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Measuring the Profitability and Effectiveness of Foreign Exchange Market Intervention: Some Canadian evidence

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ABSTRACT

When the major industrial countries decided to move to a system of managed flexible exchange rates following the collapse of the Bretton Woods system, many observers thought that this would reduce, if not eliminate, the need for official foreign exchange market intervention. During the past fifteen years, however, intervention in most countries, including Canada, has risen steadily in both frequency and intensity.

This paper presents new empirical evidence on the profitability and effectiveness of Canadian intervention from 1975 to 1988. The results suggest that the government's foreign exchange operations have been very profitable and have tended to be stabilizing, in the sense that authorities were typically pushing the exchange rate towards its long-run trend and helping to reduce short-run volatility in the market.

RÉSUMÉ

Lorsque, après l'effondrement du système de Bretton Woods, les grands pays industriels ont décidé d'adopter un régime de changes flexibles contrôlés, de nombreux observateurs croyaient que cela réduirait ou même éliminerait la nécessité des interventions officielles sur les marchés des changes. Or, depuis quinze ans, la fréquence et le volume des interventions augmentent régulièrement dans la plupart des pays, y compris le Canada.

Cette étude présente de nouveaux résultats empiriques concernant la rentabilité et l'efficacité des interventions de l'État canadien entre 1975 et 1988. D'après ces résultats, les opérations sur devises de l'État canadien ont été très rentables et ont eu tendance à stabiliser le marché des changes, en ce sens que les autorités, orientant généralement le taux de change vers sa tendance à long terme, contribuaient à réduire sa volatilité à court terme sur le marché.

1 INTRODUCTION

When the major industrial countries decided to move to a system of managed flexible exchange rates following the collapse of the Bretton Woods system, many observers thought that this would reduce, if not eliminate, the need for official foreign exchange market intervention. The demand for international reserves was also expected to decline. In retrospect, however, it appears that both predictions were overly optimistic. During the past fifteen years, exchange rate considerations have played an increasingly important role in the conduct of domestic monetary policy, as well as in international policy co-ordination.[1] As a consequence, intervention in most countries has risen steadily in frequency and intensity, and official holdings of international reserves have grown by more than U.S.$250 billion.[2]

Despite the continued use and evident appeal of foreign exchange market intervention, authorities and academics remain divided on whether or not it is an effective policy tool. Arguments in favour of intervention rest on three plausible, yet largely unsupported, assumptions:

(1) Exchange markets are prone to destabilizing speculation that can cause exchange rates to move in an erratic, volatile manner and to deviate from their equilibrium values for prolonged periods of time.

(2) Persistent misalignments and erratic exchange rate movements impose significant costs on the real economy by increasing uncertainty, distorting relative prices and reducing world trade.

(3) Official intervention can help reduce these costs by stabilizing exchange markets -- through either the direct effect that intervention has on the net demand for a currency or the signal that it conveys about future policy intentions and market developments.

Though assumption (1) appears to be consistent with recent exchange market behaviour, and assumptions (2) and (3) have considerable intuitive appeal, proponents of intervention have nevertheless had a difficult time providing convincing empirical support for any of these propositions. Their difficulty is understandable given the problems that international economists have had in trying to estimate a reliable exchange rate model. Without such a model, it is virtually impossible to identify the equilibrium value of a particular currency, to measure the amount of "excess volatility" in exchange markets, or to determine how exchange rates might have moved in the absence of intervention.

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1. See Obstfeld (1988), and Frenkel and Goldstein (1988).

2. Total reserve holdings (excluding gold) in G-7 countries increased from U.S.$60 billion in 1973 to more than U.S.$310 billion in 1988 (International Financial Statistics, IMF, June 1980 and May 1989).

While exchange rates have displayed much greater variability in recent years than they did during the Bretton Woods period, there is no direct evidence that would suggest they have been excessively volatile. Similar, and perhaps even more erratic, behaviour has been observed in other financial markets, though governments have not felt the same obligation to actively intervene.[3]

A number of papers have been published over the years purporting to show a significant negative relationship between the volume of world trade and the variability of exchange rates.[4] However, the authors have so far been unable to determine whether this variability was caused by destabilizing speculation or other, more fundamental, factors and whether additional intervention might have provided an effective remedy. Other researchers have had difficulty uncovering any systematic relationship between trade and exchange rate variability, and note that the theoretical support for such a relationship is questionable in any case due to the ambiguous effect that increased uncertainty has on risk-taking behaviour.[5]

Recent tests of portfolio behaviour in international capital markets have also provided little support for extended exchange market intervention. In many cases, researchers have been unable to reject the null hypothesis of perfect asset substitutability, implying that the portfolio balance effects associated with intervention can have at best a small and temporary influence on exchange rate movements.[6]

Lacking any direct evidence on the need for, or effectiveness of, intervention, researchers have been forced to turn to various indirect measures. The best known is probably the profits test, first proposed by Milton Friedman in 1953. In his "Case for Flexible Exchange Rates," Friedman observed that "speculation can be destabilizing in general only if speculators on the average sell when the currency is low in price and buy when it is high." Conversely, profitable speculation would generally be stabilizing since speculators would have to buy low and sell high in order to make money. Moreover, since intervention

3. Frenkel and Goldstein (1988) have shown that the short-run variability of real and nominal exchange rates over the past 15 years has been much smaller than that of interest rates, equity prices and commodity prices. See also Obstfeld (1988) and Marston (1987).

4. See, for example, Kenen and Rodrik (1986), Cushman (1983), and DeGrauwe (1988). Côté (1986) has conducted similar empirical tests on Canadian data and has found that the relationship between exchange rate variability and trade is not "economically significant" (even though at times it appears to be statistically significant).

5. This occurs because the increased risk associated with exchange rate volatility has offsetting income and substitution effects (See DeGrauwe 1988).

6. See Caramazza et al. (1986) and, for Canada, Boothe et al. (1985). It may still be possible for intervention to have a significant and lasting effect on exchange rates, however, through the signal that it provides to private agents concerning possible policy changes and future market developments.

by national authorities was nothing more than "official speculation," according to Friedman, he suggested that its success or failure could be judged on the same basis as its private sector counterpart, i.e. "whether the [government] agency makes or loses money."

Though research since has questioned the relationship between exchange rate stability and economic welfare, and has also shown that profits are neither a necessary nor sufficient condition for intervention to be stabilizing, the profits test has managed to retain much of its initial appeal. Proponents and critics of intervention continue to be attracted by the simplicity and deceptive logic of Friedman's test. Those who believe that intervention has little or no effect on exchange rates are still prepared to tolerate government involvement in this area, provided they can be assured that it will not cost taxpayers any money. Others, who believe that intervention is an effective policy tool, recognize the limitations of profits tests but argue that the existence of profits increases the probability that intervention is "working in the right direction" and is therefore welfare-improving.[7]

The purpose of this paper is to present some new empirical evidence on the profitability and effectiveness of Canadian intervention over the period 1975 to 1988. Though other researchers have conducted similar analyses for Canada and other major countries, the present study incorporates a number of refinements that we believe lend greater precision and reliability to our results. These include both methodological improvements, in terms of the treatment accorded interest income and financing costs, and the use of more reliable and precise data. The results suggest that official Canadian foreign exchange market intervention has been very profitable over the post-Bretton Woods period. Indeed, total profits on trading and investment income from 30 June 1975 to 1 July 1988 exceeded Can.$1.625 billion. Nevertheless, there have been long periods during which substantial losses were recorded. It would be a mistake, therefore, for governments to regard intervention as a dependable source of additional revenue. The evidence presented later in the paper also suggests that governments should be wary of using profits to gauge the success or failure of their intervention activities. The effectiveness of intervention should probably be judged on the basis of other factors more closely related to the stated objectives of national authorities, such as reduced exchange rate volatility and the maintenance of "orderly markets."

