Excess volatility and speculative bubbles in the Canadian dollar (real or imagined?)

John Murray, Simon van Norden and Robert Vigfusson[1]

Introduction

The financial liberalisation and technological innovation that have taken place during the past twenty-five years have produced a highly integrated and increasingly competitive world financial system in which trillions of dollars are traded every day. There is little question that these developments have, on balance, been welfare improving. However, concerns have been raised about the problems that such enormous and unregulated capital flows might pose for the efficient pricing of financial assets and the stability of domestic and international financial markets. Greater competition, advanced information systems and exotic new securities have, according to some observers, led to increased speculation and excessive price volatility. Stocks, bonds and foreign exchange seem more susceptible to sudden and destabilising shocks, and frequently trade at prices that appear inconsistent with market fundamentals. The solutions that have been put forward to remedy these problems vary from increased financial supervision and regulation, to "throwing sand in the wheels"[2] and more stringent forms of price control. All involve greater intervention by the public sector.

Before any ambitious policy responses are contemplated, however, three fundamental questions need to be answered. The first is whether asset prices are in fact subject to excess volatility; the second is whether this volatility imposes any significant costs on real economic activity; and the third is whether the public sector can do anything to improve the situation (or, conversely, whether the cure might be worse than the disease). The remaining sections of this paper will concentrate mainly on the first (and logically prior) question of whether asset prices have misbehaved, using the Canadian dollar as a representative asset and testing for excess volatility and speculative bubbles. Other financial assets will be examined as well, but primarily for purposes of comparison with the dollar.

The exchange rate is arguably the most important asset price in a small open economy like Canada and has been subject to extensive investigation in the past. These considerations and the availability of high quality data, covering a large sample period, make it a natural vehicle for our analysis. The one drawback is the absence of any generally accepted model of exchange rate determination. Without such a benchmark, it is difficult to draw any strong conclusions about the nature and degree of price volatility in exchange markets, and the relative importance of fundamental versus speculative forces at different points in time. Several tests can nevertheless be applied, providing suggestive if not conclusive evidence on market efficiency and speculative behaviour.

The remainder of the paper is divided into four sections. Section 1 describes the behaviour of the Canadian dollar over a twenty-five year period beginning in June 1970, when Canada decided to return to a flexible rate system.[3] Broad movements in the dollar are examined, as well as

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2 "[T]hrowing sand in the wheels" is a phrase coined by James Tobin to describe the effect of transactions taxes and other restrictive measures on the operation of securities markets.

3 Canada operated under a flexible rate system from 1950 to 1962, and was the only major industrial country to do so during this period.

daily changes in its level, and compared with those of other major currencies and financial assets. This review of stylised facts is followed in Section 2 with a series of tests designed to check for persistent misalignments in the currency. Purchasing Power Parity (PPP) is tested (and tentatively rejected), along with a reduced-form model of real exchange rate determination which is estimated using cointegration techniques. Section 3 extends the analysis with a test for speculative bubbles based on a regime-switching specification in which the market is dominated at different times by speculative noise traders and other agents who are guided by more fundamental factors. The final section concludes the paper with a summary of the results and a brief discussion of their policy implications.

In the main, the empirical sections of the paper provide little support for the excess volatility argument and those who believe that government intervention is required to deal with destabilising speculative behaviour. The short-term variability of the dollar, like that of most other financial assets, has not shown any tendency to increase over time, despite a tenfold increase in the average daily volume of Canadian dollar transactions during the last twenty-five years. Evidence from the structural model that is estimated in Section 2 suggests than most of the broad movements in the dollar can be explained by changes in market fundamentals as opposed to aberrant chartist activity. Although the regime-switching model presented in Section 3 finds evidence of speculative activity and noise trading, periods of increased exchange rate volatility are often dominated by fundamentalists - not chartists - correcting the price deviations that occasionally appear because of the speculative activities of other traders. In short, the market is performing more or less as it should, and is not in any obvious need of remedial government action.

1. Alternative measures of volatility

Calls for a return to pegged exchange rates, the imposition of a Tobin tax, or simply more aggressive central bank intervention in defence of the dollar, are often based on the assumption that exchange rates have become increasingly volatile over time and detached from economic fundamentals. The tables and graphs in this section provide a partial answer to these concerns, and some useful background information for the empirical tests that are presented in subsequent sections. The short-run and the long-run movements of the Canadian dollar over the 1970-95 period are examined, as well as those of several other currencies and financial assets.

1.1 Movements in the Canadian dollar: 1970-95

Canada moved to a flexible exchange rate system on 1st June 1970 - three years before most other major industrial countries. Since that time the Canadian dollar has moved within a range of approximately 35 US cents, reaching a post-war high of US$ 1.04 on 25th April 1974 and an all-time low of 69.1 US cents on 4th February 1986 (see Chart 1). Two major cycles can be identified in both the bilateral Canadian/US dollar exchange rate and the nominal effective exchange rate, corresponding to periods of economic strength and weakness, shifts in world commodity prices and changing domestic and foreign inflation differentials.[4]

The close correspondence between movements in the bilateral and effective exchange rates is testament to the dominant role that the United States plays in Canada's international trade.[5] Movements in the real effective exchange rate (see Chart 2) are typically more muted than those of the

4 For a more detailed discussion of recent movements in the Canadian dollar, see Lafrance (1988) and Lafrance and van Norden (1995).

5 The United States accounts for over 80% of Canada's exports and 75% of its imports.

nominal exchange rates, but follow the same general time path and display significant variability over the sample period.[6]

Tables and charts based on the percentage change in the Canadian dollar at daily, weekly and monthly frequencies reveal a very different pattern than the expanded cycles described above, and one that is more consistent with the random walk processes that characterise short-term movements in other asset prices.

Chart 1

Bilateral and effective Canadian dollar exchange rate

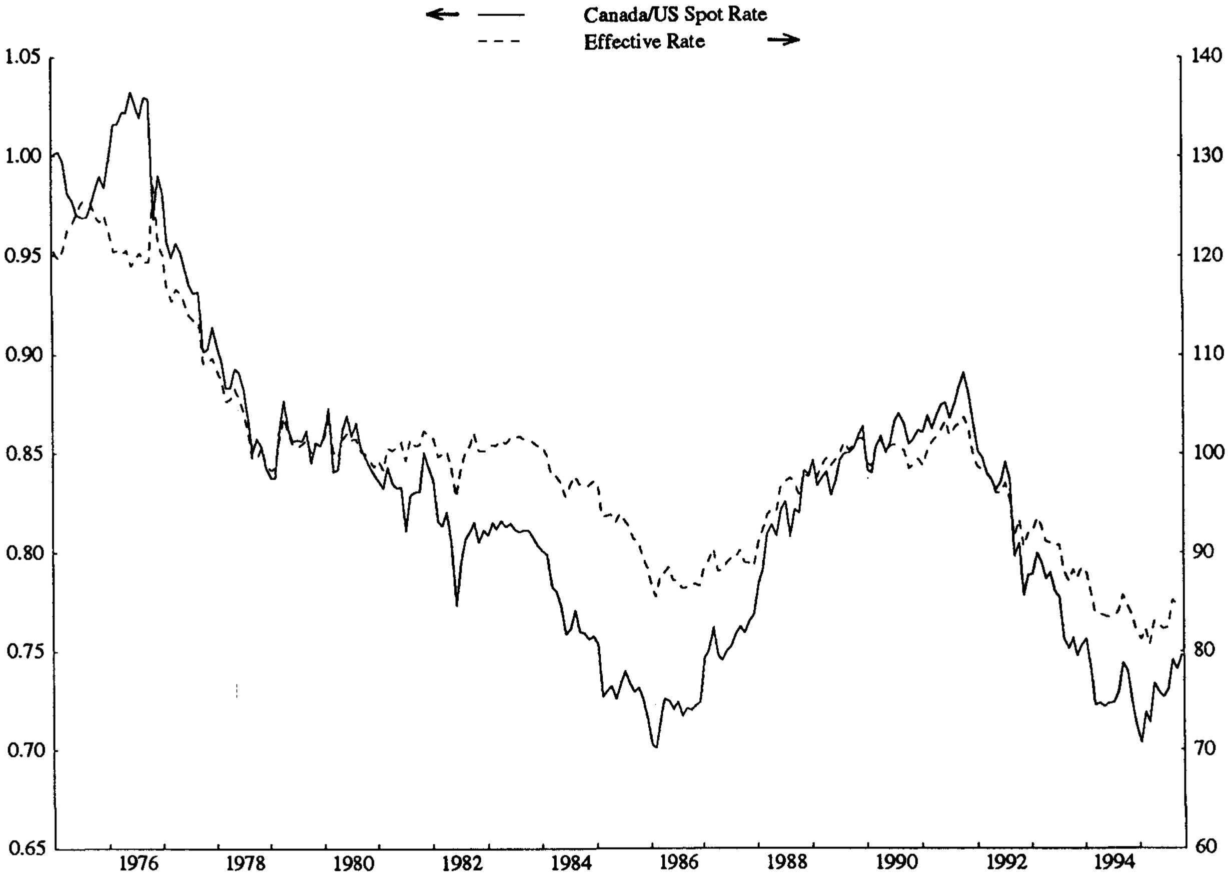


Table 1

Summary statistics for changes in the Canadian dollar

(sample period: January 1975 to October 1995)

