# Rules Versus Discretion in Foreign Exchange Intervention:
# Evidence from Official Bank of Canada High-Frequency Data

18 October 2004

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**Abstract**

The Bank of Canada is one of very few central banks that has kept records of the intraday timing of its intervention operations. This paper contains an empirical analysis of a high-frequency data-set of official Bank of Canada intervention data and exchange rates (quoted at the end of every 5-minute interval over a 24-hour period). The data-set covers the January 1995 to September 1998 period and is of particular interest as it spans over two distinctly different intervention regimes - a first regime characterized by purely rules-based ("mechanistic") intervention versus a second regime characterized by both rules-based and discretionary intervention. This unique feature of the data at hand allows for a test of the hypothesis that discretionary intervention is more effective than rules-based intervention. Additionally, the paper introduces the issue of currency co-movements to the intervention literature. Specifically, the analysis is carried out using both the readily observable CAD/USD exchange rate as well as the CAD/USD exchange rate adjusted for general currency co-movements against the USD. Employing an event-study methodology and different success criteria for investigating the effectiveness of sterilized intervention, we find that intervention does not systematically affect movements in the CAD/USD or reduce realized price volatility. This is the case for both rules-based and discretionary intervention. Our findings are robust across different criteria for what characterizes effectiveness, to changes in window length and to changes in the event definition itself. Furthermore, our findings are also robust to adjusting for currency co-movements.

# 1    Introduction

The growing literature on foreign exchange rate market microstructure has made important contributions towards a better understanding of how exchange rate markets process and react to new information.[1] Furthermore, market microstructure models incorporating central bank intervention have advanced our understanding of how central bank intervention may affect exchange rates.[2] In a recent contribution, Dominguez (2003b) expands the model by Bacchetta and van Wincoop (2003) to include interventions. She shows that only those interventions that provide information about future fundamentals should be expected to have long-term effects, while interventions providing "non-fundamentals" information may potentially exacerbate non-fundamentals driven exchange rate movements in the short run. An important implication of her analysis is that the short-run effects of intervention may differ from the long-run effects. Dominguez (2003b) notes that, in contrast to studies of long-term effects of intervention, empirical studies of intra-day effects of intervention generally find evidence that intervention matters.[3]

An interesting issue that has not been thoroughly addressed by the empirical intervention literature is whether rules or discretion matter in terms of intervention effectiveness. In this paper, we employ official, high-frequency (intra-day) data on Bank of Canada (BoC) intervention in the CAD/USD exchange rate market over the 1 January 1995 to 30 September 1998 period. The data-set covers two distinctly different BoC intervention regimes and contains unique information on whether intervention operations were discretionary or carried out in accordance with a rules-based ("mechanistic") policy framework. This "natural experiment" feature of the data at hand facilitates both a test of

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[1] See Evans and Lyons (2002) and Lyons (2001) for important contributions.
[2] See, for example, Dominguez (2003a), Evans and Lyons (2001) and Pasquariello (2001).

the hypothesis that discretionary intervention is more effective than rules-based and a general investigation of intra-day effects of intervention.

During the first regime, which ended on 11 April 1995, BoC intervention operations were very frequent as well as purely mechanistic. A CAD/USD exchange rate movement of a certain size would trigger intervention and, furthermore, appreciations and depreciations would generate the same response in absolute terms. On 12 April 1995, a new intervention program with both a mechanistic and a discretionary component was introduced, thus allowing for more flexibility with respect to timing as well as with respect to magnitude of interventions.[4] Accordingly, the data set allows for a distinction between interventions carried out under the pre- versus the post-April 1995 regime and, more importantly, between mechanistic and discretionary intervention operations.

An additional contribution of this paper is that we take into account the issue of currency co-movements. Eun and Lai (2004) point out that the issue of currency co-movement has not been given much attention by the academic literature. Not surprisingly, the issue has not been addressed in previous studies of intervention. However, currency co-movement is of potential importance to our study, especially since we are focusing on unilateral intervention conducted by a relatively small central bank and aimed at managing a minor currency vis-à-vis a major currency.[5] For example, if the USD is depreciating against not just the CAD but against other currencies in general following BoC purchases of CAD, there is little reason to believe that the USD depreciation against the CAD should

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[3] See Dominguez and Frankel (1993), Edison (1993), King (2003), and Sarno and Taylor (2001) for surveys of the intervention literature.

[4] In September 1998, the BoC abandoned the mechanistic component and retained only the discretionary part. The BoC has not intervened in the CAD/USD market since 17 September 1998, which is also the last intervention day in our sample.

[5] Canada is a small, open economy with spot turnover in its currency representing about 2% of total daily average foreign exchange turnover during the time-period under study (BIS 1999).

be ascribed to the unilateral BoC intervention event. We attempt to address this concern by carrying out the analysis using the readily observable or "raw" CAD/USD exchange rate as well as a "filtered" CAD/USD rate. The latter is calculated as the difference between the percentage change in the ("raw") CAD/USD rate and a weighted average of the percentage change in the three major exchange rates, that is the DEM/USD, JPY/USD and GBP/USD rates.

The BoC is to our knowledge one of only two central banks that has kept records of the intraday timing of its intervention operations.[6] However, the BoC data-set is not publicly available and only two internal studies (available as BoC working papers) have investigated the high-frequency BoC intervention data. Beattie and Fillion (1999) provide a time-series analysis of the effects of intervention on the implied volatility of CAD/USD exchange rate options over the 12 April 1995 to 30 January 1998 time-period. They find that mechanistic intervention was widely anticipated by the market and had no impact on volatility, and some evidence that discretionary intervention was unanticipated and associated with a short-term decrease in volatility.[7] In the second study using the high-frequency BoC intervention data, D'Souza (2002) incorporates both intervention data and data on BoC transactions aimed at replenishing reserves in order to test market microstructure hypotheses. He finds that foreign exchange traders treat a central bank intervention operation as any other customer order and suggests that, in order to be effective, central banks must be able to forecast overall net customer trades at the time of intervention.

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[6] The other central bank is the Swiss National Bank.
[7] These findings are consistent with Murray, Zelmer and McManus (1996), who analyze official daily BoC intervention data over a time-period covering both intervention regimes. For other daily data studies of BoC intervention see also Phillips and Pippenger (1993) and Rogers and Siklos (2003). These two studies do not employ official BoC intervention data.

Two recent studies of official, high-frequency Swiss National Bank intervention data are of particular relevance to this study, both in terms of findings and methodology. Fischer and Zurlinden (1999) focus on (scaled) exchange rate changes measured between consecutive interventions and use an irregular time-series model as the foundation for their analysis. They find that only initial interventions matter while subsequent interventions are ineffective. In a recent contribution, Payne and Vitale (2003) extend the analysis conducted by Fischer and Zurlinden (1999). Within the context of an event study approach, they find some evidence of a systematic link between intervention and both exchange rate returns and volatility. In particular, they show that intervention operations have short-run effects on the CHF/USD exchange rate lasting from 15 minutes to up to two hours following intervention. Payne and Vitale (2003) also find that intervention has a stronger impact when the Swiss National Bank moves with-the-market ("leaning with the wind") and when its intervention is concerted with other central banks.