The rest of the paper is divided into four sections. Section 2 discusses the results of previous studies and examines the improvements that have been made over the years in the measurement and interpretation of intervention

7. Friedman belongs to a third group, which believes that intervention is effective but more likely to be destabilizing when practised by government officials.

profits. Section 3 describes the data and methodology that were used in the present study and reports the profits earned by Canadian authorities over the 1975 to 1988 period, as well as in various subperiods. Section 4 reviews the different factors -- such as transactions costs, liquidity premiums, information asymmetries, "noise trading" and other market imperfections -- that might account for the large positive profits uncovered in this and other recent studies. Some of the competing hypotheses that have been advanced to explain intervention profits are then investigated, using an alternative test of intervention effectiveness developed by Wonnacott (1982). The paper concludes with a short summary and a cautionary note concerning the riskiness of intervention and the uncertain relationship that profits bear to authorities' more basic policy objectives.

2 PREVIOUS PROFIT STUDIES

Very little empirical work was done on the profitability of intervention, prior to 1982.[8] One notable exception was a paper written by Eastman and Stykolt in 1956, shortly after Friedman first published his famous dictum. The authors examined the performance of Canada's Exchange Fund Account from 1950 to 1954, but were unable to draw any strong conclusions regarding the success or failure of official intervention during this period. Although the Exchange Fund Account managed to earn a modest profit and authorities were able to reduce some of the day-to-day fluctuations of the bilateral Canada/U.S. exchange rate, Eastman and Stykolt suggest that "the effect of its operations was to interfere somewhat with the longer-term upward trend in the value of the Canadian dollar." [9]

Since Canada was the only major country to operate under a managed flexible exchange rate prior to 1973, the lack of empirical research in this area is understandable. Additional studies had to await the breakdown of the Bretton Woods system and the accumulation of sufficient data to make the analysis worthwhile.[10]

One of the first, and certainly best known, papers on intervention in the post-Bretton Woods period was published by Taylor in 1982. Taylor used monthly data on exchange rates and reserve levels in nine major industrial countries (Canada, France, Germany, Italy, Japan, Spain, Switzerland, the United Kingdom and the United States) to investigate the profitability of central bank intervention from the early 1970s to 1979. According to his estimates, central banks lost between $11 billion and $12 billion over this period and probably contributed to the destabilization of foreign exchange markets by resisting necessary adjustments in nominal exchange rates.[11] Taylor noted that these losses, which were persistent and statistically significant, appeared to confirm Friedman's prediction that "government officials risking funds that they do not own themselves" were unlikely to be "better judges of the likely movements in foreign-exchange markets than private individuals risking their own funds."[12]

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8. A number of theoretical papers were written, however, questioning the relationship between speculative profits, exchange rate stability and economic welfare. See, for example, Baumol (1957), Telser (1959) and Salant (1974).

9. See p. 227, Eastman and Stykolt (1956).

10. Though national authorities intervened throughout the Bretton Woods period, their objectives were somewhat different than under the flexible rate period, and exchange rate movements were typically so small (with the exception of occasional realignments) that profitability was not a major concern.

11. Canada was estimated to have lost U.S.$82 million on its intervention activities from June 1970 to December 1979.

12. Friedman (1953).

As one might expect, these charges did not go unchallenged. A number of studies criticizing both the methodology and conceptual underpinnings of Taylor's work appeared within months of his article. Criticism centred on (1) the sample sensitivity of the results; (2) the treatment of unrealized capital gains and losses; (3) the exclusion of net interest income from the profit calculations; and (4) possible biases in the statistical tests.

Most important in this regard, according to his critics, was Taylor's decision to exclude net interest income from his profit calculations. The numbers that he presented in his paper included only those profits and losses that were directly related to the purchase and sale of foreign exchange, and were based on the following simple formula:

$$(1) \quad \pi_t = \sum_{i=1}^{t} [n_i(e_t - e_i)]$$

where,

π = profits (losses)
n = purchase (sale) of foreign exchange
e = spot exchange rate (domestic currency price of one unit of foreign exchange).

Cumulative profits from period 1 to t were equal to the dollar value of foreign exchange sales, less the dollar value of foreign exchange purchases, plus any unrealized capital gain (or loss) on net reserve holdings at end of period. Since net interest income from the investment of foreign exchange was ignored, the profitability of exchange market intervention may have been either over or understated by a wide margin. In fairness to Taylor, however, it should be noted that he was aware of the problem and addressed it in a footnote.[13] Citing the results of an earlier study (Taylor 1981), he suggested that his numbers would have remained essentially unchanged even if the appropriate adjustments had been made for investment income and financing costs.

A more serious bias may have been introduced by Taylor's choice of sample periods. The U.S. dollar traded at historically low levels through much of 1978 and 1979, and many central banks intervened with sizable dollar purchases to help correct this apparent undervaluation. Because Taylor's sample ended in 1979 and the additional dollar holdings of central banks were priced at depressed December 1979 exchange rate levels, large (unrealized) capital losses were recorded.

Researchers also criticized Taylor's use of average monthly data for exchange rates and the fact that gross intervention activity was proxied by month-end changes in net reserve levels (n_i). These rough estimates may have masked

13. See p. 359, Taylor (1982).

significant intramonth movements in exchange rates and intervention activity, causing profits to be further understated.

Lawrence Jacobson reworked Taylor's results for the United States in a Federal Reserve Staff Study published in 1983. The first part of his study focussed on U.S. intervention in deutsche marks during the 1970s, the same sample period that Taylor had examined. Jacobson then extended the results to 1981 and included an adjustment for net interest earnings to see how profits would be affected.[14] The following equation was used in his calculations:

$$(2) \quad \pi_t = \sum_{i=1}^{t} [n_i(e_t - e_i) + e_i(r^*_i - r_i)\sum_{j=1}^{i} n_j]$$

where

r = domestic (foreign *) interest rates.

The first term in equation (2) is identical to equation (1) and simply calculates the profits and losses on foreign exchange trading; the second term captures the net interest income that was earned on reserves and is the main factor distinguishing the two studies.

