests that the potential simultaneity bias might be not very large at that frequency.
16. In the estimated equations, two other specification techniques are used to reduce the simultaneity bias. First, only values of intervention variables lagged by (at least) one 10-minute interval are used in the estimated equations. Second, the normalization of intraday returns by the daily volatility forecast helps to reduce the simultaneity problem to the extent that volatility is highly persistent on a daily basis, which makes it partly predictable.
17. Future work should include more efforts in modelling the other characteristics of the two regimes and could allow for stochastic regime changes in volatility.

equations include the absolute amount of intervention done over the previous three 10-minute periods (i.e., the previous half-hour). A longer structure of 12 lags (two hours of actual time) is used for unexpected intervention. It is assumed that the signalling content of central bank discretionary intervention is fully revealed to the market with some lags, although some market participants might have superior information for a short period of time.[18] To capture the lagged effect of unexpected intervention, the estimated equation simply constrains the coefficients on the fourth, fifth and sixth lags of the intervention variables to be equal; the coefficients on the seventh, eighth, and nineth lags, to be equal; and the coefficients on the tenth, eleventh, twelveth lags, to be equal. Finally, for both types of intervention, the equations include the amount of cumulative daily intervention to capture the possibility of persistent effects of intervention on foreign exchange volatility throughout the whole day. A persistent effect might be found for discretionary intervention if the “risk” of future intervention is raised by actual intervention.

As was also discussed in Section 2, the equations include a position variable (*POS40*) that aims to capture the stabilizing effect of the non-intervention band. The position variable is defined as the absolute difference between the current level of the exchange rate and the closest target band. The variable is defined until intervention occurs, after which the variable is set to zero. The relationship between the position variable and the volatility of the exchange rate, which is undoubtedly non-linear, has the following quadratic form in the estimated equation: $\beta_4 \bullet POS40_{t-1} + \beta_5 \bullet POS40^2{}_{t-1}$. Given that the relationship is assumed to be positive and concave (i.e., a decrease in the position variable, when the Canadian dollar approached the non-intervention band, leads to a larger decrease in future volatility when *POS*40 approaches zero), the estimated coefficient β_4 should be positive and the coefficient β_5, negative. However, a preliminary investigation showed, perhaps not surprisingly, that the non-linear relationship is difficult to fit to the data. Presumably this is because the non-intervention band does not provide any stabilizing effect when the exchange rate is far away from the upper or lower limits of the band (i.e. when the position variable is large).[19] Our strategy in modelling this form of non-linearity is to define a threshold position value, below which the position variable will influence future volatility, but above which it will simply have no effect. We experimented with different values for this threshold and found that a value of 40 points presents the most significant relationship between the position variable and the volatility of the Canadian dollar.[20] In practice, a dummy variable (set to 1 if the lagged position variable is below 40 points, and 0 otherwise) is attached to the position variable to take into account that the stabilizing effect works only when the Canadian dollar exchange rate is within 40 points from the non-intervention band.

18. Longer lags were never significant for expected intervention, possibly because its effect (if any) is rapidly embodied in exchange rates.

19. We also experimented with other non-linear relationships between the volatility of the Canada dollar and the position variable, such as the logarithmic and the logistic transformations of the position variable. The simple quadratic is the one that seems to provide the best fit of the data.

20. This procedure introduces a selection bias in the estimated effect of the position variable. Consequently, any inference about the effect of this variable should be taken with caution.

As discussed in Section 3, the function $f(t, n)$ represents the flexible Fourier form that is introduced to explain the intraday pattern in volatility. The variable *D0700* is a dummy variable introduced at the opening to capture the discontinuity of the Fourier form. The estimated equation also includes a dummy variable (*DHOL*) that is introduced to account for the lower activity in days that are a holiday either in Canada or in the United States. Finally, the equation includes the news component of *k* different macroeconomic announcements $I_{k,\,t-i}$. The time-lag index, *i,* is such that the impact of announcements will be measured up to 30 minutes after the news release. However, as the results will show, most of the effect of the announcements is completed in the first 10 or 20 minutes.

4.1 The results: Base sample

The estimation results of the ABS, SQR, and LOG models for the base sample from 12 April 1995 to 30 September 1997 are reported in Table 3. This sample consists of 32,676 observations of 10-minute exchange rate returns, normalized by their corresponding daily volatility. The sample used for estimation excludes keying errors, non-core business hours, weekends and weekdays that are holidays in both the United States and Canada. Note also that the error process is likely to exhibit heteroskedasticity, given the large number of factors that influence the exchange rate over a 10-minute period. Consequently, the standard errors have been adjusted using the Newey-West estimated variance-covariance matrix. However, as shown at the bottom of Table 3, the residuals still exhibit significant skewness and kurtosis. Consequently, any inference about the coefficients should be taken with caution.

The explanatory power of the regressions is relatively small, with a RBAR-squared that ranges from 6 per cent in the LOG model to 12 per cent in the SQR model. This modest performance is not that surprising for models of volatility with high-frequency data.[21] Another way to describe the predictive ability of the models is to compare the average actual volatility with the average fitted volatility for each of the 10-minute periods over the business day. This comparison appears on Figures 3 to 5, where the average fitted volatility values are shown in bold and the actual values are shown as bars. (Figures 3 to 5 also display the success of the flexible Fourier form alone in capturing the intraday seasonality. The fitted seasonal volatility values are represented by the dotted lines and plotted against the right axis.) The average fit appears to be generally good, although it is also clear that some of the large changes in intraday volatility are not well captured by the estimated equations. For example, the increases in average volatility between 8:30 and 8:40 and between 9 and 9:10 are difficult to fit. In future work, the inclusion of additional news variables released at 8:30 might help to explain part of the increase in volatility at that time of the day. Moreover, it is possible that the increase in volatility between 9 and 9:10 is attributable to the

21. Andersen and Bollerslev (1998) report that many volatility models with high-frequency data exhibit an RBAR-squared smaller than 10 per cent, and even smaller than 5 per cent. In fact, according to them, the RBAR-squared is not an accurate measure of a model’s ability to predict volatility.

uncertainty about monetary policy that, from time to time, comes from the decision to not change the operating band for the overnight rate. As only the effect of the actual changes is captured in the estimated equations by the announcement dummy, the impact of the decisions to not change the band when a change is expected does not appear in the equations. In an effort to better capture the news component in monetary policy, we tried to introduce in the equation a measure of the expected changes in the overnight rate. This is calculated by the difference between the interest rates on the 90-day commercial paper at the end of the previous day and the actual overnight rate at 9 a.m (adjusted for a "normal" term premium of 25 basis points). This variable was not significant when the announcement dummy was included in the equation.

The results in Table 3 show that the level of foreign exchange variability over the past 30 minutes is important in explaining the current level in all three models. However, the estimated coefficients are not very large (ranging from 0.10 to 0.30 for the first lag, and always below 0.10 for the second and third lags), which suggest that a large volatility shock will be usually followed by short intervals of (slightly) higher than normal volatility. It is also interesting to note that the autoregressive coefficients show that volatility is less persistent in the intervention regime. This could suggest that foreign exchange intervention reduces not only the mean of volatility, but also the short-term persistence of volatility shocks.