Mean	Std. dev.	Mean = 0[1]	Skewness	Kurtosis	Minimum	Maximum
0.0037	0.266	0.42	0.00	0.00	- 1.9229[2]	1.778[3]

[1] The reported values for Mean = 0.0, Skewness and Kurtosis are the marginal significance levels. A value of 0.005 indicates significance at the 5% level. [2] Observation occurred on 21st November 1988. Negative values indicate appreciations. [3] Observation occurred on 31st December 1988.

6 The nominal and real effective exchange rates reported in the paper are mostly taken from the BIS database and are calculated with trade and exchange rate data from twenty-one industrial countries.

Chart 2

Nominal and real effective Canadian dollar exchange rate

(January 1975 = 100)

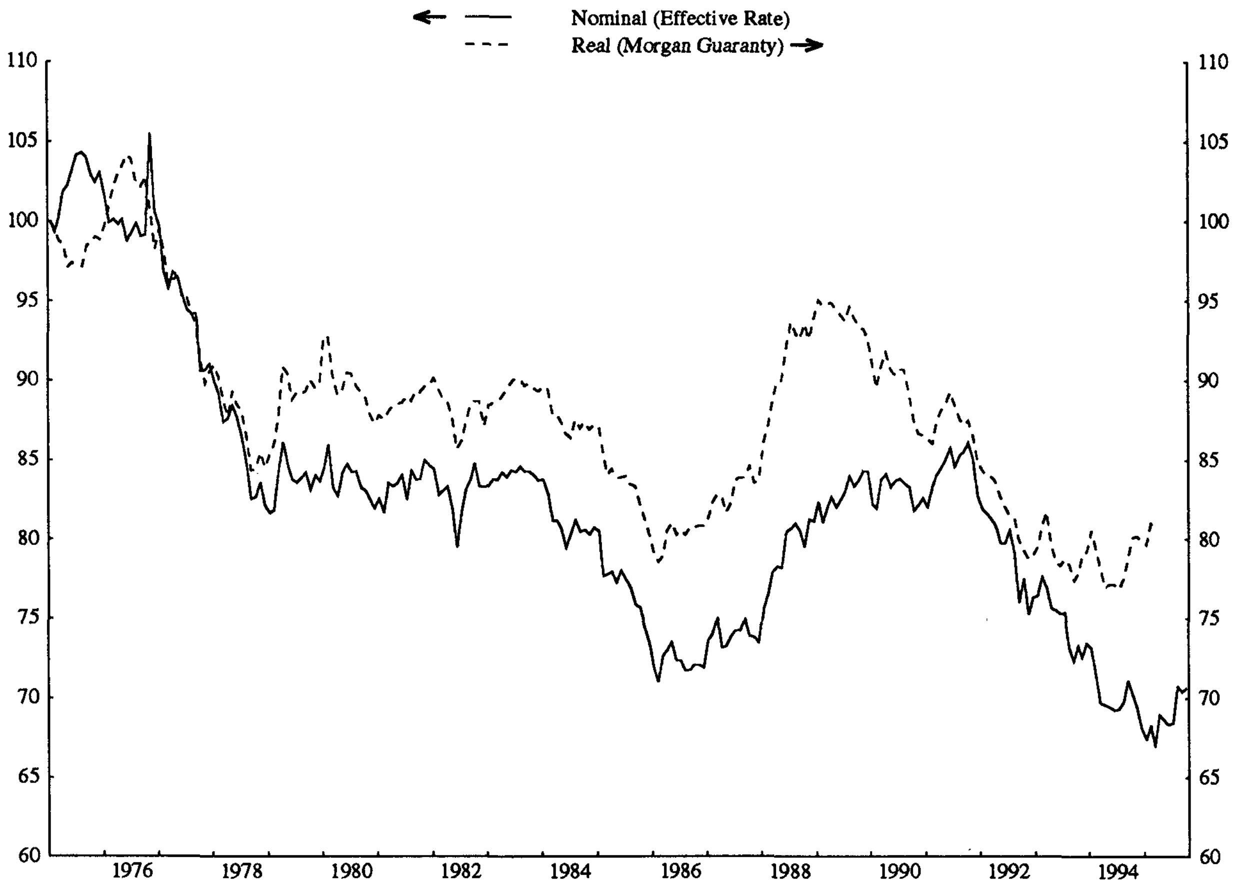


Table 2

Sample autocorrelation coefficients*

1	2	4	8	16	32	64
0.028 [0.022]	- 0.008 [0.021]	0.005 [0.021]	- 0.005 [0.021]	- 0.036* [0.021]	0.025 [0.018]	0.007 [0.017]

* Autocorrelation coefficients calculated over 1 to 64 days. Hetroskedasticity-adjusted standard errors are shown in brackets below each coefficient. None of the estimates is statistically significant at a 5% level.

Daily changes in the bilateral Canadian/US exchange rate appear to be independently and identically distributed about a zero mean, and slightly skewed to the left (indicating a small bias in favour of depreciations). Tests for normality suggest that the distribution is unimodal, but with a somewhat steeper peak and fatter tails than the normal distribution (see Table 1) - a leptokurtotic trait common to most financial assets.

Sample autocorrelation coefficients at different horizons have a maximum value of 0.036, implying very little persistence in the data (see Table 2). More importantly for purpose of the present analysis is the absence of any clear trend in exchange rate variability over the sample period. Some differences are observed when the daily changes are averaged over five and ten-year intervals, and a slight upward drift is noted from the 1980s to 1990s, but none are statistically significant (see Table 3).[7]

Instead what one observes in Chart 3 are periods of relative stability, interspersed with spells of market turbulence. These turbulent episodes are scattered throughout the sample period and seem to persist for a period of time, giving the daily, weekly and monthly series a hetroskedastic quality that some might associate with speculative activity. Sample autocorrelation coefficients calculated from squared percentage changes in daily exchange rate data exhibit much greater persistence than the original data, especially over shorter time horizons (see Table 4), and suggest the presence of autoregressive conditional hetroskedasticity (ARCH).