When Jacobson replicated Taylor's tests using equation (1), he found that losses over the 1973 to 1979 period on deutsche mark intervention totalled $504 million -- comparable to the $564-million dollar figure obtained by Taylor. Net positive returns equal to $288 million were recorded, however, when Jacobson extended the sample by two years. Moreover, adding net interest income, in the manner suggested by equation (2), boosted total profits by an additional $480 million or approximately 167 per cent.[15] These dramatic changes highlighted the importance of including net interest income in the profit calculations and the sensitivity of the results to changes in the sample period.

A similar series of tests was performed by researchers at the Bank of England in 1983, using data on U.K. intervention from 1976 to 1982.[16] Like Jacobson, they found that large losses could be transformed into sizable profits through relatively minor changes in the sample period, or by including net interest income in the calculations. Positive profits were also reported by Victor Argy

14. This section of the paper draws extensively from Leahy (1989), Appendix A.

15. Two different approaches were used to estimate net interest income. In the first, r was proxied by the yield on three-month U.S. Treasury bills, and r* was proxied by the three-month Frankfurt interbank rate. In the second, the interest differential (r - r*) was set equal to the three-month forward discount. The profit numbers quoted in the text are based on the second approach. Net interest income calculated using method (1) could be biased since U.S. Treasury bills and Frankfurt interbank deposits have very different risk and liquidity characteristics.

16. Bank of England, *Quarterly Bulletin*, September 1983.

(1982) when he conducted a number of parallel tests on data from Germany and Japan, as well as the United Kingdom. Argy used a formula similar to Jacobson's, but with one significant difference. In order to overcome problems related to unrealized capital gains and losses at the end of the sample period, he restricted his simulations to periods in which net intervention was equal to zero, so that central banks were not left holding an open foreign exchange position.

$$(3) \quad \sum_{i=1}^{t} n_i = 0$$

Argy's intervention data ran from 1973 to 1979. Although losses were reported on Japanese intervention from March 1973 to October 1977, and on U.K. intervention from September 1974 to December 1977, net profits on trading and interest income were realized by all three countries (Germany, Japan and the United Kingdom) over the 1977 to 1979 period.

Corrado and Taylor (1986) criticized Argy for imposing a "symmetry" constraint on intervention, arguing that it biased his results in favour of profits.[17] They showed that conditional profits would necessarily be positive under Argy's restriction, provided exchange rates followed a random walk and authorities intervened in a symmetric manner over the sample period by "leaning against the wind." (This would be true even though the expected value of unconditional profits was zero by assumption.) By requiring net intervention to be zero, Argy had effectively limited his calculations to those subperiods in which exchange rates tended to reverse direction, allowing authorities to earn positive profits by buying when exchange rates declined and then selling at a profit when rates rebounded.

Mark Leahy (1988) extended the analysis found in these earlier studies and incorporated a number of significant improvements that allowed him to overcome, or at least minimize, many of the problems noted above. First, he tested the profitability of U.S. intervention in both deutsche marks and yen, using daily -- as opposed to monthly -- data to avoid the kinds of time aggregation problems that might have affected Taylor's results. Second, unlike Argy, he based his initial results on the longest sample period possible (July 1973 to January 1988) and then divided the series into several subperiods, without regard to whether net intervention was zero. Net open positions at the end of each period were evaluated using three different exchange rates -- the actual end-of-period rate and two alternative rates, set 20 per cent above and below the actual rate. The latter were designed to test how sensitive

17. Some of the results reported by the Bank of England (1983) and by Jacobson (1983) were also run over sample periods in which this constraint was imposed.

the results might be to subsequent movements in the exchange rate.

In addition, Leahy used a more general formula, which allowed him to adjust the foreign-domestic interest differential for changes in the exchange rate and permitted net interest income to compound over time:

$$(4) \quad \pi_t = \sum_{i=1}^{t} \{n_i[(e_t - e_i) + (e_t\tilde{r}^*_i - e_i\tilde{r}_i)]\}$$

where

$$\tilde{r}_i = \prod_{j=1}^{t-i} (1 + r_{i+j-1}) - 1$$

and

$$\tilde{r}^*_i = \prod_{j=1}^{t-i} (1 + r^*_{i+j-1}) - 1$$

Domestic interest rates (r) were proxied by the yield on three-month U.S. Treasury bills, as in Jacobson's study, and foreign interest rates (r*) were proxied by the three-month Frankfurt interbank rate and the three-month gensaki rate.

Leahy estimated that net profits on U.S. intervention in deutsche marks from March 1973 to January 1988, with and without net interest income, were $4.284 billion and $2.859 billion, respectively. The corresponding figures for intervention in yen were $1.172 billion and $967 million. Though positive profits were reported in 21 of the 23 periods that he examined, most of the earnings were concentrated in two subperiods, 1977 to 1981 and 1985 to 1988 -- when intervention levels were high and the dollar displayed its greatest volatility.

3 THE PROFITABILITY OF CANADIAN INTERVENTION

3.1 Methodology and data

The present study of Canadian intervention is very similar in concept and application to Leahy's, but with three notable exceptions. First, profits are calculated using the actual exchange rates at which intervention was transacted, as opposed to noon rates or other estimated values.[18] Second, net interest earnings are calculated using the one-day swap exchange rate on Canadian and U.S. dollars (otherwise known as the "TOM-NEXT" or tomorrow-next rate) as opposed to three-month treasury bill rates.[19] Third, trading profits are divided into realized and unrealized components, to separate those returns that are known with certainty from others that are more susceptible to future changes in the exchange rate.

The sample period runs from 1 July 1975 to 30 June 1988 and includes only U.S. dollar intervention.[20] Though Canada occasionally intervenes in other currencies, both individually and in concert with other G-7 central banks, the majority of its operations have been conducted in U.S. dollars.

The starting point for the analysis was determined by the availability of daily data on (gross) intervention activity and one-day swap rates. Consideration was given to using estimated daily data (or alternatively, aggregated monthly data) and extending the analysis back to 1 June 1970, when Canada first returned to a floating-rate system. However, actual data were preferred, to ensure the accuracy of our results. Using estimated daily data would have introduced small, but potentially serious, biases into our calculations; using monthly changes in reserve levels and monthly average exchange rates, like Taylor, would have forced us to ignore transactions that were reversed within the month. As well, intervention could have been seriously mispriced in months where exchange rates were extremely volatile.

The formula that was used to calculate intervention profits was a modified version of Leahy's more general specification:

$$(5) \quad \pi_t = \sum_{k=1}^{t} m_k \left[e_k - \left(\sum_{j=1}^{k} v_j e_j \Big/ \sum_{j=1}^{k} v_j \right) \right]$$

18. Unlike Jacobson and most other researchers, we also use actual data on the amount of daily intervention, as opposed to rough approximations based on net month-to-month changes in reserve levels.

19. The "TOM-NEXT" swap exchange rate is equal to the overnight interest rate differential on Canadian and U.S. instruments and corresponds to the financing costs of rolling a U.S. dollar position on a day-to-day basis. It also adjusts for the one-day settlement lag associated with Canada/U.S. dollar foreign currency transactions.