4.1.1 The macroeconomic news announcements

This section tries to identify which of the macroeconomic news releases has the greatest impact on exchange rate volatility. Based on the product of the coefficients attached to each announcement in the 30-minute interval that follows its release and the average surprise in each announcement, the results of the ABS and SQR models show that the following five announcements have the largest effect on volatility: *changes in the operating band for the overnight rate,*[22] *the FOMC meetings, the U.S. employment report, the Canadian merchandise trade report, and the Canadian GDP at factor cost.*[23] In general, those announcements have large effects on foreign exchange volatility because they are capable of generating large surprises. On the contrary, the coefficients on the Canadian CPI announcements are among the largest, but the small size of the average surprise makes their effect on foreign exchange volatility relatively minor. The relative effect of each announcement on volatility in the LOG model is not consistent with the ranking of the previous two models. This possibly reflects the fact that the largest news has less measured impact in a model where the endogenous variable shows less variability.

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22. It is interesting to note that the coefficients on the changes in the overnight rate are rarely significant at the conventional 10 per cent level, although those announcements have the largest effect on volatility. This might reflect the difficulty in assessing the true unexpected component in the changes of the overnight rate.

23. These results are broadly in line with those of Murray, Zelmer, and McManus, who found that only a few announcements have a significant impact on the volatility of the Canadian dollar: changes in the operating band, the Canadian national accounts, and the Canadian GDP at factor cost.

In general, in the ABS and SQR models, the regularly scheduled announcements do not increase volatility beyond the first 10 or 20 minutes, as the new information is rapidly processed by the market. For example, based on the SQR model, the U.S. employment report increases volatility by a factor of 1.5 times the standard deviation in the first 10 minutes following the release (i.e., an effect of about 10 exchange rate points on the level of the currency, assuming an initial exchange rate of Can$1.40 per US$). However, there is no discernable effect beyond 10 minutes as neither the second nor third lagged coefficient is of any sizeable importance.

The impact of changes in the operating band and of FOMC meetings provides an interesting basis for further discussion. Changes in the overnight operating band have a larger and slightly more prolonged impact on volatility than regularly scheduled FOMC meetings, possibly because the exact timing of the announcement, rather than the actual changes in interest rates, surprises the markets. In the ABS model, the change in the operating band elevates volatility by a factor equivalent to about 2 times the "normal" volatility during *each* of the two 10-minute periods that follows the announcement.[24] In the SQR model, the effect is equivalent to about 5 times the normal volatility. This represents an effect of about 15 to 25 points on the *level* of the currency after 20 minutes, depending on the model. This contrasts with the impact of FOMC announcements, which engender volatility that is hardly distinguisble on average from "normal" circumstances. Moreover, it is interesting to note that actual announcements of changes in the federal funds rate reduces volatility, suggesting that most changes were expected by the markets.

4.1.2 The intervention variables

It is evident from the regression results presented in Table 3 that expected intervention (*Eint*) had no direct impact on the reduction of intraday exchange rate fluctuations. In fact, the results show that expected intervention was usually associated with small increased volatility in future periods, as the coefficients on the 10-minute and cumulative expected intervention variables are both positive, although not significant. The expected intervention is not believed to have a significant negative impact on volatility since its effect had already been discounted by the market when it occurred. This argument also explains why the position variables (*POS40* and its squared value) have a significant effect in the three models. This result is interpreted to mean that the stabilizing effect of expected intervention might appear as the Canadian dollar approached the upper or the lower limits of the target band. When the dollar exceeded the band, actual intervention

24. For the purpose of the following discussion, normal volatility is defined as one standard deviation of actual intraday volatility (see Table 2).

did not have any direct impact as it was already expected.[25] However, one has to recognize that the stabilizing effect of the non-intervention band was not large. For example, the estimated coefficient on the position variables in the SQR model suggests that a change of 10 exchange rate points in the level of the exchange rate—when the currency is already 15 points below the closest limit of the non-intervention band—reduced future volatility by a factor equivalent to only 1 exchange rate point.

The results in Table 3 show that unexpected intervention (*Uint*) does appear to be moderately stabilizing, at least in the ABS and SQR models. In fact, while unexpected intervention has no significant measurable impact in the hour that follows intervention, it is significant in reducing volatility in the second hour and throughout the whole day. Figure 7 traces the dynamic effect of a US$150 million of intervention in the three models. For each model, the simulation results are normalized by the standard deviation of the dependant variable. The results of the ABS and SQR models are similar. They show that the effect of unexpected intervention peaks about two hours after the beginning of intervention, possibly reflecting the time required for the signal to be fully incorporated into market expectations. At its peak, intervention reduces volatility by a factor equivalent to 3/10 of normal 10-minute volatility in the ABS model, and of one-half of normal volatility in the SQR model. (Note that the peak effect is about the same in the LOG model as in the ABS model, although it is only significant in the latter). These effects seem small in comparison to the effect of some macroeconomic news releases. However, unexpected intervention has a long-lasting effect throughout the whole day, not just for 10 minutes or 20 minutes. As mentioned before, the persistent effect of a first round of intervention could result from the perceived “risk” of further intervention during the rest of the day.

An alternative way to measure the effect of unexpected intervention is to look at the effect of the cumulative daily intervention on daily volatility. The coefficient on the cumulative daily unexpected intervention in the ABS and SQR models (combined with the autoregressive process of the models) suggests that an intervention of US$150 million reduces exchange rate volatility for the rest of the day by a factor equivalent of one-tenth to one-third of the *average* level of volatility during the day, depending on the model. This effect is larger than that estimated by Murray, Zelmer, and McManus (1996) with daily data, which suggests that US$150 million of intervention reduces daily volatility by about 4 per cent. This difference could reflect, among other things, the benefits of using intraday data in measuring the effectiveness of foreign exchange intervention.

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25. In our discussions with the market, a further explanation to reconcile the apparent contradiction of moderately stabilizing non-intervention bands and slightly destabilizing intervention was proposed. The banks‘s traders generally assume that the pressures on the currency are modest within short time intervals, and that the probability of the non-intervention band being violated is small. For example, when the currency is 5 to 10 points away from the upper limit of the non-intervention band, traders feel comfortable buying small amounts of Can$ because they know that they will be able to sell them to the Bank of Canada at only small loss if the currency depreciates. However, when the Bank actually intervenes, it is a signal to the traders that they underestimated the pressure on the currency and they quickly reversed their positions. This, combined with the possible effects of stop-loss orders after the intervention level, contributes to a quick spike in volatility after the first intervention.

4.2 The results: Extended sample

This section presents the results for the extended sample that ends on 30 January 1998. The results, given in Table 4, focus on the effect of the intervention variables, the other results being left out of the tables only for simplicity. As discussed in Section 2, the frequency of discretionary intervention increased significantly in the more recent period, following the beginning of the Asian crisis. While the base sample included twenty-three 10-minute intervals (or nine days) of discretionary intervention over a period of 2 1/2 years, such intervention was conducted over 83 intervals (or 21 days) during the period from October 1997 to January 1998.

As shown in Table 4, the effect of expected intervention remained insignificant (and slightly positive) in the extended sample, but the non-intervention band retained its significant stabilizing effect. However, unexpected intervention is now less successful at moderating the volatility of the Canadian dollar. This suggests that the small impact of discretionary intervention in the October–January episode, combined with the higher frequency of intervention during that time, partly offset the significant stabilizing effect that intervention had in the earlier period.