Chart 3

Squared percentage changes in Canadian dollar

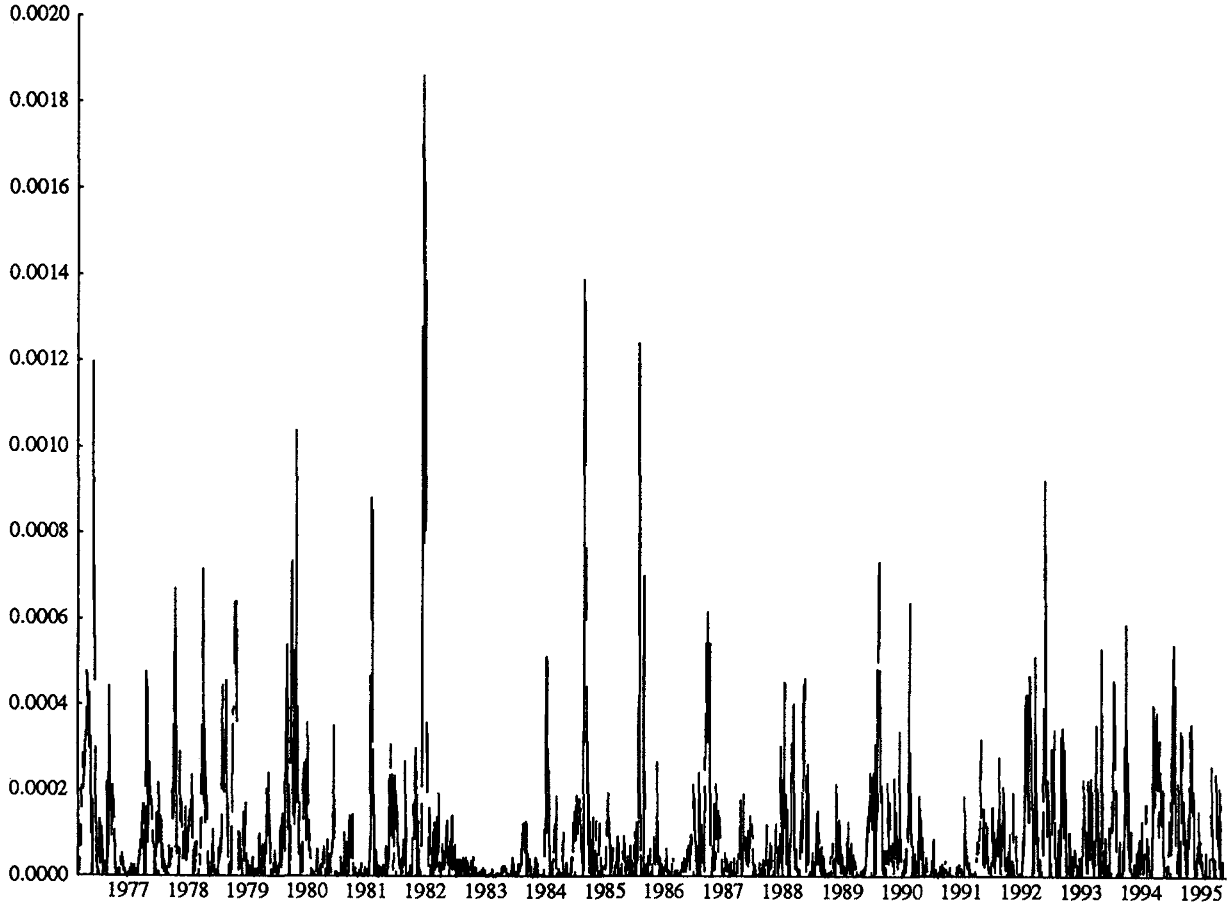


Table 3

Standard deviations of changes in the Canadian dollar*

	1975-79	1980-84	1985-89	1990-95	1975-85	1985-95
Daily	0.01055	0.00868	0.00861	0.00947	0.00955	0.00908
Weekly	0.01007	0.00847	0.00847	0.00927	0.00922	0.00891
Monthly	0.01198	0.00999	0.00928	0.01065	0.01056	0.01000

* Calculated as percentage differences in the actual exchange rate and an underlying trend, proxied by a three-month centred moving average.

7 For a more detailed analysis of the statistical properties of the Canadian/US exchange rate see Amano and Gable (1994).

Tests for homoskedasticity against the alternative of ARCH can be obtained from a regression of the form:

$$r_t^2 = \beta_o + \sum_{i=1}^{p} \beta_i r_{t-1}^2 + \varepsilon_t, \tag{1}$$

where r is the percentage change in the exchange rate s_t (calculated as r_t = ln (s_t/s_{t-1})*100) and p is the order of test (set equal to 1). The test statistic is distributed as a χ^2, with $p+1$ degrees of freedom, and is calculated as $T{\cdot}R^2$ where T is the sample size and R^2 is the coefficient of determination. The results suggest the presence of several different orders of ARCH in the daily data.

Table 4

Tests for hetroskedasticity and ARCH

No. of days	**1**	**2**	**4**	**8**	**16**	**32**
Autocorrelation ..	0.119	0.097	0.099	0.067	0.095	0.029
ARCH	0.000*	0.000	0.000	0.000	0.000	0.088

* Probability of accepting the null hypothesis of homoskedasticity at different time horizons.

Attempts to model the systematic component of this exchange rate volatility using Engel's (1982) ARCH specification and Bollerslev's (1986) Generalised ARCH (or GARCH) specification have so far proven unsuccessful. The models have poor explanatory power and misbehaved residuals, indicating that few movements in variance can be captured by the ARCH or GARCH representations. Greater success has been achieved, however, with state-dependent regime-switching models. The results from these models, and other evidence of excess volatility and speculative bubbles, are reported below in Section 3.

1.2 Volatility in other currencies and financial assets

It is difficult to judge whether the movements in the Canadian dollar described above are exceptionally large or worrisome from an economic perspective. While the volatility of the dollar during the past twenty-five years has not increased noticeably, its erratic behaviour might still pose a problem in terms of reduced market efficiency and a lower level of economic welfare. Greater uncertainty could lead to biased asset pricing and reduced international trade and investment activity. Comparisons with other currencies and financial assets can be helpful in this regard, providing a benchmark with which to judge the performance of the Canadian dollar and determine whether its behaviour is in any way unusual or atypical.

Summary statistics for the Canadian dollar, the Deutsche Mark, the yen and the US dollar are reported in Table 5. While the Deutsche Mark is generally more stable than the Canadian dollar over the 1975-95 period, the other two currencies display somewhat greater variability. The most volatile series is the Japanese yen, with a standard deviation that is roughly three times larger than that of the Deutsche Mark. Given the dramatic differences that are observed in the trend movements of each currency, however, the results are surprisingly similar (see Charts 4, 5a and 5b).

Table 5

Standard deviations of the Canadian dollar, Deutsche Mark, US dollar and yen*

(monthly data)

	1975-79	1980-84	1985-89	1990-95	1975-85	1985-95
Canadian dollar	0.01226	0.00909	0.00960	0.01075	0.01054	0.01020
Deutsche Mark	0.01118	0.00883	0.06673	0.00823	0.00968	0.00755
US dollar	0.01192	0.01704	0.01928	0.01740	0.01478	0.01822
Yen	0.01876	0.02148	0.01987	0.02402	0.01977	0.02213

* Deviations are calculated as the difference between the actual effective exchange rate and an underlying rate proxied by a three-month centred moving average.

Once again, there is no suggestion of a significant upward (or downward) trend in volatility - with the possible exception of the yen. Two of the currencies, the Canadian dollar and the Deutsche Mark, display less volatility in 1985-95 than in 1975-85, while average movements in the yen over the two sample periods are roughly similar. The only currency that has shown a noticeable jump in the last ten years is the US dollar, but even its volatility has declined since 1985-89.

Although stocks, bonds and foreign exchange have very different risk characteristics, and are typically driven by different economic fundamentals, short-term movements in their prices can nevertheless be compared to see if the concerns that have been expressed about excess volatility in the exchange market have more support in other markets. As with the exchange rate statistics reported earlier, data for stocks and bond prices have been adjusted with a three-month centred moving-average to remove any biases that might arise from persistent movements in the series.[8]

Tables 6 and 7 contain few surprises. The standard deviations of stock prices are generally larger than those of bonds, which are in turn much larger than those of the Canadian dollar (and the other currencies reported in Table 5). Although the numbers display a great deal of variability across countries and over time, there is only one case in which the standard deviation increases noticeably towards the end of the sample period - the Japanese Nikkei. In all other cases asset price volatility has tended to decline, leading one to wonder why so much attention had been directed to this issue.

The answer, in part, may be that the performance of financial markets throughout the flexible exchange rate period has been worse, by some measures, than that of the immediate post-war period, before market liberalisation, globalisation and the collapse of Bretton Woods.[9] Alternatively, observers may be more concerned with the long-term trends in the various series than with their short-term variability. It is not obvious, however, that the long-term trends can be credited to the destabilising behaviour of speculators or easily contained by government intervention and regulatory control.

8 Since continuous monthly data on Japanese government bonds were only available after 1982, the sample was limited to 1983-95.

9 Certain brief, but dramatic, episodes such as the stock market crash of 1987, the ERM collapse of 1992 and the jump in long-term interest rates in 1994 may have also created a biased impression of asset market behaviour over the recent period.