20. The daily intervention data include all U.S. dollar transactions that were undertaken by Canada's Exchange Fund Account for the purpose of influencing the Canada/U.S. exchange rate. It excludes other U.S. dollar transactions related to government requirements for foreign exchange, including those for external debt servicing and transactions with other central banks.

$$+ \{\sum_{i=1}^{t} v_i(e_t - e_i) - \sum_{k=1}^{t} m_k[e_k - (\Sigma v_j e_j / \Sigma v_j)]\}$$
$$+ \sum_{i=1}^{t} e_i[(r^*_i - r_i)(\sum_{j=1}^{i} (v_j - m_j)]$$

= (realized trading profits)

+ (unrealized capital gains)

+ (net interest earnings)

where

(6) v_i = addition to an existing U.S. dollar position, where

$$n_i > 0 \text{ and } \sum_{j=1}^{i-1} n_j > 0, \text{ or } n_i < 0 \text{ and } \sum_{j=1}^{i-1} n_j < 0$$

and

m_i = reduction in an existing U.S. dollar position, where

$$n_i < 0 \text{ and } \sum_{j=1}^{i-1} n_j > 0, \text{ or } n_i > 0 \text{ and } \sum_{j=1}^{i-1} n_j < 0$$

Though equation (5) does not adjust net interest earnings for exchange rate movements, and excludes some of the interest income that would have accumulated on realized trading profits, it has the advantage of allowing us to divide total profits into three separate components: realized trading profits, unrealized capital gains, and net interest earnings. Any errors that these exclusions and approximations might introduce into our profit estimates are measured in a second set of simulations based on equation (4).

Referring to equations (5), (6) and (7), one can see that a distinction is made between intervention that adds to an existing U.S. dollar position, v_i, and intervention that partially reverses a position, m_i. If intervention on day i adds to an existing U.S. dollar position, or creates a new one (equation (6)), the average cost of v_i is simply recalculated to include the new transaction.

When intervention reverses an open U.S. dollar position, however, in whole or in part (equation (7)), intervention is booked at the average cost of the existing position, $\Sigma v_j e_j / \Sigma v_j$, and any additional Canadian dollars that are earned on the purchase or sale are added to realized profits, $m_k[e_k - (\Sigma v_j e_j / \Sigma v_j)]$. If a loss is incurred, realized profits are reduced.

At the end of the period, the outstanding U.S. dollar position is valued at the closing exchange rate, e_t. Any difference between the average Canadian dollar cost of this final position and its current market value is treated as an unrealized capital gain or loss, $\Sigma v_i(e_t - e_i)$.

A priori it is not clear which interest differential should be used to calculate net interest earnings on daily U.S. dollar positions, $[(r^*_i - r_i)(\Sigma(v_j - m_j)]$. The practice followed by many commercial banks and investment houses is to assume that foreign exchange positions are rolled from day to day. Nevertheless, one might argue that it is more appropriate to use an interest differential with a term to maturity greater than one day, since governments typically finance their international reserves and invest the proceeds over a longer time horizon.

Our decision to work with one-day swap rates, in preference to other interest rates such as the yield on three-month treasury bills, was based on three considerations. First, as noted above, the one day rollover is consistent with current practices in the private sector. Second, it would have been difficult to continually adjust our interest differential to reflect changes in the actual maturity composition of the Canadian government's investment and financing operations. Third, and most important, it allowed us to draw a sharp distinction between what one might term "pure" intervention activities and the government's investment/financing decisions.

3.2 Results

Nine separate simulations were run on Canadian intervention data. The first included the full sample, 1 July 1975 to 30 June 1988. The remaining eight were run over various subperiods in order to test the sample sensitivity of our results. Reserves were set equal to zero at the start of each period to simplify the calculations and to facilitate comparisons across periods.[21]

3.2.1 Full sample

According to the first simulation, foreign exchange market intervention in Canada generated Can.$1,625 million in net profits from 1 July 1975 to 30 June 1988 (See Table 1, column (1)). More than 78 per cent of these returns came from net interest earnings, however, with realized trading profits contributing only 21 per cent. Since, by coincidence, cumulative reserves at the end of the period were essentially zero, unrealized trading profits amounted to less than $1 million. As a consequence, "inventory valuation" effects did not pose a serious problem in this simulation.

21. As of 30 June 1975 Canada's official international reserves totalled U.S.$5,330 million, of which U.S.$3,110 million were held in the form of U.S. dollar denominated assets. Outstanding Government of Canada foreign currency borrowings on this date were less than U.S.$200 million.

TABLE 1

PROFITABILITY OF CANADIAN INTERVENTION
(millions of Canadian dollars)

	Full Sample	Split Sample		Pre and Post Feb. 86	
	1 July 75 30 June 88 (1)	1 July 75 31 Dec. 81 (2)	1 Jan. 82 30 June 88 (3)	1 July 75 4 Feb. 86 (4)	5 Feb. 86 30 June 88 (5)
Realized Trading Profits	348	-18	446	-526	55
Unrealized Trading Profits	1	42	-20	-1,062	-433
Net Trading Profits	349	24	426	-1,588	-378
Net Interest Earnings	1,276	32	689	511	-94
Total Profits	1,625	56	1,115	-1,077	-472
Exchange Rate:					
- End of Sample	C$1.2135	1.1855	1.2135	1.4442	1.2135
- Start of Sample	C$1.0298	1.0298	1.1855	1.0298	1.4442
Net Intervention (millions of U.S.$)	92	-3,593	3,685	-10,037	10,126
Average cost of U.S. Dollar Exposure	1.2037	1.1971	1.2191	1.3384	1.2562
Total Purchase of U.S. Dollars (m. of U.S.$)	79,784	40,368	39,415	58,486	21,298
Total Sales of U.S. Dollars (m. of U.S.$)	79,692	43,961	35,730	168,523	11,172
Gross Intervention	159,476	84,329	75,145	127,009	32,470

	Symmetric Intervention		Exchange Rate Movement	
	29 Sep. 80 19 Apr. 88 (6)	19 Sep. 85 16 Mar. 87 (7)	2 June 82 29 Feb. 84 (8)	4 Feb. 82 29 June 88 (9)
Realized Trading Profits	490	216	51	455
Unrealized Trading Profits	-	-	15	-57
Net Trading Profits	490	216	66	398
Net Interest Earnings	825	142	-	647
Total Profits	1,315	358	66	1,045
Exchange Rate:				
- End of Sample	1.2297	1.3142	1.2495	1.2064
- Start of Sample	1.1705	1.3802	1.2491	1.2064
Net Intervention (millions of U.S.$)	-	-1	910	4,159
Average cost of U.S. Dollar Exposure	N/A	1.3540	1.2327	1.2201
Total Purchase of U.S. Dollars (m. of U.S.$)	43,286	7,728	7,717	39,126
Total Sales of U.S. Dollars (m. of U.S.$)	43,286	7,729	6,807	34,967
Gross Intervention	86,572	15,457	14,524	74,093

Although large net profits were reported for the period as a whole, substantial trading losses were realized (on a cumulative basis) through the first half of the 1980s (See Figure 1). These losses reflected the marked weakness of the Canadian dollar and the large net sales of U.S. dollars that took place prior to 1986 (Figures 2 and 3). The subsequent sharp appreciation of the Canadian dollar and related purchases of U.S. dollars from heavy intervention have allowed Canadian authorities to more than recoup their earlier losses.