There are various hypotheses that could explain why discretionary intervention does not seem to be very successful in the October–January episode. One possibility is that the Bank of Canada intervened within the context of a large drop in commodity prices that affected the fundamental value of the Canadian dollar, which probably made the effectiveness of intervention difficult to quantify. Alternatively, one might suggest that the signalling content of intervention was possibly ambiguous during that period. There was a perceived reluctance of the Bank to raise its official interest rate to support its intervention when the inflation rate was below the mid-point of the 1 to 3 per cent target range. An implication of the latter explanation is that effectiveness of intervention diminishes as its frequency increases without additional monetary policy signals or actions.

Knowing that intervention activities are usually grouped in sequences of different length, the models are estimated by breaking down the effect of intervention into three parts: on the first day of each sequence (DAY1); on the second and third days (DAY2&3); and over the remaining days of the sequence (DAY4+). Discretionary intervention is assumed to be more effective at reducing foreign exchange volatility at the beginning of an intervention sequence, because it then coveys the initial, and stronger, signal about the intentions of the central bank to stop an undesired trend in the currency. However, as discretionary intervention continues for a long period of time, its effect becomes less powerful either because the information content is getting smaller or because the signal becomes more ambiguous. (This is unless intervention is quickly followed by a change in the official interest rate.)

The summary results of the sequence analysis are presented in Table 5. In the extended sample, nine sequences of intervention are identified (DAY1 is a dummy variable sets to 1 on the nine days where a sequence is initiated). Six of the nine sequences last for 2 or 3 days (DAY2&3

is a dummy variable sets to 1 on the eleven days that represent the second and third days of each sequence). Two sequences last four days or more (DAY4+ is a dummy variable sets to 1 on the seven days that represent the fourth day and the subsequent days of each sequence). For simplicity, the first three lags of each intervention variable are constrained to have the same effect. The results of the ABS and SQR models suggest that discretionary intervention was successful at reducing foreign exchange volatility in the first three days of an intervention sequence, as shown by the coefficients on the cumulative intervention variables in DAY1 and DAY2&3 (although the coefficient on DAY2&3 is not significant at the 10 per cent level in the ABS model). Based on the estimated coefficients and the average amounts of daily intervention in DAY1 and DAY2&3, it is calculated that intervention reduces volatility by a factor of one-quarter of the average daily volatility on each of the first three days of an intervention sequence. However, the results show that intervention had no significant effect on volatility beyond the third day.

5. Concluding remarks

This paper investigates the effectiveness of Canada's foreign exchange intervention to moderate intraday currency fluctuations. It was suggested that the use of high-frequency data (with a frequency higher than a business day) would help in assessing the impact of intervention, since the foreign exchange market responds quickly to financial news, including those about intervention. Similar to the results reported by Murray, Zelmer, and McManus (1996) with daily data, we find that rule-based intervention had no direct impact on the reduction of the volatility of the Canadian dollar. However, there is some evidence that the existence of a non-intervention band provided a statistically significant stabilizing role for the currency within each day, albeit of a small importance. This result is interpreted to mean that the stabilizing effect of *expected* intervention might appear as the Canadian dollar approached the upper or the lower limits of the non-intervention band. When the dollar exceeded the band, actual intervention did not have any direct impact as it was already expected.

Moreover, results show that discretionary intervention was effective in stabilizing the Canadian dollar over the base sample from April 1995 to September 1997 (albeit this conclusion depends on how intraday volatility is measured). Some of the estimated effects of intervention were significantly larger than those obtained by Murray, Zelmer, and McManus, possibly reflecting the benefits of using intraday data in measuring the effectiveness of foreign exchange intervention. However, when the data for the October 1997–January 1998 period are included in the sample—a period where the frequency of discretionary intervention significantly increased—unexpected intervention became less effective at moderating the volatility of the Canadian dollar. It is suggested that the signalling content of intervention was possibly ambiguous during that period, given the perceived reluctance of the Bank to support its foreign exchange intervention by raising its official interest rate when the inflation rate was below the mid-point of the 1 to 3 per cent target range. As such, the empirical results show that the effectiveness of an intervention sequence diminished as it increased beyond a few days.