Chart 4

Effective exchange rates
(monthly data)

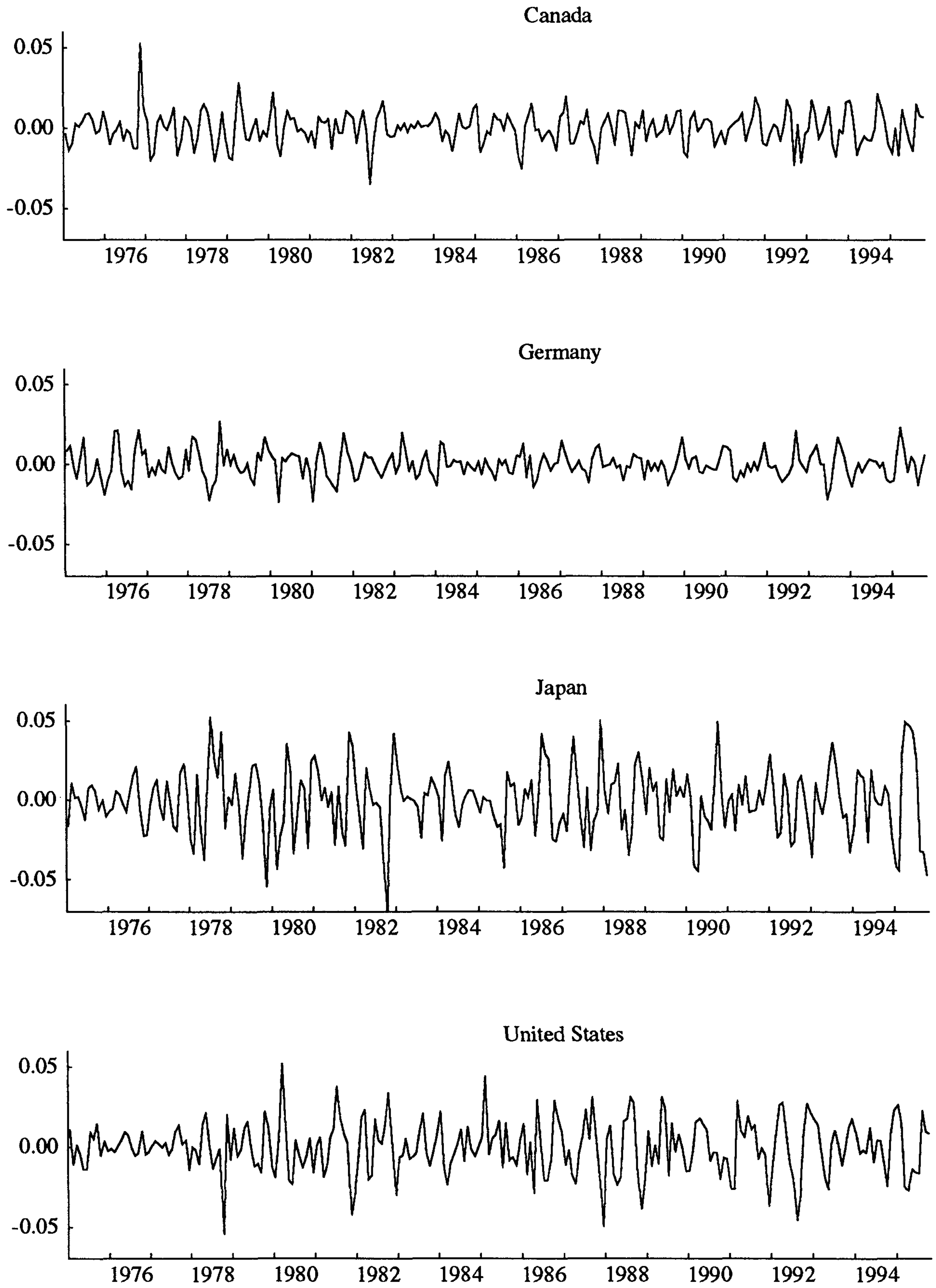


Chart 5a

Effective exchange rates

(January 1975 = 100)

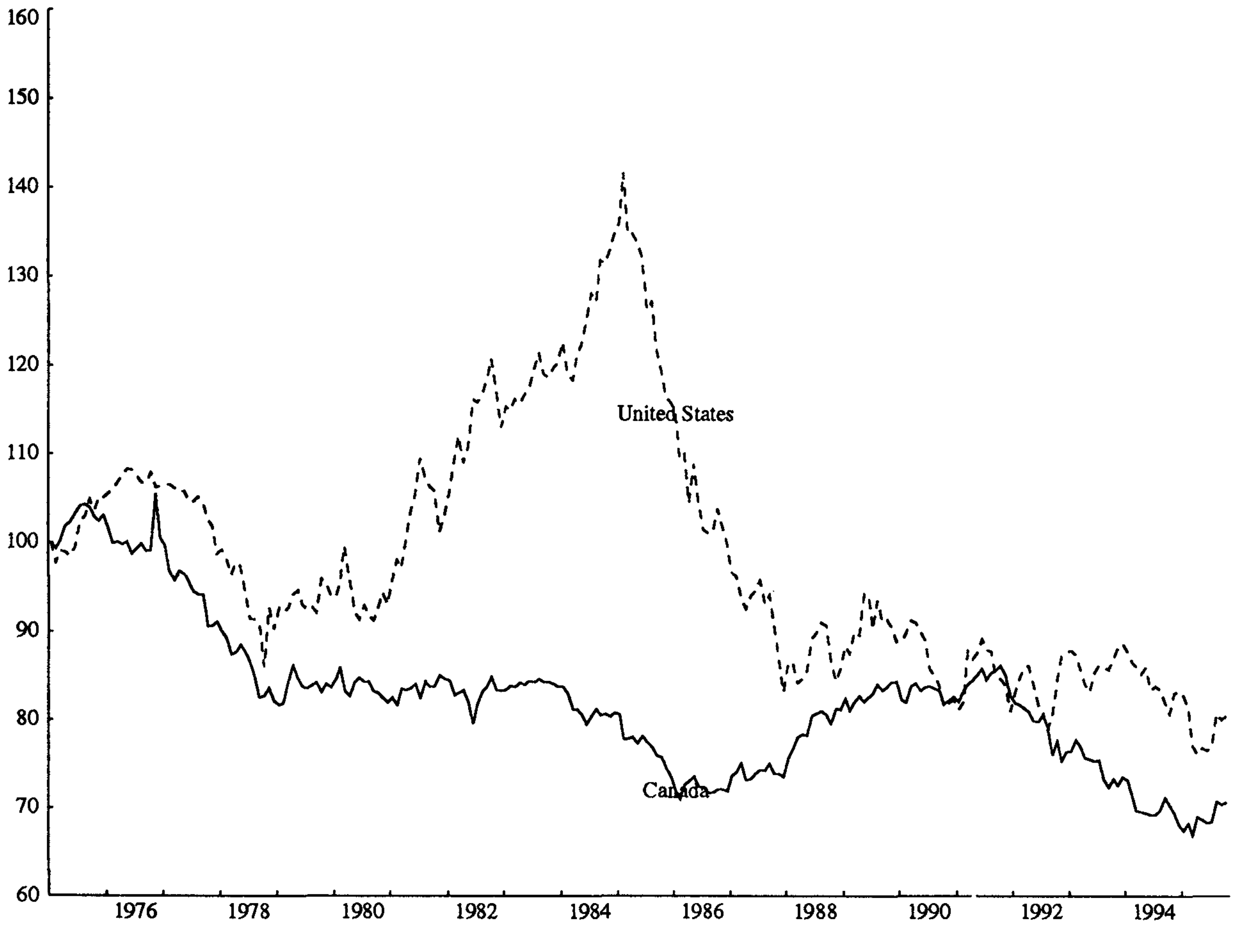


Table 6

Standard deviations in bonds and foreign exchange*

(monthly data)

	1985-89	1990-95	1983-89	1983-95
Canadian dollar	0.00928	0.01065	0.00833	0.00943
Canadian bonds	0.03234	0.03346	0.03021	0.03162
German bonds	0.02748	0.02324	0.02504	0.02419
Japanese bonds	0.07476	0.05310	0.06717	0.06077
US bonds	0.03578	0.03189	0.03386	0.03289

* Standard deviations were calculated with ten-year government bond yields; stock prices were taken from the TSE 300, the German DAX, the S&P 500 and the Nikkei; the exchange rate is defined as the bilateral Canadian dollar/US dollar.