The $348-million figure recorded opposite realized trading profits over the entire sample may appear somewhat surprising, since net intervention was slightly positive ($90 million) and the Canadian dollar continued to trade well below its 1975 levels throughout the simulation.[22] Two factors are responsible for this result. First, intervention programs in Canada and elsewhere are typically structured so that the intensity of intervention increases as exchange rates drift further from their underlying trend or "fundamental values." Therefore, the average cost of intervention is increasingly biased toward the peaks and troughs of the exchange rate cycle as authorities lean more heavily against the wind. Second, authorities have had to intervene on a progressively larger scale over the years because of a significant increase in the volume of transactions that are conducted in the market. The net effect of these developments on the average cost of intervention has been to introduce a non-linearity into the process, which in this case served to increase profits.

The high interest rates that Canada experienced from 1975 to 1988 relative to those in the United States, combined with our large cumulative Canadian dollar position over most of the period, are responsible for the $1,276 million reported in net interest earnings. Further, since Canada was a net seller of U.S. dollars through most of this period, it was able to use the proceeds of these sales to help meet its regular financing requirements and avoid issuing expensive (i.e. high interest paying) domestic bonds. Large net savings were realized, therefore, even though the government had to service its U.S. debt in depreciated Canadian dollars, since the sizable Canada-U.S. interest differential more than offset any exchange rate losses (i.e. the ex post uncovered interest parity condition failed to hold).

3.2.2 Sensitivity tests

(1) Splitting the sample

The general pattern observed in the full simulation was basically unchanged when the sample was split at the midpoint, 1 January 1982. Net trading profits and net interest earnings were positive in both subperiods (Table 1, columns (2) and (3)), though realized trading profits were negative from 1 July 1975 to 31 December 1981.

22. While net purchases of Canadian dollars were only $90 million, gross intervention exceeded Can.$159 billion.

The much larger returns reported in the second subperiod suggest that most of the trading profits earned during the past 13 years can be attributed to events surrounding the dramatic depreciation and subsequent recovery of the Canadian dollar in 1985 to 1986. Canadian authorities intervened heavily throughout the period, selling U.S. dollars as the Canadian dollar hit record lows and later buying U.S. dollars as the Canadian dollar appreciated. This experience is similar to that of the United States and certain other countries, where the profitability of intervention appears to have been concentrated in one or two subperiods.

(2) Pre and post 4 February 1986

On 4 February 1986, the Canadian dollar hit a record low against the U.S. dollar -- U.S.$0.6913. Dividing the sample at this point generates large losses in both subperiods and in all but two profit categories (See Table 1, columns (4) and (5)). The results are notable, not because they are unexpected but, rather, because they illustrate how it is possible to report losses in each subperiod yet show significant profits overall.[23]

(3) Symmetric intervention

Corrado and Taylor have shown that when authorities lean against the wind in a symmetric fashion and exchange rates cycle about a constant value, realized trading profits will almost invariably be positive.[24] The simulations presented here and in section (4) are designed to test this proposition when at least one of Corrado and Taylor's two conditions is satisfied.

Columns (6) and (7) report the results for two subperiods in which net intervention was approximately zero. The simulations are similar to those proposed by Argy (1982) as a means of overcoming the inventory valuation problem, with $\Sigma n_i = 0$. As expected, realized trading profits are positive in both subperiods, though once again there is evidence that total profits are much larger when data for 1985 to 1986 are included in the sample.[25]

(4) Mean-reverting exchange rates

Realized trading profits remain positive when the constraint on net intervention is relaxed and is replaced with a similar zero condition on net exchange rate movements, $\Sigma e_i = 0$ (Table 1, columns (8) and (9)). Some unrealized capital losses are incurred from February 1982 to June 1988; however, the asymmetry

23. For an explanation, see Bank of England (1983).

24. Longworth (1980) has shown that Canadian intervention is generally symmetric and can be reasonably approximated by a simple differential smoothing rule or, equivalently, a "leaning against the wind" trading strategy.

25. Unrealized trading profits are zero by definition.

that was noted above with regard to the size of total profits over this period is still evident.

To test the reliability and accuracy of our calculations, each of the nine simulations presented above was reestimated using Leahy's formulation (See Table 2). The results were very similar to those reported in Table 1, with one exception -- the 1 July 1975 to 4 February 1986 period.[26] Though equation (4) tended to give somewhat larger numbers than equation (5), there was no systematic pattern to the errors. The largest difference, barring the Can.$739 million gap in column (4), was only Can.$62 million and corresponded to the cumulative error over the entire sample period.

TABLE 2

COMPARISON OF ALTERNATIVE PROFITABILITY MEASURES
(millions of Canadian dollars)

	Full Sample	Split Sample		Pre and Post Feb. 86	
	1 July 75 30 June 88 (1)	1 July 75 31 Dec. 81 (2)	1 Jan. 82 30 June 88 (3)	1 July 75 4 Feb. 86 (4)	5 Feb. 86 30 June 88 (5)
Equation (4)	1,687	119	1,068	-1,816	-446
Equation (5)	1,625	56	1,115	-1,077	-472
Difference	62	63	-47	-739	26

	Symmetric Intervention		Exchange Rate Movement	
	29 Sep. 80 19 Apr. 88 (6)	19 Sep. 85 16 Mar. 87 (7)	2 June 82 29 Feb. 84 (8)	4 Feb. 82 29 June 88 (9)
Equation (4)	1,261	307	77	1,020
Equation (5)	1,315	358	66	1,045
Difference	-54	-51	11	-25

26. The principal reason for this large discrepancy is the exchange rate adjustment that is applied to net interest income in Leahy's formulation. Wide swings in exchange rates such as those experienced over the 1975 to 1986 period magnify the differences between calculations based on equation (4) and those on equation (5). The recovery of the Canadian dollar served to reduce the approximation error in equation (5) in subsequent periods. See Leahy (1989), Appendix A, for a more detailed explanation.

4 DISCUSSION

The most striking feature of the profitability results that have been reported for Canada and other industrial countries in recent years is their consistency. Canada, the United Kingdom and the United States all show large profits over the flexible exchange rate period, once their samples are extended to include the 1980s and net interest earnings are added to trading profits. One suspects that similar results would obtain for Germany and Japan if the same methodology were applied, since central banks have tended to co-ordinate their intervention activities in recent years, entering the market at the same time and attempting to push rates in the same direction. These strong results would appear to provide convincing evidence against Taylor's earlier claims that intervention was necessarily costly to central banks and probably destabilizing to foreign exchange markets.

Although the results seem to provide strong support for continued foreign exchange market intervention, the profit numbers should be interpreted with caution. There are a number of questions that must be answered before we can conclude that intervention is an effective and useful policy tool. In particular, we would like to know (1) why intervention has been so profitable, and (2) whether it has actually served to stabilize exchange rates.