Figure 1: Target zone for the exchange rate

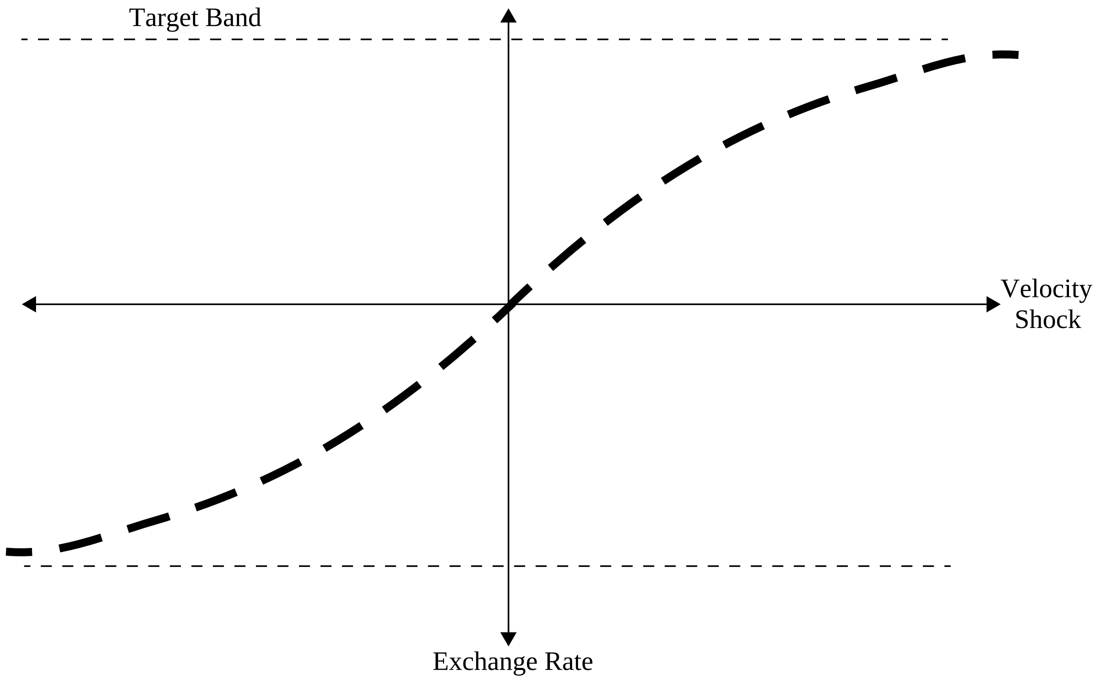


Figure 2: Autocorrelation function of intraday exchange rate volatility

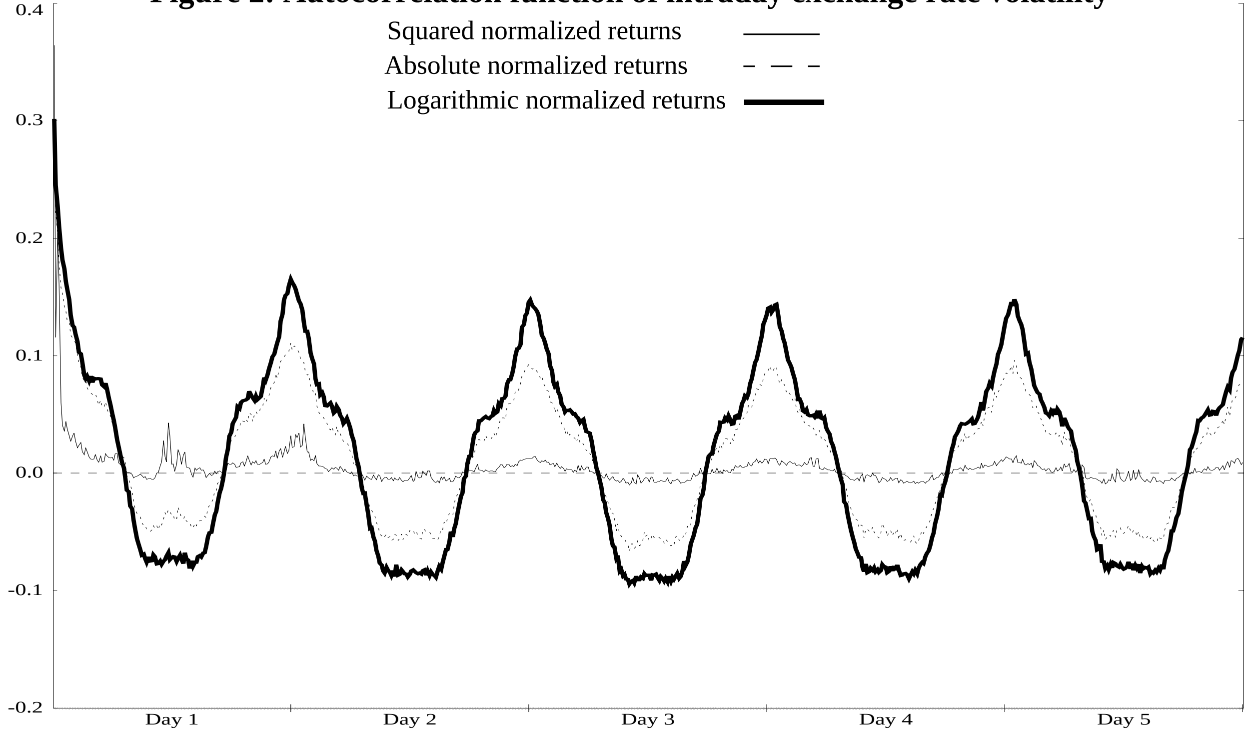
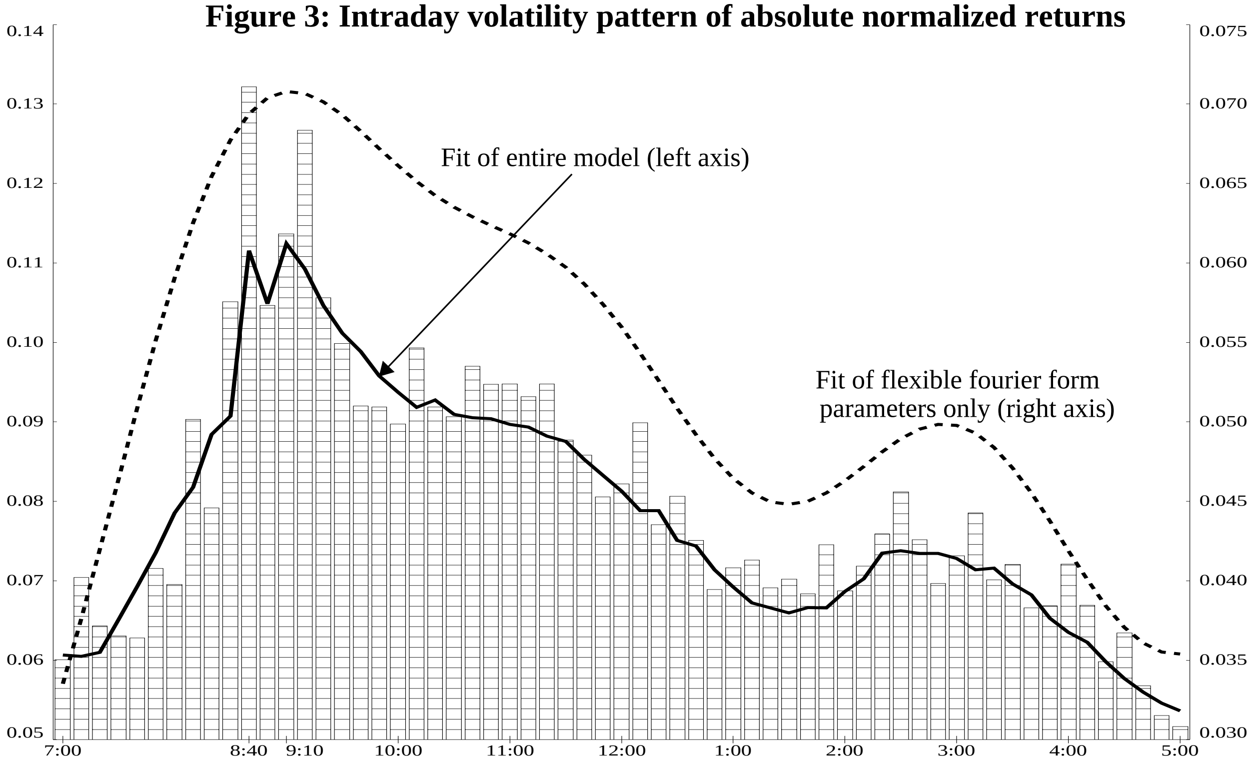
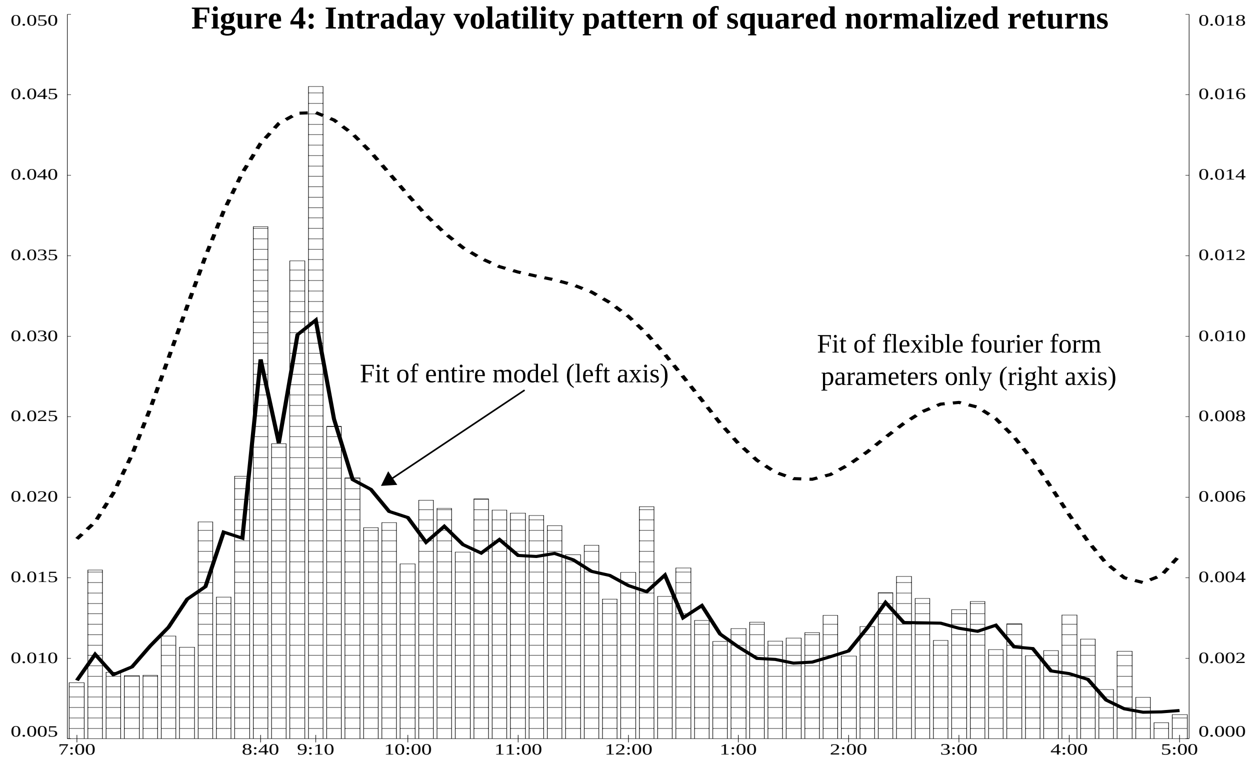