Chart 5b

Effective exchange rates

(January 1975 = 100)

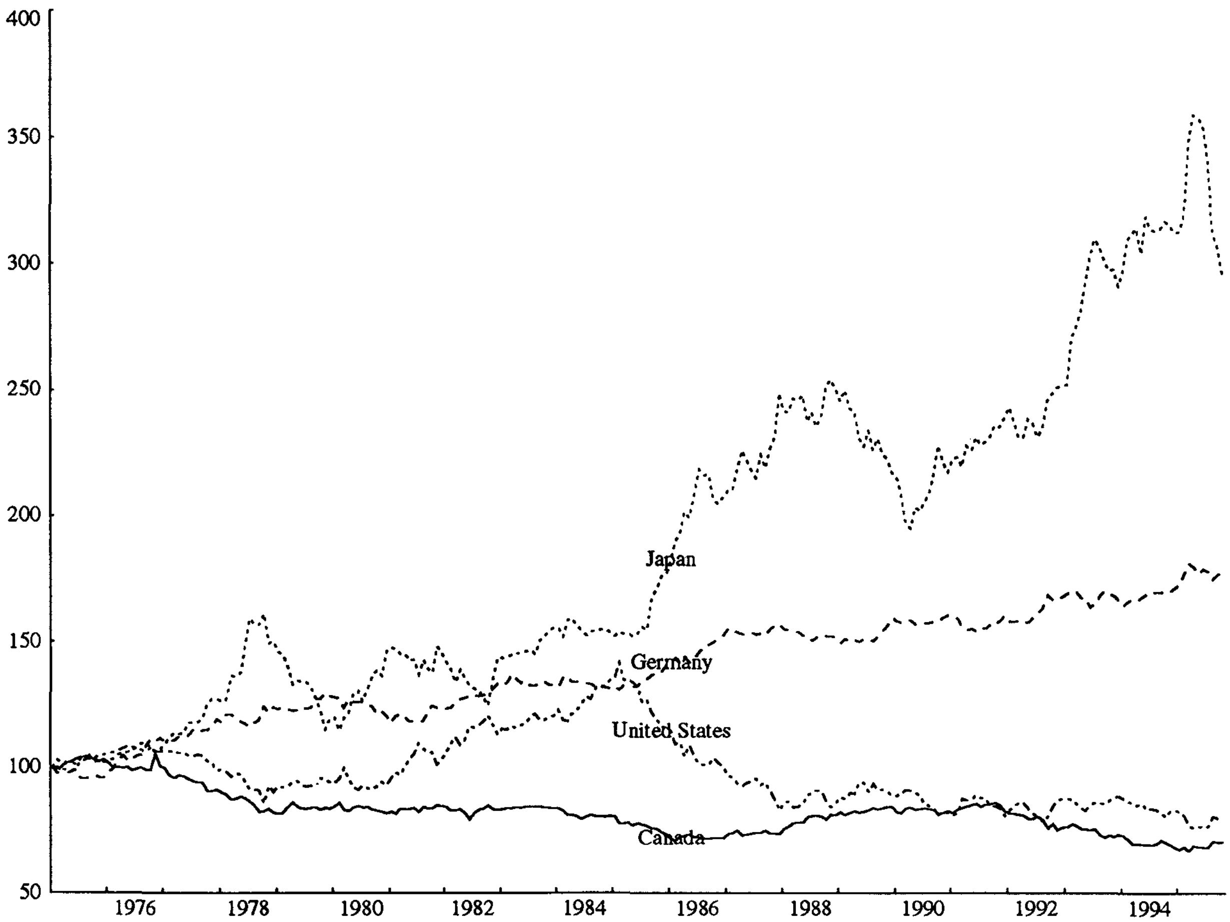


Table 7

Standard deviations in stocks and foreign exchange*

(monthly data)

	1985-89	1990-95	1983-89	1983-95
Canadian dollar	0.00928	0.01065	0.00833	0.00943
Canadian stocks	0.03869	0.02425	0.03599	0.03116
German stocks	0.05341	0.04153	0.04718	0.04494
Japanese stocks	0.02890	0.05036	0.02615	0.03884
US stocks	0.04398	0.02564	0.03950	0.03380

* See note to Table 6.

1.3 Volatility in pegged versus flexible exchange rates

Pegged exchange rates are frequently recommended as a means of ensuring stability in at least one asset price. These proposals are often based on questionable comparisons of exchange market behaviour in the 1950s and 1960s, however, when capital markets were less developed and subject to widespread control. As a result, it is unlikely that efforts to re-create this period of relative tranquillity would meet with similar success.

Tables 8-11 provide some information on exchange rate and interest rate movements in Canada, France, Italy and the United Kingdom over the past twenty years, during which Canada operated under a flexible rate system, France and Italy operated (for the most part) under an adjustable peg, and the United Kingdom alternated between the two systems. In order to highlight the differences between the systems, and to give the pegged exchange rate system every opportunity to demonstrate its superiority in containing excess volatility, the calculations are based on bilateral rates. Movements in the Canadian dollar are measured against the US dollar, and movements in the French franc, Italian lira and pound sterling are measured against the Deutsche Mark.

The variability in nominal and real interest rate differentials for the four countries are reported in Tables 10 and 11. Canada's short-term interest rate differentials are calculated using US interest rates as a base, and those of France, Italy and the United Kingdom are calculated using German interest rates. As can be seen from the data, average interest rate differentials in the European countries operating under the ERM tend to be much higher, especially over the first half of the sample, than those in Canada.

Three important points can be drawn from the data concerning the sustainability and attractiveness of the pegged exchange rate system. The first is that average deviations in the exchange rate under the European Exchange Rate Mechanism (ERM) are not noticeably different from those under the flexible system, owing to occasional realignments in the system and regular movements within the ERM target bands. The second is that the implied real exchange rates for each country are slightly more volatile than the nominal exchange rates, owing to the added variability created by differences in national rates of inflation. The third, and most important, is that the gains in exchange rate stability are often purchased at the expense of greater interest rate instability.

The major results that have been reported in Section 1 can be summarised as follows:

(i) no significant increases in asset price volatility were uncovered over the 1975-95 period with the exception of the yen and Japanese stocks;

(ii) the price behaviour of the major currencies was not noticeably different from that of other financial assets, though their short-term variability was frequently much lower;

(iii) the Canadian dollar was generally more stable than the other currencies, both in terms of its short-run movements and its longer-run cycles;

(iv) the ERM provided somewhat greater exchange rate stability than the flexible rate system over the 1975-95 period, but at the expense of greater nominal and real interest rate volatility.

Sizable shifts in the nominal and real effective value of the Canadian dollar over time, and periods of exaggerated short-term variance, as evidenced by the ARCH estimates, suggest that speculative activity might nevertheless have an influence on price behaviour in the Canadian exchange market. The remaining sections of this paper examine trend movements in the Canadian dollar to see if fundamentals or speculative whim play a dominant role in exchange rate determination.

Table 8

Standard deviations in nominal exchange rates
(monthly data)

	1975-80	1980-85	1985-90	1990-95	1975-85	1986-95
Canadian dollar	0.01010	0.00977	0.00913	0.01073	0.00973	0.01004
French franc	0.01176	0.00863	0.00618	0.00601	0.01067	0.00614
Italian lira	0.02072	0.00978	0.00707	0.02081	0.01677	0.01597
Pound sterling	0.02450	0.02177	0.02010	0.01763	0.02365	0.01916

Table 9

Standard deviations in real exchange rates*
(monthly data)

	1975-80	1980-85	1985-90	1990-95	1975-85	1986-95
Canadian dollar	0.01026	0.01001	0.00934	0.01120	0.01000	0.01035
French franc	0.01171	0.00935	0.00636	0.00689	0.01090	0.00662
Italian lira	0.02067	0.01015	0.00739	0.02113	0.01670	0.01613
Pound sterling	0.02463	0.02262	0.02097	0.01769	0.02423	0.01986

* Real exchange rates were calculated by subtracting a 12-month moving average of consumer price inflation differentials from each of the series.