4.1 Why has intervention been so profitable?

One explanation for the apparent profitability of intervention is that it is simply the result of chance or luck. Since most of the profits that have been reported for the various central banks have been concentrated in just one or two subperiods, this argument cannot be dismissed out of hand. Critics suggest that these favourable results could easily have been reversed if authorities had acted differently during these periods, or if they were presented with similar situations in the future. The argument is not entirely convincing, however, since profits in most other periods, though somewhat smaller, are nevertheless positive.[27]

The existence of significant transactions costs has also been suggested as a possible explanation. The profits that were reported above, and in earlier studies, make no allowance for the operating costs that central banks incur maintaining their trading rooms and formulating intervention policy. In private financial institutions these costs would be covered by the bid-ask spreads on market rates, which currently average 4 to 5 basis points on Canada-U.S. dollar interbank transactions. Some rough calculations and a quick examination of Table 1 indicate this omission could not have been an important factor in Canada.

27. Taylor (1982) suggested a statistical test for gauging the significance of intervention profits, but his methodology has since been challenged by Spencer (1985, 1989).

Although gross intervention in Canada over the 1975 to 1988 period was U.S.$159 billion, the implicit transactions costs associated with this activity could not have exceeded U.S.$80 million ($159 billion x .0005). In any case, it is clear that most of the profits reported on Canadian intervention came from net interest earnings rather than trading activity, whereas one would have expected the latter to be far more important and consistently positive if the absence of transactions costs were the reason for the Bank of Canada's success in foreign exchange markets.

An alternative explanation for the large intervention profits relies on information asymmetries. Central banks may have a more accurate view of the forces that affect exchange rates and may be better able to anticipate the effects of future policy actions than are private agents. While one might think that authorities could avoid the need for intervention in situations such as this, by simply releasing their privileged information to the public, Mussa (1982) has suggested that they may face a credibility problem, making it necessary to signal their serious intent by intervening and, in effect, "putting their money where their mouth is." Despite the ingenious nature of this argument, few observers seem prepared to give it much weight.

The existence of liquidity and risk premiums would seem to provide a more credible explanation for both trading profits and net interest earnings. Leahy, for example, has suggested that reported net interest earnings may be biased because the interest rates that are used in profit calculations are not tied to instruments with equivalent liquidity or risk characteristics. Short-term foreign interest rates may consistently exceed "comparable" short-term U.S. interest rates because the latter are regarded by market participants as more liquid or subject to smaller credit risks. Central banks that carry short U.S. dollar positions could therefore expect to earn positive profits equal to this liquidity/risk premium. Once again, however, the explanation would seem to have limited applicability in Canada. Past studies have shown that Canadian and U.S. short-term instruments are near-perfect substitutes, and that the liquidity premium on the former (if one exists) is probably less than 25 basis points.[28]

Alternatively, one could argue that these profits reflect the risk-averse behaviour of private market participants and their unwillingness or inability to take a long view of the fundamental forces determining exchange rates. The recent literature on speculative behaviour in financial markets has drawn attention to two distinct types of traders: destabilizing speculators, who trade on "noise" (chartists?), and stabilizing speculators, who trade on market fundamentals.[29] Stabilizing speculators are able to make more accurate predictions about

28. See Caramazza et al. (1986), Boothe et al. (1985), and Murray and Khemani (1989).

29. See Goodhart (1987), Froot and Frankel (1986), and De Long, Shleifer, Summers and Waldmann (1988).

long-run movements in the exchange rate than are their destabilizing counterparts, but tend to be very risk averse. They realize that short-run movements tend to be dominated by noise, and they face liquidity constraints that make it difficult for them to maintain open positions for extended periods of time. As a result, they are often unable to capitalize on their superior forecasting ability.

Their task is made more difficult by destabilizing speculators, whose misguided actions add extra volatility to market rates. Unfortunately, this extra volatility tends to drive stabilizing speculators from the market and thus exacerbates the problem. In Friedman's simple model, the remaining destabilizing speculators would soon lose their money, allowing stabilizing speculators to reenter the market. This does not happen in the more sophisticated version of the model, however, because greater volatility increases the risk premiums that are incorporated in market rates. Destabilizing speculators, who are not only willing to bear the additional risk but are actually responsible for it, are therefore in a position to benefit from the mayhem that they have created. Because they are able to make money in spite of themselves, from large-risk premiums, they remain a destabilizing force in the market.

This situation provides an obvious opening for a risk-neutral player with deep pockets and inside knowledge of market developments -- such as a central bank. Proponents of intervention suggest that authorities should be able to stabilize rates and realize substantial profits, filling the vacuum created by the absence of private, stabilizing speculators. According to these proponents, the results of our profitability tests confirm that this is actually taking place. Less sympathetic observers reply that central banks may simply be the destabilizing speculators that have managed to earn money in spite of themselves.

4.2 Has intervention been stabilizing?

The question of whether central banks can actually stabilize exchange rates through intervention (as opposed to simply earning a profit) is clearly the most critical element in the intervention debate. Though it is impossible to provide a definitive answer to this question, some suggestive evidence can be obtained using an alternative test that was first proposed by Wonnacott (1982).[30]

Wonnacott argues that if the principal objective of intervention is to reduce the short-run variability of exchanges rates, central banks should try to sell

30. Wonnacott (1982) applied his test to U.S. intervention in deutsche marks using data from the late 1970s. Mayer and Taguchi (1983) used the same approach to study intervention by Germany, Japan and the United Kingdom. Their results, like those of Wonnacott, were generally very supportive of intervention.

Pippenger and Phillips (1973) used an alternate approach based on cross-spectral and regression analysis to study intervention in Canada from 1952 to 1960. They also concluded that intervention had been stabilizing.

foreign exchange whenever the actual rate lies above its long-run trend, and buy foreign exchange whenever it lies below the long-run trend. Their success can be judged by the number of times intervention pushes exchange rates in the right direction.

Wonnacott applies this test by proxying the long-term trend with a centred moving average, and then determines whether the deviation between actual exchange rates and the moving average is positive or negative.

(8) $DEV = [e_i - MA(e)_k] > \text{or} < 0$

where

$MA(e)_k$ = centred moving average, with lag length k.

If DEV is > 0 and intervention is "working in the right direction," n_i should be negative, indicating that the central bank is selling foreign exchange. The conditions would be reversed, of course, if DEV were negative.

The performance of central banks is measured by the success ratio,

(9) $$SR = \sum_{i=1}^{t}(d_i) / \sum_{j=1}^{t}(D_j)$$

where

d_i = 1 if intervention was in the right direction (and zero otherwise).

D_j = 1 if intervention took place (and zero otherwise).

Alternatively, SR can be weighted according to the dollar value of intervention.