We follow recent papers by Fatum (2000), Fatum and Hutchison (2002, 2003), Payne and Vitale (2003) and others in employing an event study methodology for analyzing the effects of intervention on exchange rates.[8] In our context of analyzing exchange rate movements around high-frequency intervention events, spot exchange rates quoted at the end of every 5-minute interval over a 24-hour period are investigated. Specifically, we examine 5 through 120 minute windows around clusters of intraday intervention transactions and, consistent with Fatum and Hutchison (2003), assess the effectiveness of intervention according to three different criteria for what may constitute effectiveness.

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[8] An event study is a very general test of a specific hypothesis and does not rely on a structural model of exchange rate determination. This is a desirable feature given the lack of consensus

In contrast to existing intra-day intervention studies, we do not detect any significant effects of BoC intervention. Intervention does not systematically affect the ("raw") CAD/USD exchange rate over the 5 through 120 minutes succeeding an intervention event. This finding is robust across different success criteria, changes in window length and changes in the event definition itself. The analyses of separate sub-samples of mechanistic and discretionary intervention events yield qualitatively identical results, both rejecting that intervention has immediate effects. Carrying out the analysis using the CAD/USD exchange rate adjusted for currency co-movements (the "filtered" rate) confirms that BoC intervention over the period under study had no detectable effects.

The rest of the paper is organized as follows. The next section provides an overview of institutional aspects of BoC intervention pertaining to the period under study. Section 3 presents the data. Section 4 discusses the event study methodology and the criteria for assessing effectiveness. Section 5 presents the results and section 6 concludes the paper.

## 2.      Institutional Aspects

The BoC intervenes in the CAD in its capacity of fiscal agent for the Government of Canada. In order to do so, the BoC uses the Government's foreign exchange reserves, held in the Exchange Fund Account. In accordance with the Canadian Currency Act, foreign exchange reserves may be used to protect the external value of the monetary unit of Canada. With respect to foreign exchange intervention, this mandate has been interpreted to mean maintaining an orderly market for the CAD, i.e. BoC intervention is aimed at

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over the appropriate structural exchange rate model, but the drawback is that the particular channel of transmission (if intervention is effective) is not identified.

smoothing (intraday) movements of the exchange rate and providing liquidity to the foreign exchange market when needed.

BoC intervention in the CAD/USD exchange rate market is unilateral (in particular, the US Fed is not intervening in the CAD/USD market) and characterized as "leaning against the wind" in the sense that CAD are bought (sold) when the CAD depreciates (appreciates) against the USD. All BoC intervention operations are sterilized on a daily basis.

During the 1995 to 1998 period, intervention in the CAD/USD exchange rate typically took place during North American market hours from 8:00 a.m. to 4:00 p.m. EST, with some instances of intervention continuing overnight during European market hours.[9] Intervention was passive, with the BoC leaving offers to buy and sell CAD rather than hitting bids.

The period under study features two distinct intervention regimes. A rules-based regime characterized by a mechanical – and therefore predictable – response to exchange rate movements was in place until 12 April 1995. During this regime, the BoC determined when to intervene by monitoring a 100-basis point "non-intervention" band. When the exchange rate breached one end of this band, intervention operations (in terms of USD purchases or sales against CAD) were conducted at pre-set levels of intensity, with intensity measured by the amount of intervention that occurred for each basis point change in the CAD/USD. The standard amount was CAD 4 million per basis point.[10] The non-intervention band was dragged or "ratcheted" in the direction that intervention occurred

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[9] If the currency continued to move in one direction at the end of the North American trading hours, the BoC would leave instructions with a European agent, typically the Bank of England, in order for the agent to carry out intervention on behalf of the BoC.

[10] In case of a highly volatile exchange rate market, the intensity of intervention was increased to CAD 6 or CAD 8 million per basis point.

according to the amount and intensity of the most recent intervention operation. Under this mechanistic framework, intervention was persistent and would continue until the CAD/USD reversed direction and moved back inside the non-intervention band. As a result, the BoC intervened on average on almost every other business day during this regime.[11]

On 12 April 1995, a revised intervention regime was introduced. It was designed to increase the "signaling" effect of intervention by reducing its frequency, increasing its magnitude, allowing for more discretion with respect to its timing, and raising the visibility when it occurred.[12]

Specifically, the non-intervention band was widened to 140 basis points and was rebased daily around the 4:00 p.m. EST North American closing exchange rate. The daily rebasing reduced the frequency of intervention to less than 10% of business days by 1996, as the currency would have to move by 70 basis points in either direction following rebasing before new intervention would occur. The visibility of intervention was increased by increasing the standard intensity of intervention to CAD 8 million per basis point. Furthermore, intervention was primarily conducted through foreign exchange brokers, who were instructed to announce BoC intervention as soon as the first transaction of the day had been completed.

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[11] Intervention during this period was typically conducted directly with dealers at the major chartered banks who were instructed to keep the intervention activity secret.

[12] The change in intervention policy followed a major review of the purely mechanistic intervention regime and reflected the growth of the currency markets as well as the state of the academic literature on intervention. The BoC addressed the change in a letter sent to foreign exchange market participants on 5 April 1995: "…[The] conclusions of this work support the idea that foreign exchange market intervention is most useful when used as a signaling tool. Our analysis of the current intervention techniques we use is that they are not as effective as they could be in this regard. This is largely because the frequency of our intervention tends to reduce the "newsworthiness" of the fact that we are in the market. Also, given the volumes in today's market, the intensity of our current intervention probably adds little in terms of enhancing market liquidity." (Letter from Don Stephenson, Associate Adviser, Bank of Canada.)

Finally, the revised framework introduced greater discretion, although mechanistic elements were maintained. The wider non-intervention band continued to be dragged up or down intraday in response to each intervention operation. However, the timing of intervention could be varied to allow the BoC to intervene earlier and with greater intensity in response to what were believed to be destabilizing movements of the exchange rate. During such turbulent periods, the non-intervention band could be reset at half the distance from its normal setting, allowing the BoC to intervene sooner, and the intensity of intervention could be increased as the situation demanded. A decision to reset the band in this fashion was initiated by the BoC and authorized by the Department of Finance.

See Chiu (2003), D'Souza (2002), and Murray, Zelmer, and McManus (1996) for additional details on the BoC intervention framework during the 1995 to 1998 period.

## 3. Data

This study uses non-public, high-frequency (intraday) intervention data, provided by the BoC. The data set contains information on each individual intervention transaction, including the date, the time and the transaction size.

During the full sample period, 2 January 1995 to 30 September 1998, the BoC carried out 1530 intervention transactions on a total of 132 days, representing 13% of business days. 371 of these transactions (on a total of 40 days) took place during the intervention program that ended on 11 April 1995.