Figure 3: Intraday volatility pattern of absolute normalized returns



(time index shows the end of each 10-minute period)

Figure 4: Intraday volatility pattern of squared normalized returns



(time index shows the end of each 10-minute period)

Figure 5: Intraday volatility pattern of logarithmic normalized returns

(time index shows the end of each 10-minute period)

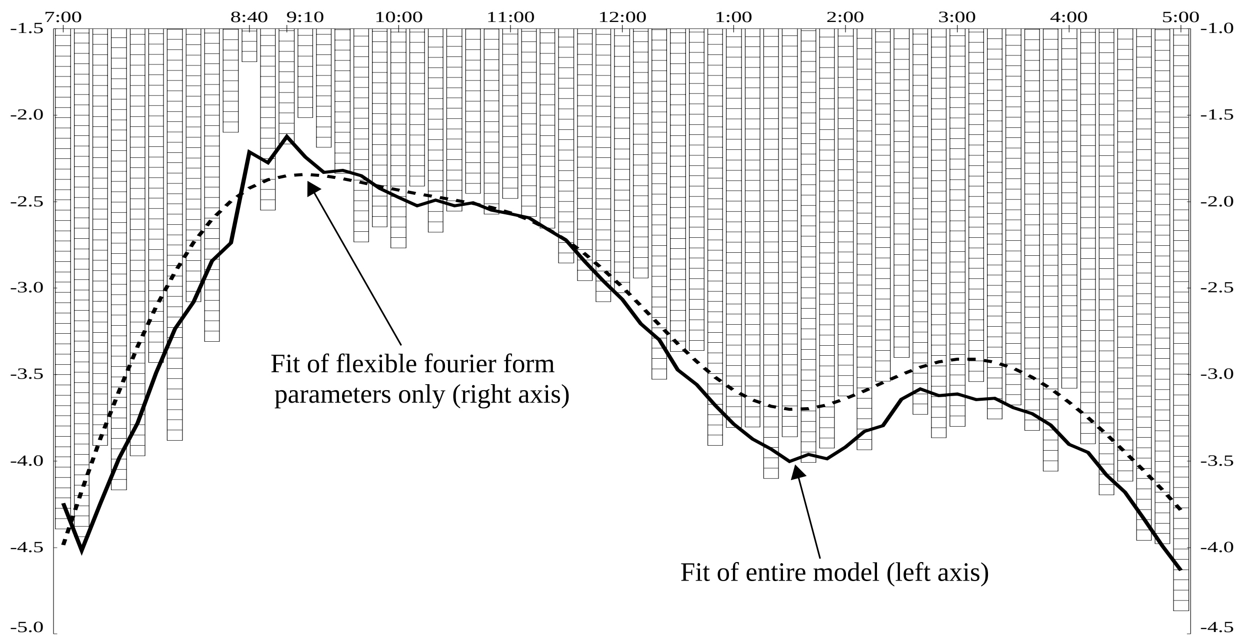


Figure 6: Daily GARCH volatility of the Can$/US$ exchange rate

Figure 7: Impact of discretionary intervention - simulation results

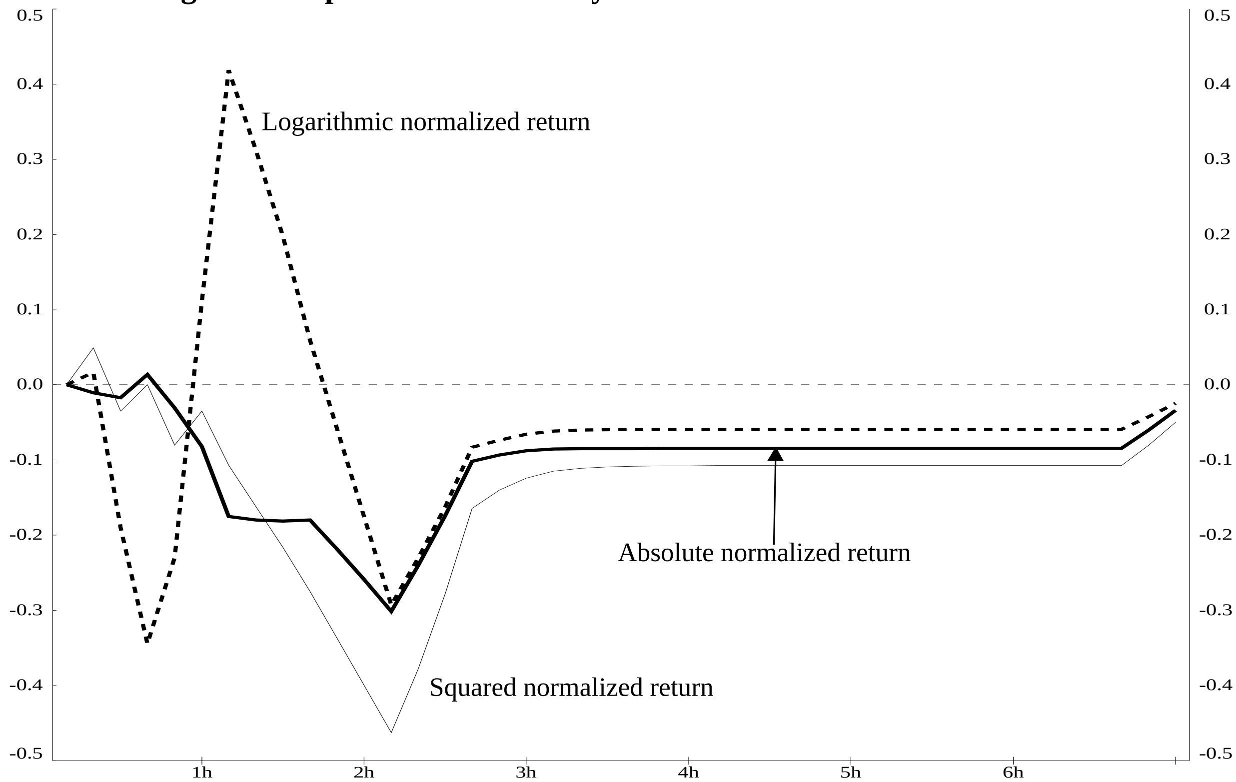


Table 1: Canada's foreign exchange intervention statistics

	April 1995 to September 1997				October 1997 to January 1998			
	Number of occurrences		Average absolute amount		Number of occurrences		Average absolute amount	
	Mech.	Discr.	Mech.	Discr.	Mech.	Discr.	Mech.	Discr.
DAILY								
All	47	9	148.0	125.7	6	21	196.5	164.7
Buying US$	26	0	146.7	0	1	0	51.0	0
Selling US$	21	9	149.6	125.7	5	21	225.6	164.7
10-MINUTE								
All	145	23	48.0	49.2	23	83	51.2	41.7
Buying US$	78	0	48.9	0	1	0	51.0	0
Selling US$	67	23	46.9	49.2	22	83	51.3	41.7