(10) $$SR(\$) = \sum_{i=1}^{t}(n_i d_i) / \sum_{j=1}^{t}(n_j D_j)$$

While SR and SR($) are similar in spirit to Friedman's profits test, they provide a more direct measure of the effectiveness of intervention and are not as susceptible to sample selection biases and other complications that affect the profit test. SR and SR($) cannot tell us whether intervention actually affects exchange rates, but are based on the assumption that if intervention is working in the right direction it will likely have some stabilizing influence at the margin. Though there is no guarantee that the moving average term, $MA(e)_k$, actually corresponds to the "long-term trend," let alone the "equilibrium rate,"

SR and SR($) should allow us to determine whether intervention was successful in reducing short-run volatility.[31]

Since it is more important that intervention be stabilizing when DEV is large, researchers have found it useful to calculate SR and SR($) with a restricted sample that excludes those observations which lie within an x per cent band of $MA(e)_k$. This adjustment also makes the test more realistic, since many central banks establish non-intervention bands within which they will not actively buy or sell foreign exchange (except, possibly, to adjust reserve levels and transact other government business unrelated to intervention).

Three alternative band widths were chosen for purposes of the tests reported below: 0.5 per cent, 1.0 per cent and 1.5 per cent, respectively, to either side of $MA(e)_k$. Because the length of the moving average term is also somewhat arbitrary, parallel runs were made using 3-month, 6-month and 12-month lags.

The results of the moving average tests for stabilizing intervention are reported in Tables 3 and 4. Two sample periods were examined: 1 July 1975 to 30 June 1988 and 1 January 1982 to 30 June 1988, corresponding to simulations (1) and (3) in the profitability tests reported above. The main conclusions can be summarized as follows:

(1) All of the success ratios are statistically significant and much larger than the 50 per cent figure that would have been anticipated if intervention had been completely random.[32]

(2) Since most of the test statistics exceed 60 per cent, and on occasion 80 per cent, it would appear that the results are also economically significant, and that intervention was generally working in the right direction.

(3) The percentage of intervention in the right direction tended to decrease with the length of $MA(e)_j$ and to increase with the width of the band around DEV. This suggests that authorities were principally concerned with reducing short-run instability, and that they were most "successful" on those occasions when it really mattered (i.e. when DEV was large).[33]

(4) Both the percentage of days on which intervention occurred and the average dollar value of intervention tended to increase with the width of the band around DEV, reinforcing the point made earlier that the level of intervention usually increased as rates moved further from their underlying trend.

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31. If $MA(e)_k$ did happen to correspond to the equilibrium value of the exchange rate, we would also be able to determine whether intervention was (potentially) successful in reducing systematic misalignments, as opposed to simply reducing short-run volatility.

32. Given the size of the sample, any value above 52 per cent would have been statistically significant at the 95 per cent level.

33. These results are also consistent with what one would expect to observe when authorities "lean against the wind" – i.e. attempt to reduce volatility by resisting exchange rate movements in either direction, rather than identifying a specific equilibrium exchange rate value.

TABLE 3

MOVING AVERAGE TESTS FOR STABILIZING INTERVENTION
(1 July 75 to 30 June 88)

	Total No. of Days	No. of Days Intervened	% of Days Intervened	% of Intervention in Correct Direction		Average Dollar Value of Intervention
				No. of Days (SR)	Dollar Value (SR($))	(millions of Can.$)
3-Month Moving Average						
All Days	3,277	2,665	81.3	62.4	64.8	59.4
|DEV| > 0.5% *	1,300	1,117	85.9	70.9	74.0	68.5
|DEV| > 1.0%	369	327	88.6	78.6	82.7	77.8
|DEV| > 1.5%	108	101	93.5	87.1	84.6	88.3
6-Month Moving Average						
All Days	3,277	2,665	81.3	59.4	62.7	59.4
|DEV| > 0.5%	1,781	1,490	83.7	62.6	74.0	63.0
|DEV| > 1.0%	810	672	83.0	64.6	82.7	68.9
|DEV| > 1.5%	292	249	85.3	79.5	84.6	82.5
12-Month Moving Average						
All Days	3,277	2,665	81.3	56.4	59.2	59.4
|DEV| > 0.5%	2,232	1,819	81.5	58.9	62.8	61.5
|DEV| > 1.0%	1,365	1,091	79.9	61.9	66.5	67.3
|DEV| > 1.5%	687	573	83.4	64.4	69.5	69.0

TABLE 3A

MEAN AND MAXIMUM ABSOLUTE VALUES OF DEVIATIONS **
(1 July 75 to 30 June 88)

	3-Month Moving Average	6-Month Moving Average	12-Month Moving Average
Mean	0.50%	0.70%	0.97%
Maximum	4.11%	4.23%	5.32%

* |DEV| > x%, excludes data for days when e_i within x% of monthly average.
** Deviations = $\{[e_i - MA(e)_i] / e_i\} .100$

TABLE 4

MOVING AVERAGE TESTS FOR STABILIZING INTERVENTION
(1 January 82 to 30 June 88)

	Total No. of Days	No. of Days Intervened	% of Days Intervened	% of Intervention in Correct Direction		Average Dollar Value of Intervention
				No. of Days (SR)	Dollar Value (SR($))	(millions of Can.$)
3-Month Moving Average						
All Days	1,638	1,194	72.9	64.1	67.3	77.1
|DEV| > 0.5% *	590	469	79.5	77.4	79.4	88.3
|DEV| > 1.0%	151	121	80.1	80.1	88.2	108.4
|DEV| > 1.5%	49	45	91.8	88.9	89.9	113.8
6-Month Moving Average						
All Days	1,638	1,194	72.9	61.3	65.4	77.1
|DEV| > 0.5%	830	625	75.3	66.2	79.4	82.4
|DEV| > 1.0%	323	231	71.5	67.5	88.2	94.3
|DEV| > 1.5%	103	84	81.6	84.5	89.9	119.8
12-Month Moving Average						
All Days	1,638	1,194	72.9	55.9	59.9	77.1
|DEV| > 0.5%	1,078	789	73.2	57.7	63.9	80.4
|DEV| > 1.0%	850	463	71.2	63.7	69.9	86.9
|DEV| > 1.5%	302	232	76.8	65.7	73.6	89.7

TABLE 4A

MEAN AND MAXIMUM ABSOLUTE VALUES OF DEVIATIONS **
(1 January 82 to 30 June 88)

	3-Month Moving Average	6-Month Moving Average	12-Month Moving Average
Mean	0.47%	0.65%	0.94%
Maximum	3.22%	4.23%	5.23%

* See note to Table 3.
** Deviations = $\{[e_i - MA(e)_i] / e_i\} .100$

(5) The percentage of days on which the authorities intervened declined over the second half of the sample. When intervention did occur, however, it was more likely to be pushing rates in the right direction, since the SRs on Table 4 are typically higher than those on Table 3.

(6) The average dollar value of intervention also increased in the second half of the sample, indicating perhaps that authorities found it necessary to adjust the scale of their operations in response to larger market volumes.

The results overall are quite encouraging and generally support the view that intervention has had a stabilizing influence in foreign exchange markets over the recent flexible exchange rate period. Some may be surprised at the relatively low numbers for "intervention in the correct direction" that are reported opposite the "All Days" category in Tables 3 and 4. It is important to remember, however, that much of the intervention that was included in these runs was either directed at very short-run, intraday volatility or was passive in nature, designed merely to adjust reserve levels rather than to actively influence rates.