The individual intervention transactions ranged from USD 2 million to USD 138 million in magnitude, with an average amount of USD 18 million and a median amount of

USD 20 million.[13] On intervention days, an average of 21 transactions occurred, with the number of transactions ranging from a low of one to a high of 83 (on 7 August 1998). The amount traded on intervention days ranged from USD 5 million to USD 1.2 billion, with a mean of USD 380 million and a median of USD 300 million

Table 1 provides descriptive statistics on the high-frequency intervention data-set. Panel A shows that a total of 1,530 intervention transactions (of which 1132 involved CAD purchases) occurred during the period under study. A total of 694 of these transactions were discretionary while the remaining 836 transactions were carried out in accordance with the mechanistic policy framework. Panel B shows that nearly 40% of these 1,530 transactions took place in 1995, nearly 6% took place in 1996, about 23% took place in 1997, and almost 31% took place in 1998. Interventions that occurred due to a mechanical rebasing of the non-intervention band dominated in 1995, while the number of discretionary interventions increased steadily from 1996 and onwards. Comparing the last two columns of panel B shows that the number of purchases and sales were largely balanced in 1995, while the ratio of purchases to sales increased dramatically over the last three years in the sample. Panel C shows that the magnitude of most individual transactions were less than USD 30 million, and, furthermore, that CAD purchases were, on average, of a larger magnitude than CAD sales.

The analysis relies on high-frequency (intra-day) exchange rate data purchased from Olsen and Associates. This data provides the spot exchange rate at the end of every 5-minute interval over a 24-hour period for the CAD/USD, DEM/USD, GBP/USD and JPY/USD exchange rates. Specifically, the bid and offer rates are provided for intervals

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[13] Transaction size may contain only little information, as intervention transactions conducted through foreign exchange brokers were often bundled together to reduce the number of individual

where an actual trade takes place, while a representative quote is used for other periods. There is practically no time-variation in the bid-ask spreads and we focus our analysis on the bid rates.

The evolution of the intervention variable against the CAD/USD exchange rate is displayed in Figure 1. Figure 2 shows the CAD/USD juxtaposed against an equally-weighted basket of the DEM, the GBP and the JPY vis-à-vis the USD, with all exchange rates indexed to 100 at the beginning of the sample period.

## 4. Methodology

The starting point for an event study is to define the event of interest and to identify the periods over which the security price is examined (the "event windows").[14] In this context, the event is defined as a cluster of intervention transactions and the event windows are the pre- and post-event minutes during which the CAD/USD exchange rate movements are analyzed.

Specifically, an event is defined as a cluster of individual intervention operations in the CAD/USD exchange rate market in one direction (in terms of purchases or sales), interspaced by at most 30 minutes of no intervention operations (the "tranquility" period that can be allowed for while still considering the surrounding intervention transactions to be part of one and the same event). Given the frequency and structure of the intervention data at hand, we adjust the methodology of Fatum (2000) and Fatum and Hutchison (2002, 2003) to accommodate the analysis of intervention data captured at this higher

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trade "tickets". The event study methodology employed in this study does not rely on information regarding transaction size.

[14] For a detailed description of the event study methodology applied to the analysis of daily data on foreign exchange market intervention, see Fatum (2000) and Fatum and Hutchison (2002, 2003).

frequency, and employ a "tranquillity" period of 30 minutes for our baseline results (and vary this number in the robustness checks). To be consistent with the high-frequency analysis presented in Payne and Vitale (2003), pre- and post-event window lengths of 5 through 120 minutes are applied.[15]

As noted by, for example, Dominguez and Frankel (1993) there is no convention on what constitutes successful intervention. We follow Fatum and Hutchison (2002, 2003) and apply three alternative criteria of success. The first criterion of success is simply whether the direction of the movement in the exchange rate is the same as the direction in which the BoC was intervening, e.g. does the value of the CAD relative to the USD increase after CAD are purchased? This measure of successfulness is referred to as the "direction" criterion and is formally expressed as follows: An event is a success if either

$$\{E_i > 0 \text{ and } \Delta s_{i+} > 0\} \text{ or } \{E_i < 0 \text{ and } \Delta s_{i+} < 0\}$$

where $E_i$ is the total amount of central bank intervention (positive values represent purchases of USD, negative values represent sales of USD) during event i and $\Delta s_{i+}$ is the CAD/USD exchange rate change (in %) during the associated post-event window.

As previously noted, the stated motivation for Bank of Canada intervention is to maintain orderly markets, thus it may be the case that intervention operations are carried out for the purpose of smoothing exchange rate movements or reducing exchange rate volatility, rather than for affecting the direction of exchange rate movements.

The second criterion defines a successful event as one where intervention is associated with a smoothing of the exchange rate movement. This criterion is formally

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[15] Additionally, the window lengths are not expanded beyond 120 minutes in order to eliminate

expressed as follows: An event is a success according to the "smoothing" criterion if either

{the event is a success according to the "direction" criterion} or

{$E_i > 0$ and $\Delta s_{i+} > \Delta s_{i-}$} or {$E_i < 0$ and $\Delta s_{i+} < \Delta s_{i-}$}

where $\Delta s_{i-}$ is the CAD/USD exchange rate change (in %) during the associated pre-event window.

The third criterion of success compares the (realized) variance of the CAD/USD exchange rate preceding and succeeding each event, respectively, and associates reduced volatility after relative to before the event with success. This criterion is formally expressed as follows: An event is a success according to the "volatility" criterion if

{$\sigma^2_{i+} < \sigma^2_{i-}$}

where $\sigma^2_{i+}$ ($\sigma^2_{i-}$) denotes the realized post-event variance (pre-event variance) of the CAD/USD exchange rate. More specifically, we use the high-frequency exchange rate data for calculating the variance of the CAD/USD exchange rate during the 30, 60, 90 and 120 minutes preceding and succeeding each event, in order to facilitate the comparison of volatility patterns around each of the events.

Three statistical tests are employed. The main test is the non-parametric sign test for the median. This test verifies whether the observed number of successes based on the

instances of pre- and post-window overlaps.

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"direction" (appreciation or depreciation), the "smoothing" (appreciation/smaller depreciation or depreciation/smaller appreciation), and the "volatility" (decreased or not) criteria are random or systematic.

With reference to the "direction" criterion for success, the null-hypothesis is that the probability of observing a positive value ("success") is the same as that of observing a negative value ("no-success"), hence the underlying probability parameter is 0.5. In other words, the random variable X (equal to the number of positive values or "successes") among n sample observations has a binomial distribution with $\mu = 0.5$. A significant sign test indicates that the observed number of successes is not a random finding attributable to the equal probability of appreciation or depreciation. For details on this test in event studies, see MacKinlay (1997).[16]

In addition, the non-parametric rank test and the matched sample (difference-in-means) tests are employed. The matched sample test is only associated with the "smoothing" criterion as it indicates, at the minimum, smaller post-event CAD depreciation or appreciation. Since both additional tests confirm the results based on the sign test, only sign test results are reported.[17]

## 4.1   Currency Co-Movements

Eun and Lai (2004) document systematic co-movement patterns across several currencies, in particular vis-à-vis the USD and to a lesser extent vis-à-vis the EUR. They find evidence that currency co-movement is significantly driven by "the competitive influence"

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[16] See Fatum (2000) for a discussion of the choice of probability parameters associated with the "direction" and the "smoothing" criteria for success.
[17] For details on the rank test in event studies, see Cambell and Wasley (1993) and MacKinley (1997). See, for example, Ben-Horim and Levy (1984, p. 458) for details on the matched sample test and Fatum and Hutchison (2002, 2003) for applications.

of major currencies on minor ones.[18] The issue of currency co-movement is of potential importance to the analysis of effectiveness of intervention, in particular as we are focusing on unilateral intervention conducted by a minor central bank and aimed at managing a minor currency vis-à-vis a major currency.