Chart 6

Exchange rates
(five-year rolling average standard deviation)

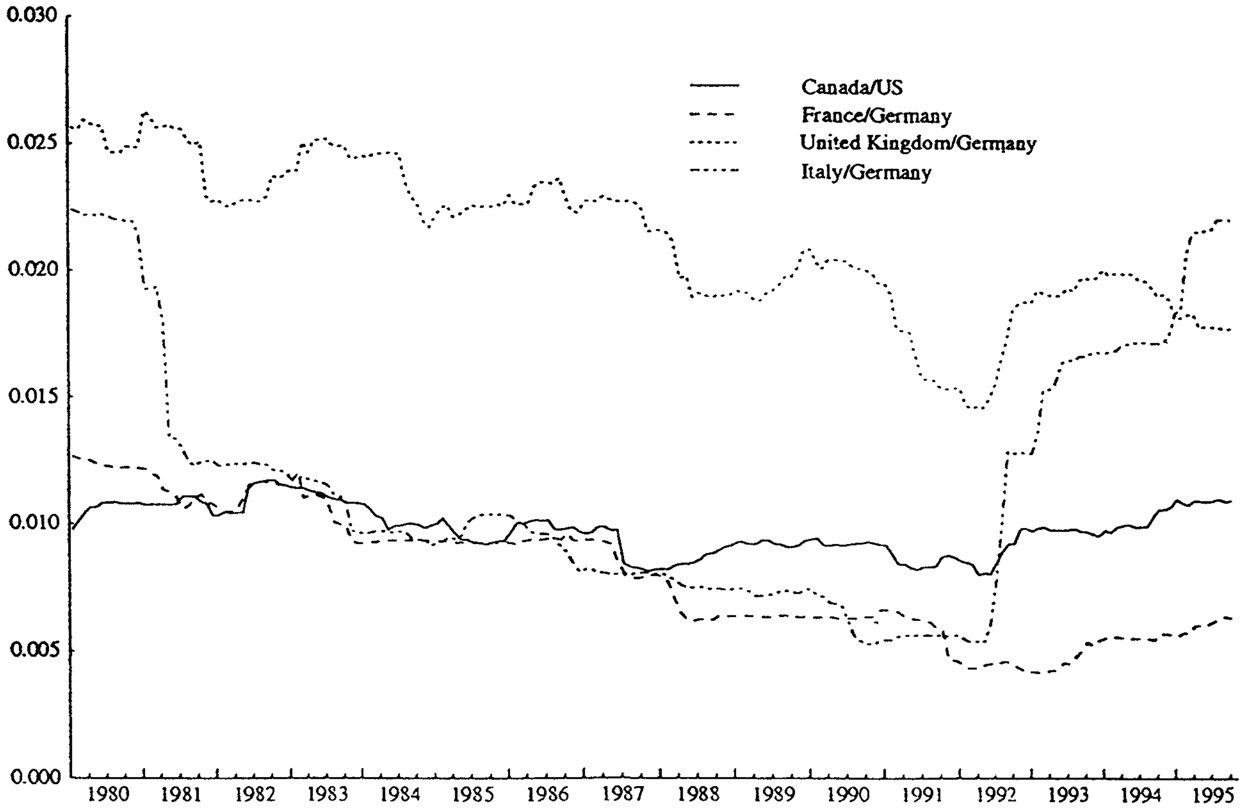


Table 10

Standard deviations in nominal interest rate differentials
(monthly data)

	1975-80	1980-85	1985-90	1990-95	1975-85	1986-95
Canada	1.17164	1.06264	0.55580	0.53863	0.92776	0.5559
France	1.16971	3.05200	1.18633	1.20859	2.67882	1.24499
Italy	2.37580	2.80958	1.07561	0.60497	2.57550	0.88980
United Kingdom ..	1.34727	0.89771	0.50316	0.25713	1.15660	0.40991

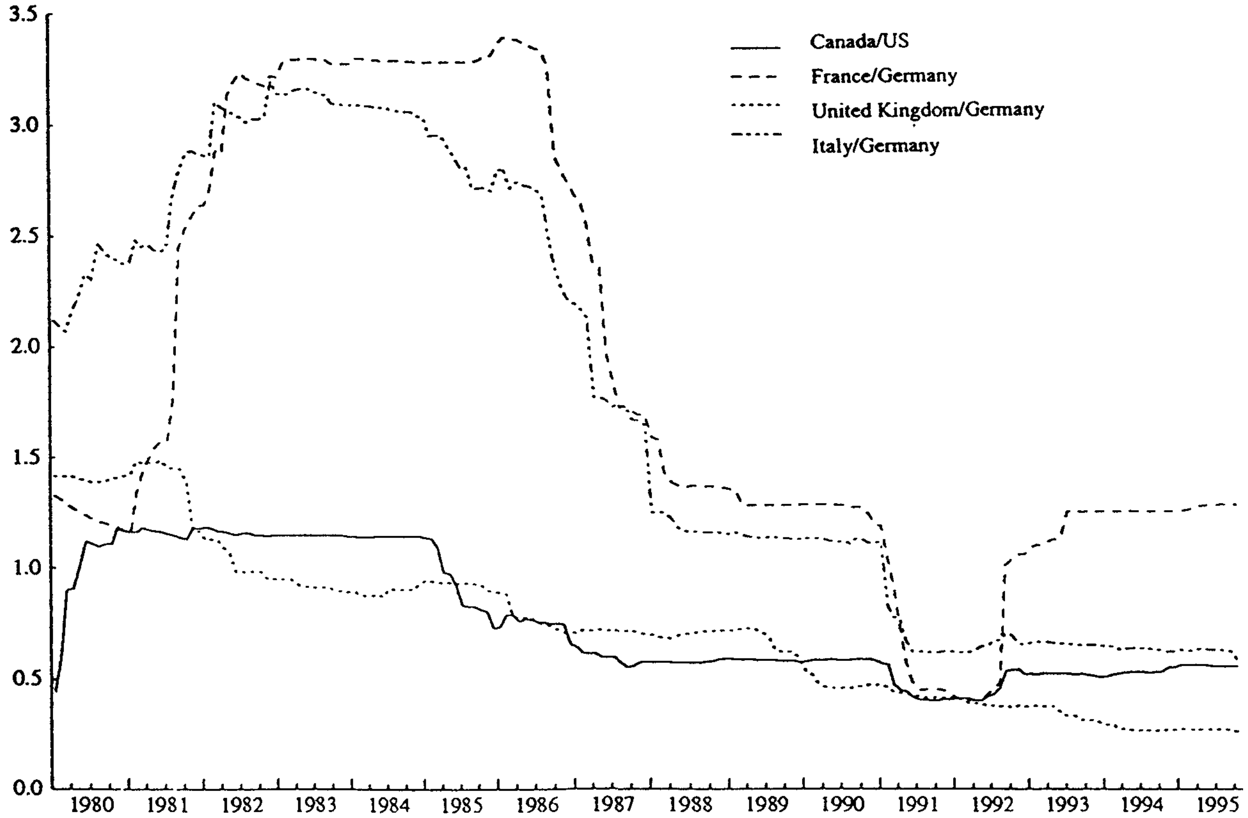
Table 11

Standard deviations in real interest rates
(monthly data)

	1975-80	1980-85	1985-90	1990-95	1975-85	1986-95
Canada	1.21053	1.07187	0.66897	0.58314	0.98516	0.63318
France	1.23519	3.13375	1.16502	1.32062	2.75328	1.28501
Italy	2.59818	2.80443	1.08820	0.69970	2.62358	0.94928
United Kingdom ..	1.61167	1.01531	0.60140	0.44965	1.34845	0.52867

Chart 7

Interest rate differentials
(five-year rolling average standard deviation)



2. Fundamental determinants of the Canadian dollar

In discussions on financial market efficiency and excess volatility, a sharp distinction is typically drawn between erratic short-run movements in asset prices and persistent misalignments. While both forms of volatility can pose a problem for the smooth functioning of real and financial markets, persistent misalignments are generally thought to represent a more serious risk.

Empirical tests of the effect that exchange rate volatility has on international trade and investment flows typically produce small and insignificant results. This could be because active markets in forward contracts, options, futures and swaps make hedging short-term currency risk relatively easy and essentially costless in the major industrial countries. Alternatively, it could be because theory makes no unambiguous predictions for the effect that increased short-run variability has on these international flows.

Persistent misalignments, in contrast, are more difficult to contend with and could seriously distort world trade. Although earlier concerns about the hysteretic effects of large and prolonged currency swings have largely disappeared, few observers would suggest that their influence is entirely benign or inconsequential. It is important therefore to determine whether the swings are driven mainly by economic fundamentals or, as some have suggested, the capricious acts of destabilising speculators, trading on past exchange rate changes and simple technical rules.

Efforts to test the relative importance of economic fundamentals and technical traders in foreign exchange markets are complicated by the fact that there is no generally accepted theory of exchange rate determination. Controlled experiments, analysing what might have happened if speculators had not been present are therefore impossible. Work by Meese and Rogoff (1983) and Backus (1984) has demonstrated that most, if not all, of the models which were popular in the late 1970s and early 1980s were subject to tremendous sample sensitivity and incapable of matching the predictive performance of a simple random walk (even when realised values of the explanatory variables were substituted into the equations).

More recently, however, authors such as MacDonald and Taylor (1992) have had some success in estimating long-run exchange rate relationships for the US dollar and other major currencies, using the cointegration techniques developed and popularised by Engel and Granger (1987). The models presented below apply similar techniques to the Canadian dollar in reduced-form specifications that were first estimated by Amano and van Norden (1993, 1995).