5 CONCLUSIONS

The profitability and stabilization tests presented in this paper provide a very different and far more positive view of exchange market intervention than many of the earlier studies published in this area. Profits from Canadian intervention exceeded Can.$1.6 billion over the 1975 to 1988 period and the "success ratio" on short-run stabilization has on occasion approached 90 per cent.

Perhaps even more encouraging is the fact that these results do not appear to be unique to Canada. Recent evidence for the United Kingdom and the United States now suggests that this strong performance was widespread.

Though national authorities can, and indeed should, take some satisfaction from these results, there is a danger that the message may be too comforting. In this regard we would like to note two concerns. First, we believe that it would be a mistake for authorities to treat their trading rooms as "profit centres" and expect to earn large positive returns on a regular basis. Past profits are no guarantee of future positive returns, and we know from experience that this activity can be very risky. Second, profits are neither necessary nor sufficient for the realization of other more basic objectives related to intervention. While they may increase the probability that intervention is "working in the right direction," the evidence to date remains largely circumstantial. To this extent, greater reliance might be placed on the alternative tests, such as those proposed by Wonnacott, that focus more directly on the effectiveness of intervention and its relationship to underlying trends in the exchange rate.

FIGURE I

Cumulative Canadian Intervention Profits
(Billions of Canadian Dollars)
Quarterly

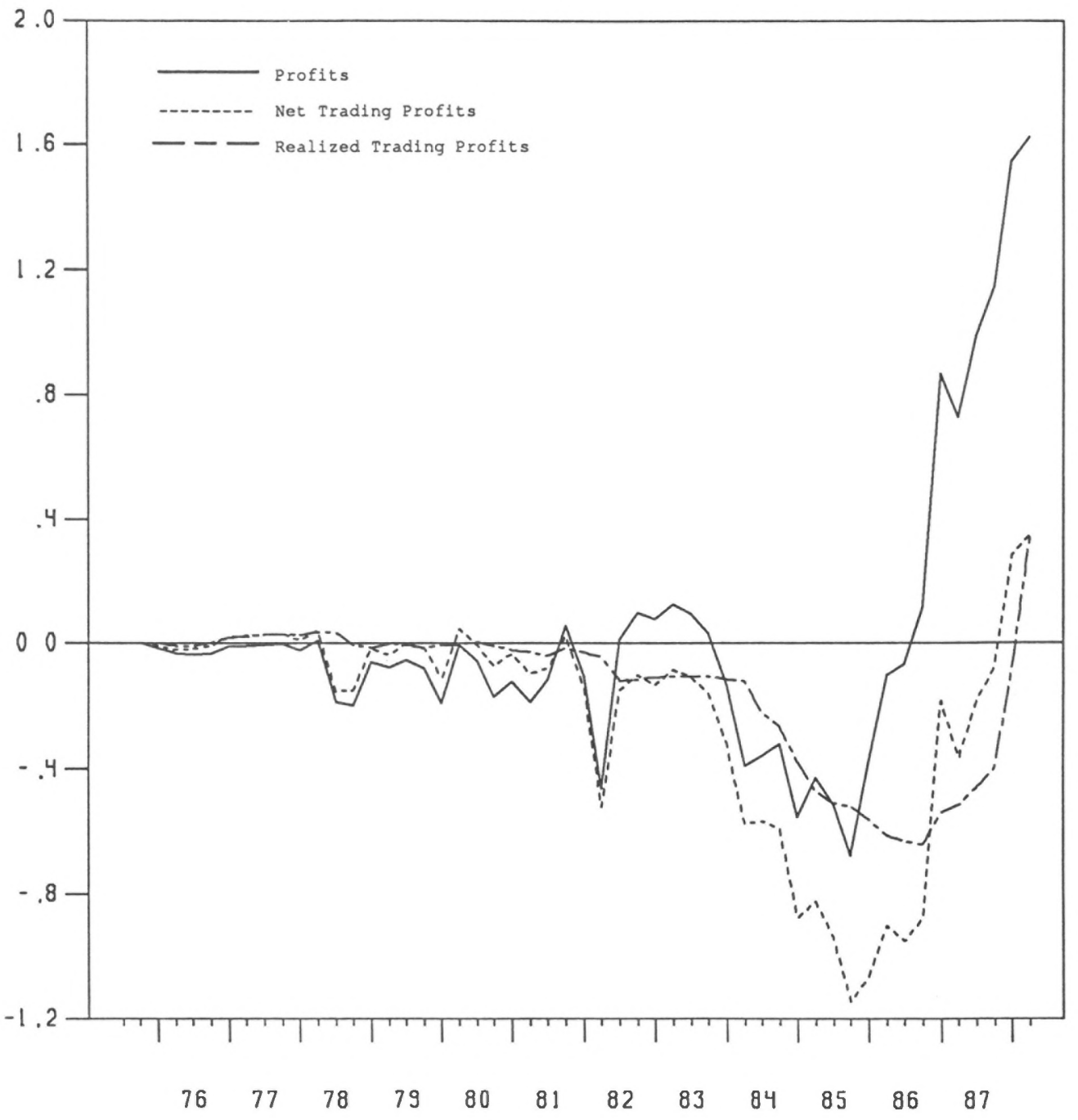
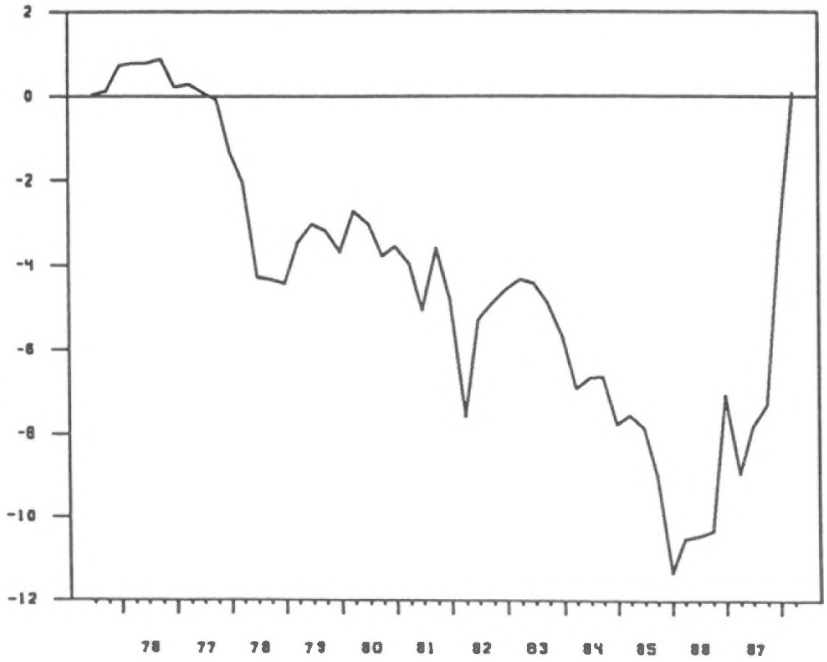


FIGURE II

Exchange Rate
(Canadian Dollar / U.S. Dollar)
Quarterly

FIGURE III

Cumulative Intervention
(Billions of U.S. Dollars)
Quarterly



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