For example, an appreciation of the CAD against the USD following a BoC intervention event characterized by CAD purchases will appear effective according to the "direction" criterion described above. However, if the USD is depreciating against not just the CAD but against other currencies in general, there is little reason to believe that the USD depreciation should be ascribed to the unilateral BoC intervention transactions.

In order to make an attempt at addressing this concern, we carry out the analysis of effectiveness on a "filtered" CAD/USD exchange rate as well as on the readily observable or "raw" CAD/USD rate. The "filtered" exchange rate measure is calculated as the difference between the percentage change in the ("raw") CAD/USD rate and a weighted average of the percentage change in the GBP/USD, DEM/USD and JPY/USD exchange rates.[19]

## 5        The Results of the High-Frequency Event Study

Using the baseline event definition that allows for a maximum of 30 minutes of no-intervention while still considering the surrounding intervention transactions to be part of one and the same event, we identify 321 separate BoC intervention events, 270 of which occurred within market hours (EST). The timing of the intervention transactions carried

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[18] As pointed out by Eun and Lai (2004), despite the vast research in co-movement of other asset prices such as bonds and stocks, the potentially highly important issue of currency co-movement has not been given much attention in the academic literature.

out within market hours is known to us, while this is not the case for the transactions that took place outside of North American market hours. Therefore, in order to fully utilize our knowledge of the timing of intervention transactions and, subsequently, the timing of the events, we focus the analysis on the 270 events that took place within market hours.

By construction of the event definition itself, each of these events are characterized as either a CAD purchases or a CAD sales event and, furthermore, each of these events are well-defined with respect to the timing of start and finish. Therefore, for each event it is straightforward to calculate the associated pre- and post-event exchange rate changes and volatilities separately for each of the 24 different window lengths (5 through 120 minutes). This, in turn, enables us to classify each event as successful or not according to each of the three criteria for success, separately across each of the 24 windows lengths.[20]

## 5.1     Direction Results

Figure 3 displays the results from the sign test based on the "direction" criterion with the underlying probability parameter of 0.50 across all window lengths (5 through 120 minutes). For all figures 3.1 through 3.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95% significance level. Figure 3.1 summarizes the findings based on all 270 events and the "raw" CAD/USD exchange rate while figure 3.2 summarizes the findings based on the same 270 events and the "filtered" CAD/USD rate. Although the number of successes is higher when analyzing the "filtered" exchange rate, the findings are robust to this adjustment for currency co-movements as

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[19] As an additional robustness check, we vary the weights when calculating the "filtered" exchange rate. Our findings are not affected by this change, thus only the results based on equal weights are reported.
[20] Due to the non-public nature of the BoC intervention data, the intervention volumes and the exact timing of events are not displayed.

none of the bars in either figure reach (or exceed) the horizontal line (at 150 successes out of 270). Therefore, the null hypothesis that the observed number of successes is random is accepted (separately) for each window length.

As pointed out earlier, the sample period under study is of particular interest, as it comprises two intervention regimes, the first characterized by mechanistic intervention and the second characterized by both mechanistic and discretionary intervention. In order to investigate whether mechanistic and discretionary intervention events affect the market differently, we redo the analysis on sub-samples of events associated with mechanistic intervention and events associated with discretionary intervention separately.[21]

Figures 3.3 and 3.4 show the results of the analysis of the 145 mechanistic events using the "raw" CAD/USD and the "filtered" CAD/USD exchange rate, respectively. None of the bars reach the horizontal line (at 83 successes out of 145). Figures 3.5 and 3.6 show the results based on the discretionary events using the "raw" CAD/USD and the "filtered" CAD/USD exchange rate, respectively. Again, none of the bars reach the horizontal line (at 73 successes out of 125). These findings suggest that BoC intervention had no immediate impact on the CAD/USD exchange rate, regardless of whether the intervention events were mechanistic or carried out with discretion.

5.2     Smoothing Results

Figure 4 displays the results based on the "smoothing" criterion and the sign test with the underlying probability parameter of 0.75 across all window lengths. Figures 4.1 and 4.2 summarize the findings based on all 270 events and the "raw" CAD/USD and the "filtered

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[21] Events containing both mechanistic and discretionary intervention transactions are classified as discretionary. Alternatively, dropping these "mixed" events from the analysis does not affect the results.

CAD/USD exchange rate, respectively. Although the observed number of successes is generally higher than the observed number of successes according to the "direction" criterion, by construction of the "smoothing" criterion that embodies the "direction" criterion, so is the number of successes necessary in order to reject the null hypothesis of randomness. Both figures show that there are no cases where the number of successes reaches the horizontal 95% significance bar (at 215 successes out of 270). Figures 4.3 and 4.4 (figures 4.5 and 4.6) display the results based on the 145 (125) mechanistic (discretionary) events and at no window length is the null hypothesis of randomness rejected.

5.3     Volatility Results

Figure 5 displays the results from the comparison of pre-event versus post-event volatility across window lengths of 30, 60, 90, and 120 minutes. In this context, the sign test determines whether the observed number of events associated with decreased CAD/USD volatility is random or systematically associated with intervention events. Since the test has an underlying probability parameter of 0.50, the horizontal 95% significance lines for all figures 5.1 through 5.6 are (pair wise) identical to the significance lines for the sign test results of the "direction" criterion, as displayed in figures 3.1 through 3.6.

Figures 5.1 through 5.6 all show that the number of events associated with decreased post-event volatility is too small to question randomness, implying that volatility patterns within the first two hours around the described events are not systematically affected by intervention. In particular, none of the bars displayed in these figures reaches the 95% significance line, regardless of window length, currency co-movement adjustment

or not, and regardless of whether the analysis is carried out separately on mechanistic and discretionary intervention events.[22]

5.4     Monetary Policy Changes and USD Intervention by Other Central Banks

As mentioned by Fatum and Hutchison (2002) and others, the event study methodology assumes that intervention defines the event and is not systematically related to other relevant economic news such as monetary policy changes or USD intervention by other central banks. This is, of course, a concern in all event studies and it is of concern in this context where several events last for several hours.

In order to address this concern, we redo the analysis of sections 5.1 through 5.3 on sub-samples of events that do not occur on days coinciding with a monetary policy change in either Canada or the United States. Table 2 shows that there are only 13 days over the nearly four-year period under study when intervention occurred on a day when the BoC changed the target for the overnight interest rate.[23] There are no cases of CAD/USD intervention coinciding with changes in US monetary policy. The results described above are robust to the exclusion of the high-frequency events occurring on days when the BoC made monetary policy changes.