Note: Includes all intervention done during core business hours from 7 a.m. to 5 p.m. Eastern time

Table 2: Statistical properties of alternative foreign exchange volatility measures

	Mean	S.D.	Skewness	Kurtosis
Raw return: R	-0.000045	0.031	-0.74	18.00
Absolute return: $\|R\|$	0.020	0.024	3.83	40.66
Squared return: R^2	0.001	0.004	46.99	3618.72
Absolute normalized return: $\|R\| / \hat{\sigma}_{daily}$	0.078	0.090	3.21	25.33
Squared normalized return : $R^2 / \hat{\sigma}^2_{daily}$	0.015	0.052	34.73	2403.48
Logarithmic normalized return : $2*\log(\|R\|+.000045) - \log(\hat{\sigma}^2_{daily})$	-7.45	4.67	-1.27	0.14

R is defined by: $100*(S_t-S_{t-1})/S_{t-1}$, where S is the C$/US$ exchange rate at each 10-minute intervals. $\hat{\sigma}^2_{daily}$ is the one-day ahead forecast of daily volatility generated from a GARCH (1,1) model. Note: All kurtosis / skewness statistics show significant departures from the standard normal at the 1% level.

Table 3: Regression results for three measures of foreign exchange volatility
Sample: 12 April 1995 to 30 September 1997

		Abs. normalized returns (ABS)		Sqr. normalized returns (SQR)		Log. normalized returns (LOG)	
		Coefficient	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
Constant: R1 (non-intervention regime)		0.033	2.20	0.013	2.22	-8.46	-8.73
Constant: R2 (intervention regime)		0.051	3.20	0.019	3.04	-8.29	-8.25
*Vol(t-1)*R1*		0.159	14.85	0.271	2.55	0.105	16.67
*Vol(t-2)*R1*		0.065	6.59	-0.044	-0.60	0.050	8.04
*Vol(t-3)*R1*		0.066	8.87	0.038	2.37	0.061	10.34
*Vol(t-1)*R2*		0.119	4.06	0.059	2.49	0.037	1.37
*Vol(t-2)*R2*		0.063	2.77	0.046	2.39	0.057	2.08
*Vol(t-3)*R2*		0.056	2.13	0.022	1.04	0.045	1.39
n / N_1		0.056	1.35	-0.012	-0.70	7.24	2.65
n / N_2		-0.018	-1.34	$0.40*10^{-2}$	0.72	-2.40	-2.65
$Cos (2\pi n / N)$		$0.48*10^{-2}$	0.61	$-0.40*10^{-2}$	-1.29	1.03	2.00
$Cos (4\pi n / N)$		$-0.41*10^{-2}$	-2.04	$-0.26*10^{-2}$	-3.29	0.023	0.18
$Cos (6\pi n / N)$		$-0.37*10^{-2}$	-3.58	$-0.18*10^{-2}$	-4.19	-0.119	-1.98
$Sin (2\pi n / N)$		0.013	8.06	$0.35*10^{-2}$	5.29	0.782	7.62
$Sin (4\pi n / N)$		$0.42*10^{-3}$	0.44	$-0.10*10^{-4}$	-0.25	-0.035	-0.62
$Sin (6\pi n / N)$		$0.98*10^{-3}$	1.32	$-0.15*10^{-3}$	-0.43	0.072	1.70
D0700		0.010	2.36	$0.16*10^{-2}$	0.92	0.816	2.51
DHol		-0.019	-5.31	$-0.39*10^{-2}$	-2.94	-1.83	-6.85
Canada: GDP at factor cost	(t-1)	0.278	2.36	0.147	1.69	6.56	4.63
	(t-2)	0.155	1.91	0.035	0.69	1.50	0.50
	(t-3)	-0.055	-0.61	$-0.57*10^{-2}$	-0.13	-1.41	-0.57

Table 3: Regression results for three measures of foreign exchange volatility
Sample: 12 April 1995 to 30 September 1997

		Abs. normalized returns (ABS)		Sqr. normalized returns (SQR)		Log. normalized returns (LOG)	
		Coefficient	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
Canada: Merchandise trade	(t-1)	0.105	2.42	0.039	1.70	2.19	1.74
	(t-2)	$0.88*10^{-2}$	0.28	$-0.82*10^{-2}$	-0.69	1.32	1.59
	(t-3)	0.100	1.98	0.053	1.70	2.67	4.98
Canada: CPI	(t-1)	0.429	2.48	0.154	2.31	12.48	2.52
	(t-2)	0.137	1.80	-0.020	-0.64	14.82	4.73
	(t-3)	0.111	0.99	0.039	1.14	4.99	1.06
Canada: Employment (LFS)	(t-1)	0.392	2.37	0.199	1.84	11.13	3.94
	(t-2)	0.039	0.58	-0.034	-0.91	6.81	3.23
	(t-3)	-0.017	-0.47	$-0.80*10^{-2}$	-0.83	2.05	0.42
Canada: Operating band changes	(t)	0.174	1.62	0.251	1.16	1.44	1.42
	(t-1)	0.194	1.83	0.254	1.48	1.61	1.65
	(t-2)	0.069	0.93	0.015	0.14	-0.069	-0.05
U.S.: Employment report	(t-1)	$0.13*10^{-2}$	4.73	$0.82*10^{-3}$	2.81	0.018	7.05
	(t-2)	$-0.11*10^{-3}$	-0.91	$-0.22*10^{-3}$	-2.06	$0.66*10^{-2}$	2.54
	(t-3)	$0.60*10^{-4}$	0.25	$-0.28*10^{-4}$	-0.15	$0.68*10^{-2}$	2.27
U.S.: Durable goods orders	(t-1)	0.041	1.77	0.025	1.33	1.03	5.29
	(t-2)	$-0.65*10^{-3}$	-0.05	$-0.67*10^{-2}$	-0.92	-0.033	-0.07
	(t-3)	0.030	2.07	0.014	1.54	0.875	4.43
U.S.: FOMC meetings	(t)	0.089	1.30	0.074	1.40	-0.911	-0.52
	(t-1)	0.056	1.51	0.017	0.91	1.08	0.74
	(t-2)	$-0.53*10^{-2}$	-0.35	-0.010	-1.77	2.29	5.70
U.S.: Changes in the federal funds rate	(t)	-0.189	-1.78	-0.242	-1.69	3.58	1.89
	(t-1)	-0.044	-0.70	-0.020	-0.28	2.66	1.45
	(t-2)	$-0.65*10^{-2}$	-0.20	$0.47*10^{-2}$	0.66	-3.12	-0.95
POS40	t-1	9.72	4.21	3.03	2.89	544	5.01
*(POS40)**2*	t-1	-2321	-3.48	-769	-2.55	-125484	-3.97

Table 3: Regression results for three measures of foreign exchange volatility
Sample: 12 April 1995 to 30 September 1997