2.1 Purchasing power parity

A traditional starting-point for exchange rate estimation is the Purchasing Power Parity condition (PPP). In the long run, it implies that nominal exchange rates will adjust over time to offset any differences in domestic and foreign rates of inflation, thereby preserving the competitive position of each country. Unfortunately, empirical support for the theory in its simplest form - with no allowance for other real economic factors that might influence the exchange rate - is limited, except over extremely long sample periods. Froot and Rogoff (1995) find evidence of PPP at time horizons extending over 100 to 700 years, while Johnson (1993) finds evidence of PPP for the Canadian dollar in samples of 50 to 80 years. Interestingly, the results for both currencies over shorter sample periods are almost always negative, indicating that it takes about 50 years for PPP to be detectable. Any real economic shocks affecting the currency must, by definition, either be transitory in nature or mutually offsetting, a remarkable coincidence given the events that have taken place during the past 50 to 700 years. These results may have more to say about the discriminatory power of the tests that have been applied, however, than the underlying economic relationships.

Three tests of PPP for the bilateral Canada/US exchange rate over a somewhat shorter period, beginning in 1959 and ending in mid-1995, are reported in Table 12. They are based on real exchange rates calculated with three different indices: the consumer price index (CPI), the wholesale price index (WPI) and the GDP deflator, and uniformly reject PPP. Two standard tests for unit roots, the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP), evaluate the null hypothesis of non-stationarity, while a third test developed by Kwiatkowski, Phillips, Schmidt and Shin (KPSS) evaluates the null hypothesis of stationarity against a unit root alternative. The latter is included as a check on the ADF and PP tests to ensure that a lack of power in these tests will not bias the results against PPP.

Table 12

Unit root tests for the Canadian real exchange rate[1]

(sample period: 1959 Q1 to 1995 Q2)

	ADF[2]	**Lags**	**PP**	**KPSS**
CPI-based	- 2.3398	5	- 3.2100	**0.948**
WPI-based	- 2.7307	6	- 8.4798	**0.659**
GDP-based[3]	- 1.8758	3	- 3.2188	**0.830**

[1] **Boldface** data indicate rejection of the null hypothesis at the 5% significance level. [2] All regressions include a constant term. Lag lengths were selected using a technique suggested by Ng and Perron (1994). [3] GDP data cover the period 1961 Q1-1995 Q2.

As Table 12 indicates, the ADF, PP and KPSS tests are all able to reject stationarity (or mean reversion) in the bilateral real exchange rate. While these results must be regarded as tentative given the (relatively) small sample that is used and the conflicting evidence produced by other authors, for purposes of the present study non-stationarity will be treated as a maintained hypothesis. The rest of this section is directed towards an investigation of the wide and (by assumption) permanent swings observed in the real Canadian dollar.

2.2 Real exchange rate determinants

The number of variables that could be considered as potential determinants of the real bilateral Canada-US exchange rate is very large, and includes (among others): the terms of trade, the current account balance, Canada's net international indebtedness, the government deficit, and alternative measures of excess domestic demand. Since the real exchange rate is known to have a unit root, only variables that are non-stationary and integrated of order one can qualify as prospective long-run explanatory variables.

Summary statistics for the three variables that were ultimately selected for the exchange rate equation by Amano and van Norden (1995) are shown in Table 13 along with the results of unit root tests based on ADF, PP and KPSS regressions. The real exchange rate (RFX), the terms of trade in non-energy commodities (TOTCOMOD) and the terms of trade in energy commodities (TOTENRGY) were all found to have unit roots.[10] Interest rate differentials (RDIFF), in contrast, were stationary. While this implies that RDIFF has no long-run relationship with RFX, later results suggest that it plays an important role in the short-run dynamics of the real exchange rate.

Once variables with a unit root have been identified, a second battery of tests must be applied to the data to check for cointegrating relationships. The tests are based on a single equation cointegration procedure introduced by Hansen (1990) and a systems approach developed by Johansen and Juselius (1990) (see Table 14). The fact that we find significant evidence of cointegration from both tests implies that TOTCOMOD and TOTENRGY can account for all of the significant long-run movements in RFX.

10 In these and other tests reported in this section, RFX is defined as the real bilateral Canada/US exchange rate based on the CPI.

Table 13

Tests for unit roots and stationarity: Augmented Dickey and Fuller (ADF), Phillips and Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests

(sample period: January 1973 to February 1992)

Variable[1]	ADF lag length[2]	ADF	PP[3]	KPSS[4]
RFX	13	- 1.790	- 1.342	**0.598**
TOTCOMOD	21	- 2.578	- 2.217	**0.565**
TOTENRGY	20	- 1.429	- 2.129	**0.558**
RDIFF	18	**- 3.212**	**- 5.233**	0.067

[1] **Boldface** data represent significance at the 5% levels. The unit-root and cointegration critical values are from MacKinnon (1991). [2] The ADF test uses the lag selection procedure advocated by Hall (1989). We start with 24 lags and test down. [3] The Phillips-Perron test statistic is calculated using the VAR-prewhitened long-run variance estimator developed by Andrews and Monahan (1992). [4] The KPSS test also uses the VAR prewhitened long-run variance estimator developed by Andrews and Monahan (1992). The KPSS critical values are taken from Kwiatkowski, Phillips, Schmidt and Shin (1992).

Table 14

Tests for cointegration

Hansen ADF and PP tests		
H-ADF lag length[1]	**H-ADF**	**H-PP[2]**
12	- 3.517	- 13.369
Johansen and Juselius test for cointegration[3]		
Number of lags	**Trace statistic**	**λ^{max} statistic**
20	47.752	28.536

[1] The ADF test uses the data-dependent lag selection procedure advocated by Hall (1989). We start the testing-down with the ADF lag length set equal to twice the seasonal frequency or 24. [2] The Phillips-Perron test statistic is calculated using the VAR pre-whitened long-run variance estimator developed by Andrews and Monahan (1992). [3] Appropriate lag lengths for the Johansen and Juselius test are determined using standard likelihood ratio tests with a finite-sample correction. However, depending on the exact critical values used, this test suggested using 15, 20 or 23 lags. Fortunately, the cointegration results were not sensitive to the choice of lag length.

The final step in the analysis is the estimation of an error-correction model (ECM). The Engle-Granger Representation Theorem implies that any system of cointegrated variables that has an ARIMA representation can be written as a ECM with the following form:

$$\Delta X = \alpha \cdot (X_{-1} \cdot \beta) + \sum_{j=1}^{n} \Delta X_{-j} \cdot \gamma_j + \varepsilon, \tag{2}$$

where vector $X \cdot \beta$ represents the deviation of X from its desired long-run or equilibrium value, α is the speed at which deviations between X and the equilibrium value are closed, and $\Delta X_{-j} \cdot \gamma_j$ captures the short-run dynamics between X and other variables. Cast in terms of RFX and its explanatory variables, the ECM that was eventually estimated appears as:

$$\Delta RFX = \alpha \cdot (RFX_{-1} + \beta^C \cdot TOTCOMOD_{-1} + \beta^E \cdot TOTENRGY_{-1}) + \gamma \cdot RDIFF_{-1} + \varepsilon. \quad (3)$$

The parameter values and test statistics are shown in Table 15, estimated with monthly data from January 1973 to February 1992.

Table 15

Error-correction model estimates for RFX

(monthly data: January 1973 to February 1992)

Variable	Parameter estimate	Standard error	t-statistic	Significance level
Constant	0.552	0.097	5.681	0.000
Speed of adjustment - α	- 0.038	0.011	- 3.446	*
TOTCOMOD	- 0.811	0.296	- 2.736	0.006
TOTENRGY	0.223	0.060	3.700	0.000
RDIFF	- 0.187	0.0043	4.390	0.000
R^2	**$\bar{R}^2$**	**Durbin-Watson**	**Ljung-box**	**Significance (45 lags)**
0.1233	0.1077	1.877	54.82	0.15

* The t-statistic for this parameter does not have the standard distribution under the null hypothesis, so conventional significance levels do not apply.