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[22] Given that the observed number of events associated with decreased post-event volatility is consistently smaller than the number of events associated with increased post-event volatility across all window lengths and, furthermore, some studies find that intervention is systematically associated with increased volatility (see Galati, Melick and Micu, forthcoming, for a recent discussion), we also test for this possibility. We find, however, that the number of events associated with increased volatility is, once again, random, thus further confirming that the observed volatility patterns within the first two hours around the intervention events are not affected by intervention.

[23] During our sample period, there were 28 days when the Canadian overnight rate target changed.

Intervention in the DEM/USD or the JPY/USD by other major central banks coincides with 4 days of BoC intervention. Dropping the associated high-frequency events from the analysis does not impact the results.

As a methodological robustness check, the baseline event definition is changed and the analysis of sections 5.1 through 5.3 redone. Specifically, an event is redefined as a cluster of individual intervention operations in one direction, interspaced by at most 60 (instead of 30) minutes of no intervention operations. Using this slightly altered event definition, 220 (instead of 270) within market hours events are identified. The analysis of these 220 events, including separate analyses of mechanistic and discretionary events, yields qualitatively identical results as the analysis of the 270 baseline events.

## 6.    Conclusion

This paper investigates the effectiveness of sterilized intervention in the CAD/USD exchange rate from 1995 to 1998, using official intervention data provided by the BoC. The data set is unique as it consists of high-frequency (intraday) data with information on the timing and magnitude of each intervention transaction. The time period studied covers two distinct intervention regimes – an earlier mechanistic regime where intervention was frequent and widely anticipated, and a revised regime that introduced more discretion on the timing of intervention, increased the intensity as well as heightened the visibility of intervention.

We use an event study framework for analyzing the effects of intervention on exchange rates and control for currency co-movements by carrying out the analysis on a readily observable or "raw" CAD/USD exchange rate as well as on a "filtered" CAD/USD exchange rate. The latter is calculated as the difference between the percentage change in

the ("raw") CAD/USD rate and a weighted average of the percentage change in the GBP/USD, DEM/USD and JPY/USD exchange rates. To our knowledge, no previous study has introduced the issue of currency co-movements to the intervention literature.

The presented findings strongly suggest that BoC intervention does not systematically affect the CAD/USD exchange rate. These findings are consistent across three different criteria for what constitutes effective intervention and across pre- and post-event windows ranging from 5 to 120 minutes. Importantly, our findings do not suggest that discretionary interventions were more effective than rules-based interventions. These findings are robust to adjustments for currency co-movements as well as to changes in the event definition itself.

Part of the explanation for why our findings reject any significant impact of BoC intervention may be that all BoC interventions - regardless of whether rules-based or discretionary - are carried out unilaterally and, by construction of the BoC intervention framework in place during the time-period under study, against-the-market ("leaning against the wind"). As noted earlier, Payne and Vitale (2003) find that Swiss National Bank intervention has a stronger impact when it is concerted and carried out with-the-market ("leaning with the wind"), thus our findings appear consistent with the implications of their study.

Sarno and Taylor (2001, p. 850) state that "[intervention] policies which are inconsistent with the underlying stance of monetary and fiscal policy are doomed to ultimate failure". Interestingly, comparing the direction of each intervention event (in terms of CAD purchases or sales) with the direction of the most recent BoC monetary policy change (in terms of tightening or loosening of monetary policy) points to a remarkably high number of events in the opposite direction of the most recent policy change. In fact, only

63% of the events over the 1995 to 1998 period were consistent with past monetary policy. This disconnect between exchange rate intervention and monetary policy may provide another important element in explaining why our findings so strongly reject that BoC intervention had any significant short-term impact on the CAD/USD exchange rate during the time-period under study.

As pointed out by Dominguez (2003b), however, short-run effects of intervention may differ from long-run-effects, in particular when interventions do not provide information about fundamentals. Our results reject that BoC intervention and intra-day exchange rate movements are systematically related, yet additional work is needed in order to address the issue of long-term impacts.

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Figure 1:    Intervention in the CAD and the CAD/USD rate
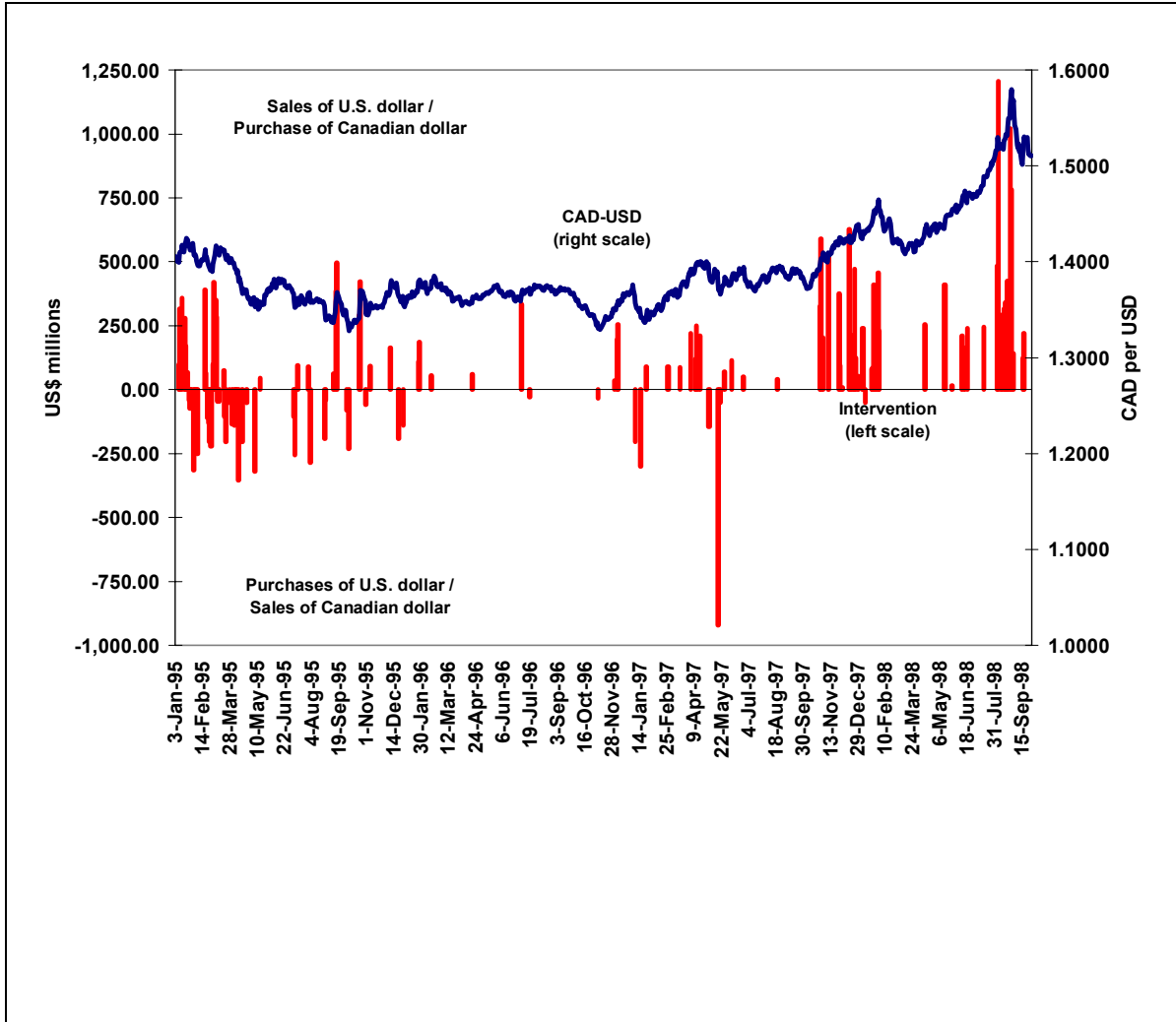
Figure 2:    Index of CAD versus Net Change in Basket of DEM, JPY and GBP (1 January 1995 = 100)