		Abs. normalized returns (ABS)		Sqr. normalized returns (SQR)		Log. normalized returns (LOG)	
		Coefficient	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
Expected intervention (Eint)	t-1	$0.33*10^{-3}$	1.39	$0.11*10^{-3}$	0.71	$0.99*10^{-2}$	1.60
	t-2	$0.11*10^{-4}$	0.05	$0.31*10^{-4}$	0.37	$-0.13*10^{-2}$	-0.21
	t-3	$0.21*10^{-3}$	1.09	$0.71*10^{-4}$	0.81	0.011	2.13
	cumulative daily	$0.24*10^{-4}$	1.29	$0.75*10^{-5}$	0.98	$0.80*10^{-3}$	1.05
Unexpected intervention (Uint)	t-1	$0.14*10^{-3}$	0.41	$0.14*10^{-4}$	0.16	$0.31*10^{-2}$	0.18
	t-2	$-0.11*10^{-3}$	-0.36	$0.18*10^{-4}$	0.15	-0.018	-1.02
	t-3	$0.13*10^{-3}$	0.54	$0.57*10^{-3}$	0.75	-0.012	-0.68
	t-4 to t-6	$-0.10*10^{-4}$	-0.07	$-0.32*10^{-4}$	-1.08	0.015	2.30
	t-7 to t-9	$-0.90*10^{-4}$	-0.67	$-0.28*10^{-4}$	-1.03	$0.21*10^{-2}$	0.56
	t-10 to t-12	$-0.18*10^{-3}$	-2.28	$-0.66*10^{-4}$	-3.77	$-0.73*10^{-2}$	-0.84
	cumulative daily	$-0.49*10^{-4}$	-1.83	$-0.25*10^{-4}$	-2.46	$-0.16*10^{-2}$	-0.88
Regression statistics:							
Usable observations			32,676		32,676		32,676
Number of parameters			58		58		58
*RBAR**2*			0.090		0.117		0.057
Durbin-Watson statistic			2.006		2.001		2.008
Standard error of estimate			0.085		0.048		4.53
Skewness of estimate			2.77		25.3		-1.23
Kurtosis of estimate			18.9		1513		0.24

Table 4: Summary results for intervention variables with extended sample from 12 April 1995 to 30 January 1998

		Abs. normalized returns (ABS)		Sqr. normalized returns (SQR)		Log. normalized returns (LOG)	
		Coefficient	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
POS_40	t-1	10.95	4.54	4.57	3.85	512	4.78
*(POS_40)**2*	t-1	-2825	-4.09	-1254	-3.70	-122612	-3.95
Expected inter-vention (Eint)	t-1	$0.19*10^{-3}$	0.82	$-0.20*10^{-4}$	-0.13	$0.74*10^{-2}$	1.27
	t-2	$-0.51*10^{-4}$	-0.27	$-0.22*10^{-4}$	-0.27	$-0.22*10^{-2}$	-0.40
	t-3	$0.24*10^{-3}$	1.43	$0.59*10^{-4}$	0.79	0.012	2.63
	cumulative daily	$0.22*10^{-4}$	1.23	$0.11*10^{-4}$	0.85	$0.92*10^{-3}$	1.29
Unexpected intervention (Uint)	t-1	$0.22*10^{-3}$	0.72	$0.22*10^{-3}$	0.82	$0.62*10^{-2}$	0.74
	t-2	$0.50*10^{-3}$	0.21	$-0.58*10^{-4}$	-0.45	$-0.29*10^{-2}$	-0.32
	t-3	$-0.14*10^{-3}$	-0.99	$-0.75*10^{-4}$	-1.12	$-0.60*10^{-2}$	-0.79
	t-4 to t-6	$0.21*10^{-3}$	2.21	$0.87*10^{-4}$	1.77	$0.58*10^{-2}$	1.55
	t-7 to t-9	0.00	0.00	$-0.70*10^{-5}$	-0.16	$0.28*10^{-2}$	1.36
	t-10 to t-12	$0.17*10^{-3}$	1.44	$0.10*10^{-3}$	1.14	$0.26*10^{-2}$	0.96
	cumulative daily	$-0.15*10^{-4}$	-0.84	$-0.12*10^{-4}$	-1.43	$0.27*10^{-3}$	0.26

Table 5: Summary results for unexpected intervention variables with sequencing effect and extended sample

Effect of unexpected intervention (Uint)		**Abs. normalized returns (ABS)**		**Sqr. normalized returns (SQR)**		**Log. normalized returns (LOG)**	
		Coefficient	**T-statistic**	**Coefficient**	**T-statistic**	**Coefficient**	**T-statistic**
DAY1	t-1 to t-3	$-0.29*10^{-6}$	-0.29	$-0.91*10^{-6}$	-0.02	-0.01	-5.14
	t-4 to t-6	$0.10*10^{-3}$	0.84	$0.13*10^{-4}$	0.35	$0.41*10^{-2}$	0.55
	t-7 to t-9	$0.13*10^{-3}$	0.88	$0.52*10^{-4}$	1.17	$0.67*10^{-2}$	2.01
	t-10 to t-12	$0.96*10^{-5}$	0.17	$-0.36*10^{-5}$	-0.22	$-0.22*10^{-2}$	-0.34
	cumulative daily	$-0.29*10^{-4}$	-3.41	$-0.18*10^{-4}$	-3.86	$0.99*10^{-3}$	2.33
DAY2&3	t-1 to t-3	$0.37*10^{-4}$	0.52	$0.51*10^{-6}$	0.02	$0.23*10^{-2}$	0.69
	t-4 to t-6	$0.24*10^{-3}$	2.70	$0.11*10^{-3}$	3.09	$0.62*10^{-2}$	1.84
	t-7 to t-9	$-0.46*10^{-4}$	-0.93	$-0.25*10^{-4}$	-2.40	$0.18*10^{-2}$	1.09
	t-10 to t-12	$-0.51*10^{-5}$	-0.15	$-0.23*10^{-4}$	-1.44	$0.56*10^{-2}$	2.63
	cumulative daily	$-0.32*10^{-4}$	-1.56	$-0.18*10^{-4}$	-2.44	$-0.12*10^{-2}$	-0.78
DAY4+	t-1 to t-3	$0.67*10^{-3}$	2.51	$0.44*10^{-3}$	1.27	0.02	4.40
	t-4 to t-6	$0.24*10^{-3}$	0.74	$0.14*10^{-3}$	0.63	$0.47*10^{-3}$	0.40
	t-7 to t-9	$-0.48*10^{-3}$	-3.07	$-0.28*10^{-3}$	-3.97	$-0.52*10^{-2}$	-0.63
	t-10 to t-12	$0.12*10^{-2}$	1.89	$0.80*10^{-3}$	1.47	0.01	1.00
	cumulative daily	$-0.68*10^{-6}$	-0.01	$-0.24*10^{-5}$	-0.49	$0.69*10^{-3}$	0.39

References

Aguilar, J. and S. Nydahl. 1998. "Central Bank Intervention and Exchange Rates: The Case of Sweden." Sveriges Riksbank Working Paper Series No. 54.

Andersen, T. and T. Bollerslev. 1996. "DM-dollar volatility: intraday activity patterns, macroeconomic announcements, and longer run dependencies." NBER Working Paper No. 5783.

———. 1997. "Intraday periodicity and volatility persistence in financial markets." *Journal of Empirical Finance* 4(2/3): 115–159.