# Figure 3: Success of Intervention Based on "Direction" Criterion

This figure displays the results of the sign test based on the "direction" criterion with the underlying probability parameter of 0.50. Intervention is a success when the CAD/USD rate moves in the direction consistent with the intervention event. Each column represents the number of successes based on a different window length, ranging from 5 to 120 minutes. For all figures 3.1 through 3.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95% significance level.
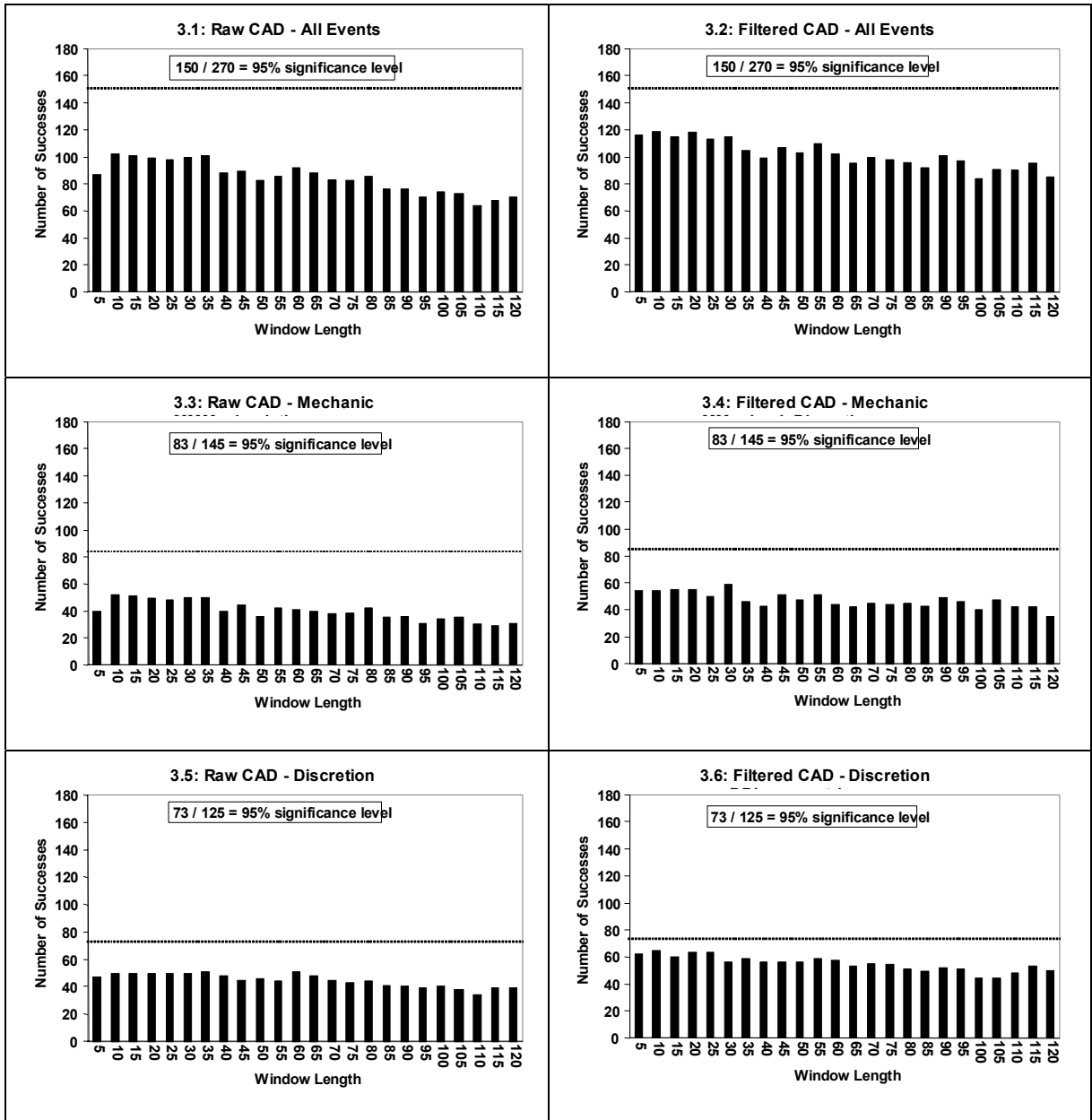
Figure 4: Success of Intervention Based on "Smoothing" Criterion

This figure displays the results of the sign test based on the "smoothing" criterion with the underlying probability parameter of 0.75. Intervention is a success when the CAD/USD rate changes direction consistent with intervention or the rate of change of the CAD/USD decreases following intervention. Each column represents the number of successes based on a different window length, ranging from 5 to 120 minutes. For all figures 4.1 through 4.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95% significance level.
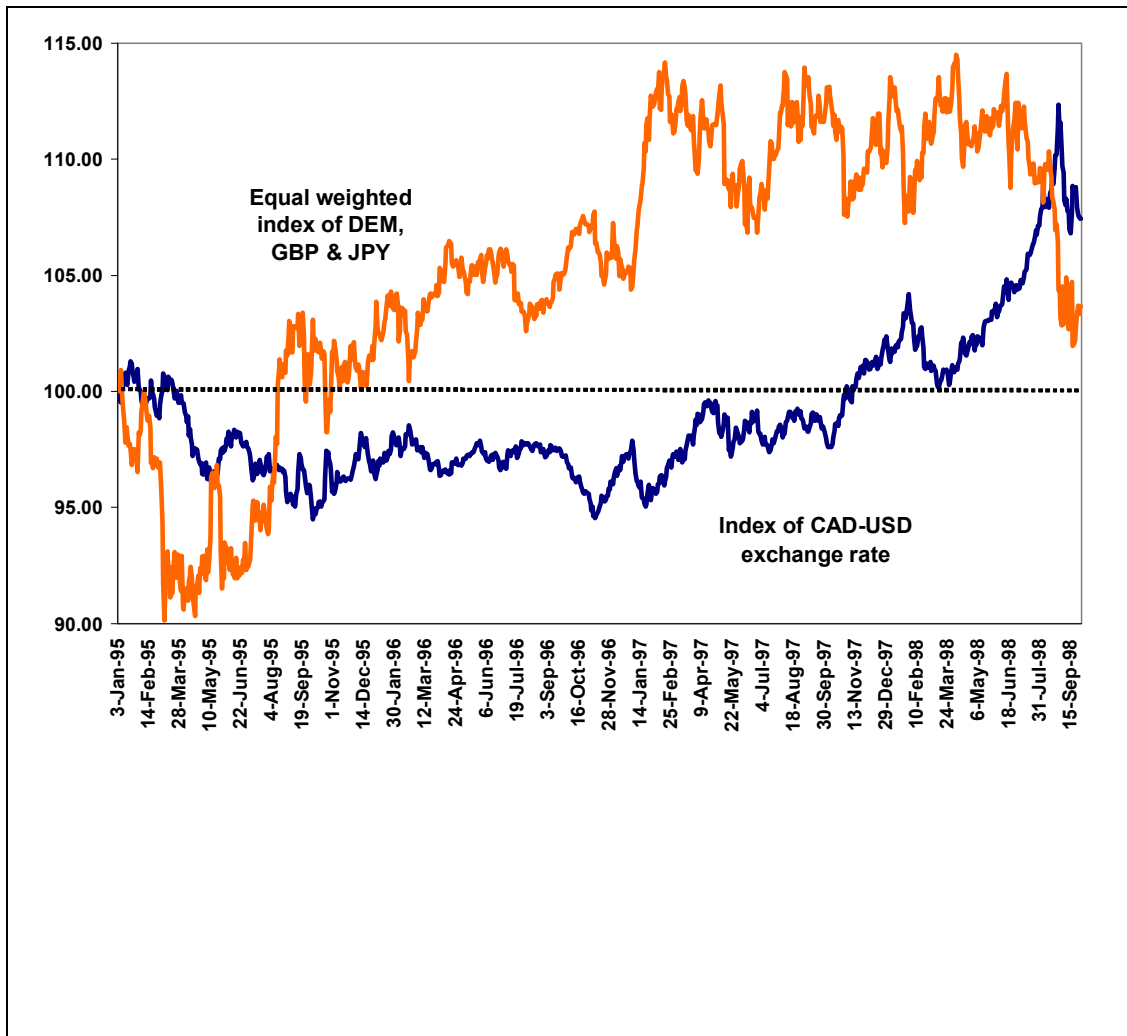
# Figure 5: Success of Intervention Based on "Volatility" Criterion

This figure displays the results of the sign test based on the "volatility" criterion with the underlying probability parameter of 0.50. Intervention is a success when volatility decreases from before to after the event. Each column represents the number of successes based on a different window length, ranging from ½ to 2 hours. For all figures 5.1 through 5.6, the horizontal line shows the number of successes necessary for rejecting randomness at the 95% significance level.
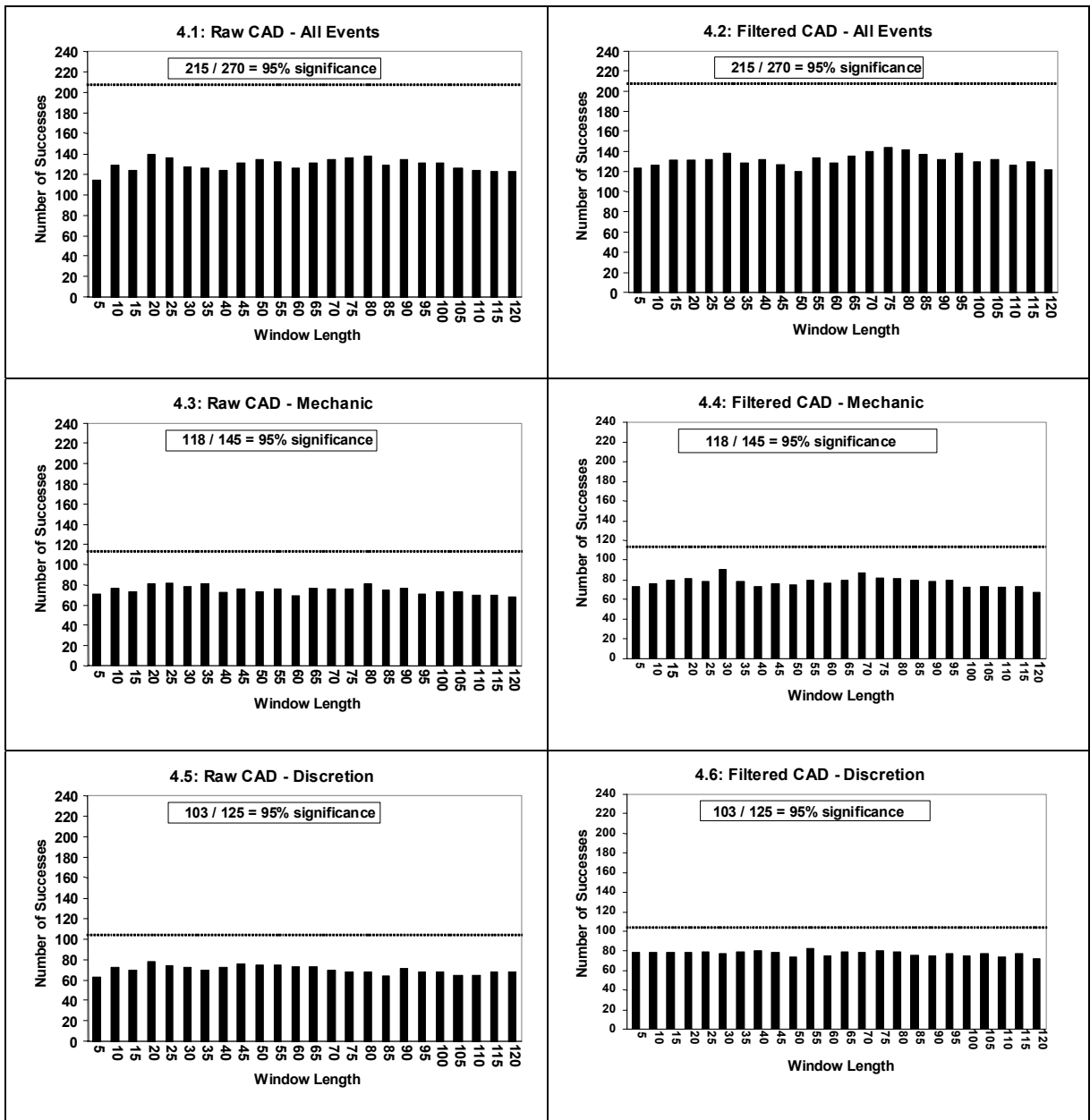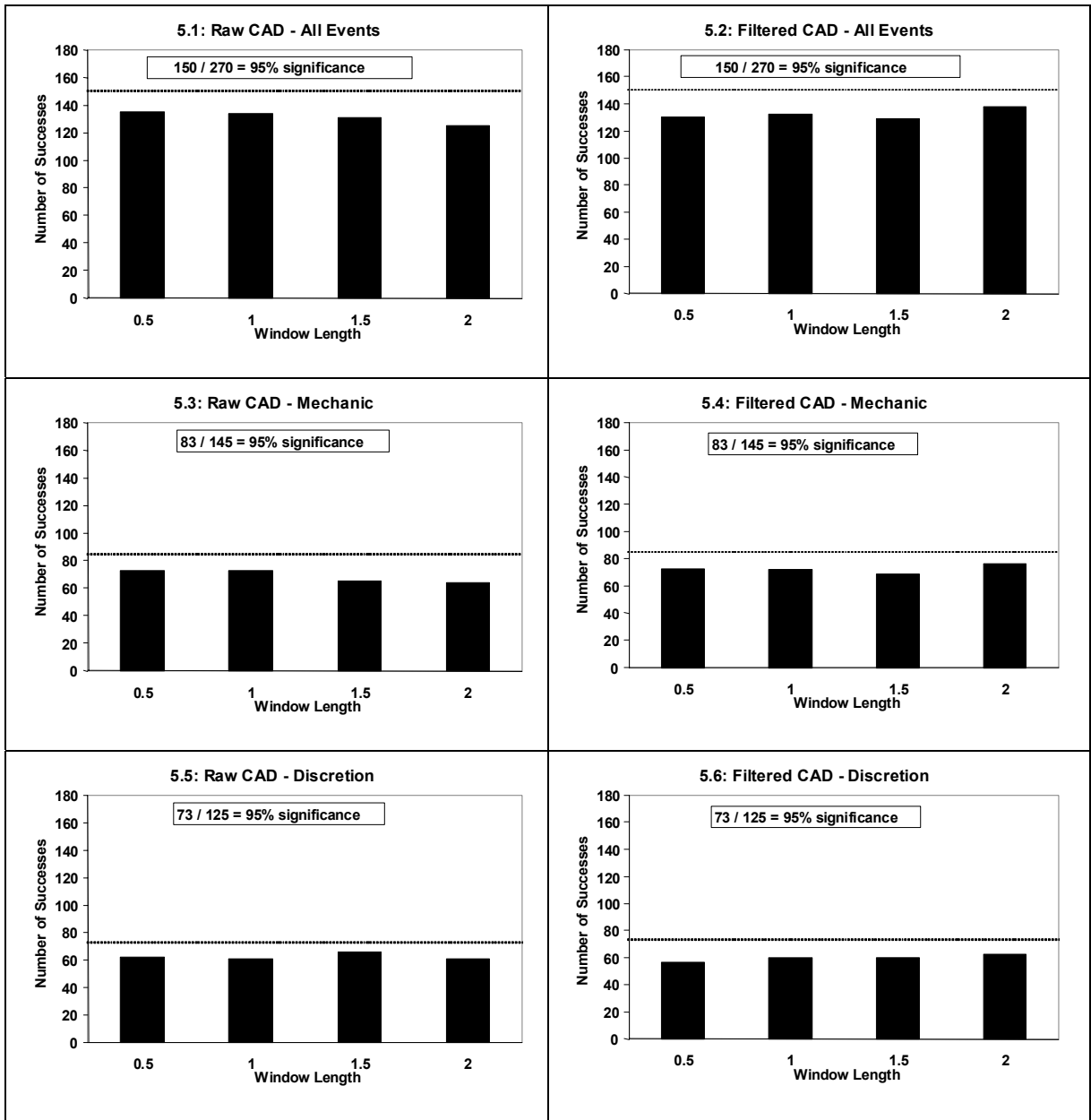
Table 1:     BoC Intervention from Jan 1995 to Sep 1998