———. 1998. "Answering the Critics: Yes, ARCH Models provide Good volatility Forecasts." Paper presented at the Econometric Society Annual Meeting in Chicago, January.

Baillie, R. and T. Bollerslev. 1991. "Intra-day and inter-market volatility in foreign exchange rates." *Review of Economic Studies* 58(3): 565–585.

Baillie, R. and O. Humpage. 1992. "Post-Louvre intervention: Did target zones stabilize the dollar?" Federal Reserve Bank of Cleveland Working Paper No. 9203.

Bollerslev, T. and I. Domowitz. 1993. "Trading patterns and prices in the interbank foreign exchange market." *Journal of Finance* 48(4): 1421–43.

Bonser-Neal, C. and G. Tanner. 1996. "Central bank intervention and the volatility of foreign exchange rates: evidence from the options market." *Journal of International Money and Finance* 15(6): 853–78.

Chang, Y. and S. Taylor. 1998. "Intraday effects of foreign exchange intervention by the Bank of Japan." *Journal of International Money and Finance* 17(1): 191–210.

Connolly, R. and W. Taylor. 1994. "Volume and intervention effects on yen/dollar exchange rate volatility, 1977–1979." In *Advances in Financial Planning and Forecasting,* Vol. 5, Part A, edited by C. Lee, 181–200. Greenwich, Conn: JAI Press.

Dacorogna, M, U. Müller, R. Nagler, R. Olsen, and O. Pictet. 1993. "A geographical model for the daily and weekly seasonal volatility in the foreign exchange market." *Journal of International Money and Finance* 12(4): 413–438.

Dacorogna, M, U. Müller, O. Pictet and C. De Vries. 1994. "The Distribution of Extremal Foreign Exchange Rate Returns in Extremely Large Data Sets." Olsen and Assoc. Research Group. Preprint, June.

Dominguez, K. 1993. "Does central bank intervention increase the volatility of foreign exchage rates?" NBER Working Paper No. 4532.

———. 1996. "The International Evidence: An Assessment of Experience with Foreign Exchange Intervention in the G-3." In *Exchange Rates and Monetary Policy: Proceedings of a conference held by the Bank of Canada, October 1996,* 363–406. Ottawa: Bank of Canada.

———. 1998. "Central bank intervention and exchange rate volatility." *Journal of International Money and Finance* 17(1): 161–90.

Drost, F. and T. Nijman. 1993. "Temporal Aggregation of GAR CH Processes." *Econometrica* 61(4): 909–27.

Drost, F. and B. Werker. 1996. "Closing the GARCH Gap: Continuous Time GARCH Modeling." *Journal of Econometrics* 74(1): 31–57.

Ederington, L. and J. Lee. 1993. "How markets process information: news releases and volatility." *Journal of Finance* 48(4): 1161–91.

———. 1996. "The creation and resolution of market uncertainty: the impact of information releases on implied volatility." *Journal of Financial and Quantitative Analysis* 31(4): 513–539.

Edison, H. 1993. "The effectiveness of central-bank intervention: a survey of the literature after 1982." Princeton University Special Papers in International Economics, No. 18.

Gallant, A. 1981. "On the bias in flexible functional forms and an essentially unbiased form: the Fourier flexible form." *Journal of Econometrics* 15(2): 211–45.

Gallant, A. 1982. “Unbiased determination of production technologies.” *Journal of Econometrics* 20(2): 285–323.

Goodhart, C., S. Hall, S. Henry, and B. Pesaran. 1993. “News Effects in a High-frequency Model of the Sterling–Dollar Exchange Rate.” *Journal of Applied Econometrics* 8(1): 1–13.

Goodhart, C. and T. Hesse. 1993. “Central bank forex intervention assessed in continuous time.” *Journal of International Money and Finance* 12(4): 368–89.

Goodhart, C., T. Ito, and R. Payne. 1996. “One day in June 1993: A study of the working of Reuters 2000-2 electronic foreign exchange trading system.” In *The Microstructure of Foreign Exchange Markets*, edited by J. Frankel, G. Galli, and A. Giovannini, 107–79. Chicago: University of Chicago Press.

Guillaume, D., M. Dacorogna, and O. Pictet. 1995. “On the intra-daily performance of GARCH processes.” Poster presented at the First International Conference on High Frequency Data in Finance, Zürich, March 29–31. Preprint by Olsen and Associates Research Group.

Harvey, C. and R. Huang. 1991. “Volatility in the Foreign Currency Futures Market.” *Review of Financial Studies* 4(3): 543–69.

Hung, J. 1997. “Intervention strategies and exchange rate volatility: a noise trading perspective.” *Journal of International Money and Finance* 16(5): 779–93.

Kaminsky, G. and K. Lewis. 1993. “Does Foreign Exchange Intervention Signal Future Monetary Policy?” Finance and Economics Discussion Series No. 93-1. U.S. Board of Governors of the Federal Reserve Board, Washington, D.C.

Klein, M. and E. Rosengren. 1991. “Foreign Exchange Intervention as a Signal of Monetary Policy.” *New England Economic Review* (May/June): 39–50.

Krugman, P. 1991. “Target zones and exchange rate dynamics.” *Quarterly Journal of Economics* 106(3): 669–82.

Levin, A., D. McManus, and D. Watt. “The information content of Canadian dollar futures options.” In *Information in Financial Asset Prices: Proceedings of a conference held by the Bank of Canada, May 1998.* Forthcoming in 1999.

Müller, U., M. Dacorogna, R. Olsen, O. Pictet, M. Schwarz, and C. Morgenegg. 1990. “Statistical study of foreign exchange rates, empirical evidence of a price change scaling law, and intraday analysis.” *Journal of Banking and Finance* 14(6): 1189–1208.

Müller, U., M. Dacorogna, and J. von Weizsacker. 1997. “Volatilities of different time resolutions - Analyzing the dynamics of market components.” *Journal of Empirical Finance* 4(2/3): 213–240.

Murray, J., S. van Norden, and R. Vigfusson. 1996. *Excess Volatility and Speculative Bubbles in the Canadian Dollar: Real or Imagined?* Technical Report No. 76. Ottawa: Bank of Canada.

Murray, J., M. Zelmer, and D. McManus. 1997. “The Effect of Intervention on Canadian Dollar Volatility.” In *Exchange Rates and Monetary Policy: Proceedings of a conference held by the Bank of Canada, October 1996,* 311–356. Ottawa: Bank of Canada.

Obstfeld, M. 1989. “The Effectiveness of Foreign-Exchange Intervention: Recent Experience.” NBER Working Paper No. 2796.

Payne, R. 1997. “Announcement Effects and Seasonality in the Intra-day Foreign Exchange Market.” Department of Economics and Financial Markets Group, London School of Economics. Manuscript.

Peiers, B. 1997. “Informed Traders, Intervention, and Price Leadership: A Deeper View of the Microstructure of the Foreign Exchange Market.” *Journal of Finance* 52(4): 1589–1614.

Phillips, L. and J. Pippenger. 1993. “Stabilization of the Canadian Dollar: 1975–1986.” *Canadian Journal of Economics* 26(2): 416–46.

Vigfusson, R. 1997. “Switching Between Chartists and Fundamentalists: A Markov Regime-Switching Approach.” In *Exchange Rates and Monetary Policy: Proceedings of a conference held by the Bank of Canada, October 1996,* 221–48. Ottawa: Bank of Canada.

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