Panel A: Overview of high-frequency (intraday) intervention transactions

|          | Mechanistic | Discretionary | Total | %     |
|----------|-------------|---------------|-------|-------|
| Buy CAD  | 444         | 688           | 1,132 | 74.0  |
| Sell CAD | 392         | 6             | 398   | 26.0  |
| Total    | 836         | 694           | 1,530 | 100.0 |
| %        | 54.6        | 45.4          | 100.0 |       |

Panel B: Frequency of high-frequency (intraday) intervention transactions

| Year  | No. transactions | % of total | No. of mechanistic | No. of discretionary | No. of buy CAD | No. of sell CAD |
|-------|------------------|------------|--------------------|----------------------|----------------|-----------------|
| 1995  | 611              | 39.9       | 611                | 0                    | 321            | 290             |
| 1996  | 90               | 5.9        | 41                 | 49                   | 77             | 13              |
| 1997  | 357              | 23.3       | 184                | 173                  | 268            | 89              |
| 1998  | 472              | 30.8       | 0                  | 472                  | 466            | 6               |
| Total | 1,530            | 100.0      | 836                | 694                  | 1,132          | 398             |

Panel C: Volume of high-frequency (intraday) intervention transactions (mill. USD)

|               | No. of trades | %   | No. of buy CAD | %   | Cum. Amount (mill. USD) | No. of sell CAD | %   | Cum. Amount (mill. USD) |
|---------------|---------------|-----|----------------|-----|-------------------------|-----------------|-----|-------------------------|
| <USD 10 mill. | 298           | 19  | 221            | 20  | 1,103.1                 | 77              | 19  | 386.0                   |
| USD10-19 mill.| 463           | 30  | 370            | 33  | 3,942.5                 | 93              | 23  | 1,050.3                 |
| USD 20-29 mill.| 452          | 30  | 294            | 26  | 6,118.0                 | 158             | 40  | 3,297.0                 |
| USD 30-39 mill.| 148          | 10  | 99             | 9   | 3,031.0                 | 49              | 12  | 1,485.0                 |
| >USD 40 mill. | 169           | 11  | 148            | 13  | 6,901.0                 | 21              | 5   | 890.0                   |
| Total         | 1,530         | 100 | 1,132          | 100 | 21,095.6                | 398             | 100 | 7,108.3                 |

Table 2:    Intervention and BoC Monetary Policy Changes

| Date | No. of trades | Direction: Purchase (P) or Sale (S) of USD | Change in overnight rate target | Overnight rate target after change |
|---|---|---|---|---|
| 10-Jan-95 | 18 | S | 0.50 | 6.00 |
| 12-Jan-95 | 20 | S | 0.50 | 6.50 |
| 17-Jan-95 | 21 | S | 0.50 | 7.00 |
| 16-Feb-95 | 16 | S | 0.50 | 8.00 |
| 10-Jul-95 | 11 | P | -0.25 | 6.75 |
| 28-Aug-95 | 2 | P | -0.25 | 6.25 |
| 31-Oct-95 | 2 | P | -0.25 | 6.00 |
| 25-Jan-96 | 8 | S | -0.25 | 5.50 |
| 18-Apr-96 | 3 | S | -0.25 | 4.75 |
| 12-Dec-97 | 2 | S | 0.50 | 4.25 |
| 30-Jan-98 | 13 | S | 0.50 | 4.75 |
| 27-Aug-98 | 45 | S | 1.00 | 5.75 |

Note:  No intervention transactions coincided with changes in U.S. monetary policy.