All of the estimates are significant (with the exception of α) and the intra-sample fit as shown in Chart 8 is remarkably close. A simple specification with only three explanatory variables is evidently able to capture most of the major movements in the real Canada/US exchange rate. Rolling Chow tests indicate that all of the parameters are stable and that the relationship shows no evidence of significant structural breaks. The negative sign on TOTCOMOD suggests that higher real commodity prices cause the exchange rate to appreciate, as one would expect given Canada's position as an important net exporter of primary materials. The parameter estimate implies that a 1% increase in TOTCOMOD produces a 0.811% appreciation in RFX, as higher world commodity prices improve our terms of trade and put upward pressure on the currency.[11] Higher interest rate differentials vis-à-vis the United States also have a favourable, though transitory, effect on the real exchange rate.

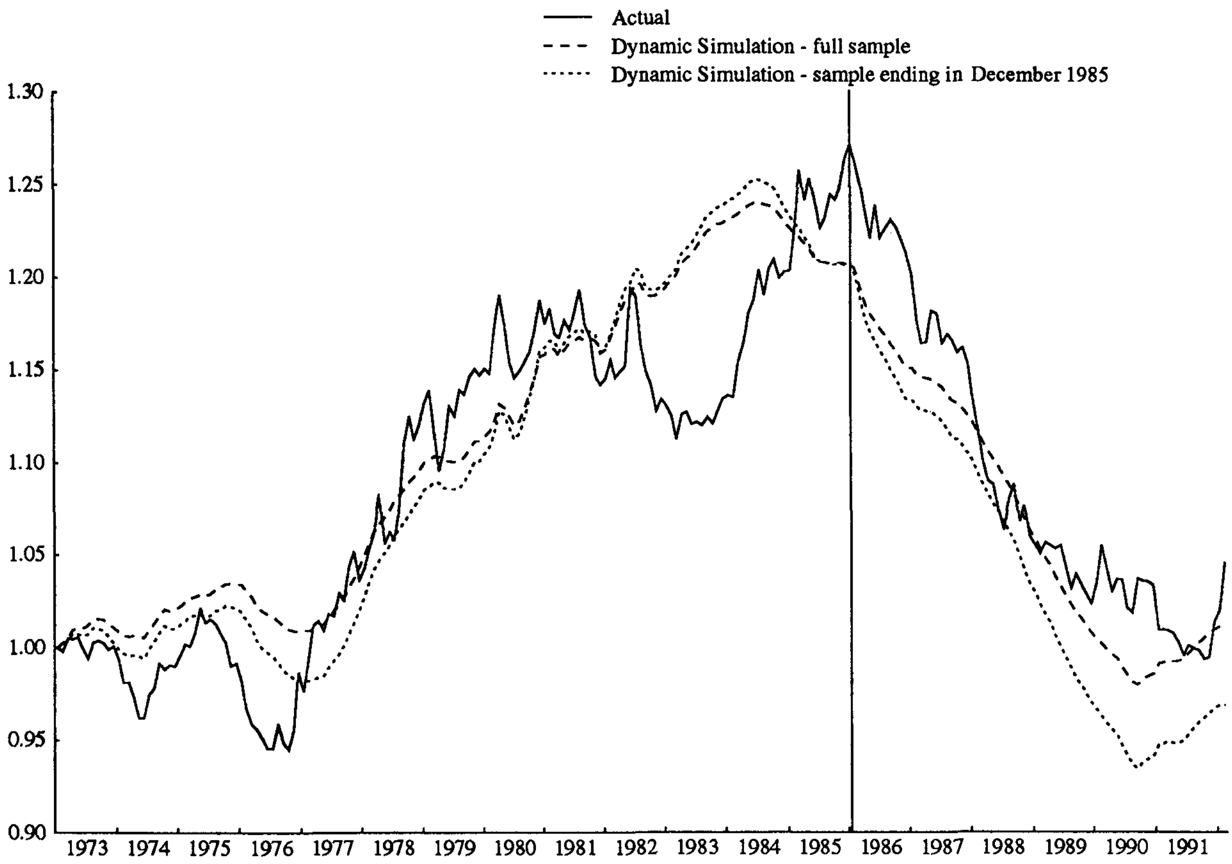
The only two surprises in the estimated model are the speed of adjustment α, which is somewhat slower than might have been expected, and TOTENRGY, which seems to have a depressing effect on the Canadian dollar. α has an estimated value of -0.038, implying that about 37% of any deviation between the long-run value of RFX and its current value is eliminated within a year. While this is not inordinately slow compared to many other specifications and does not appear to affect the explanatory power of the equation, conventional wisdom suggests that financial markets tend to clear at a much faster rate.

The negative coefficient on TOTENRGY is even more puzzling, but might be explained by the fact that Canadian manufacturing tends to be more energy-intensive than that of other nations. Increased energy prices might therefore impose sizable costs on Canadian industries and offset the benefits that Canada would otherwise realise from higher energy exports.

11 The real exchange rate is defined as Canadian dollar/US dollar, so appreciations of the Canadian dollar imply RFX falls.

Chart 8

Dynamic simulations of the RFX equation



The Ljung-Box and Durbin-Watson test statistics indicate that the residuals are generally well-behaved, with no sign of serial correlation. Although normality can be rejected at marginal significance level of 0.4 based on the Jarque-Bera test, the hetroskedasticity that was highlighted earlier in the ARCH tests in Section 1 seems to have been largely eliminated.

The predictive power of the equation, as demonstrated by its dynamic simulations and out-of-sample forecasts, is also quite reasonable and easily beats a random walk. The latter would have predicted an unchanged RFX throughout the sample period based on dynamic simulations. Cutting the sample period at February 1986 when the Canadian dollar was at an all-time low (see Chart 8) and re-estimating the equation produces almost identical results - further evidence of the stability of the relationship.

Nevertheless, there are periods in which the actual value of RFX deviates from its fitted value for an extended time and appears to over- or undershoot its equilibrium level. While omitted variables and misspecified dynamics represent possible explanations, the pattern is also consistent with the trading activities of chartists and other market participants whose mechanical and non-fundamental approach to transacting could destabilise the market. This is the topic of Section 3.

3. Speculative bubbles, chartists and excess volatility

Market observers have long maintained that trading in the foreign exchange market is dominated by agents who have little regard for fundamentals and instead base their projections on past changes in the exchange rate (i.e. momentum). The results, critics suggest, are exchange rates which are unnecessarily erratic and often inconsistent with equilibrium values. In the extreme, misguided traders and their mechanical trading strategies lead to speculative bubbles and eventual crashes. The exaggerated movements of the US dollar over the 1980s are perhaps the best known example of a speculative bubble and the one most often cited by proponents of this view.

The first researchers to formally model the interaction of fundamentalists and chartists were Frankel and Froot (1986). They began with a general model of the exchange rate that can be written:

$$s_t = cE\Delta s_{t+1} + X_t, \tag{4}$$

where s_t is the log of the exchange rate, $E\Delta s_{t+1}$ is the expected change in the exchange rate, and X_t is a vector of other exchange rate determinants. In Frankel and Froot's model, the expected change in the exchange rate is a weighted average of the expectations of fundamentalists and chartists.

$$E\Delta s_{t+1} = \omega_t E\Delta s^f_{t+1} + (1-\omega_t)\, E\Delta s^c_{t+1} \tag{5}$$

The weights ω_t are determined by a portfolio manager who favours the group that was most successful in the latest period.

The fundamentalist forecast is $Es^f_{t+1} = \theta(\tilde{s} - s_t)$ where $\tilde{s}$ is the fundamentalist forecast of the equilibrium exchange rate, and θ is the speed at which the actual s_t is expected to converge on the equilibrium rate.

In the simplest form of the chartist model, the expected future exchange rate change is assumed to be a random walk, $E\Delta s^c_{t+1} = 0$. Other authors such as DeGrauwe and Dewachter (1994) embed more elaborate representations of chartist behaviour in their models, but the basic structure of Frankel and Froot's model is essentially unchanged.

None of the authors noted above have directly tested the fundamentalist and chartist model, however. The lack of testing is due both to unobservable components in the model (which make it difficult to use standard estimation techniques) and the absence of a reliable model of fundamentalists' expectations. Vigfusson (1995) addresses these concerns by applying the fundamental model described above in Section 2 to a two-regime Markov switching specification. The main ingredients of the Markov-switching model are two forecasting equations, for the fundamentalists and chartists, respectively, and two transition equations. The forecasting equations are modelled as:

$$\Delta y_t = \theta(\tilde{y}_{t-1} - y_{t-1}) + \beta F_t + \varepsilon^f_t \qquad \varepsilon^f_t \sim N(0, \sigma^2_f) \tag{6}$$

$$\Delta y_t = \Psi(y_t) + \Gamma C_t + \varepsilon^c_t \qquad \varepsilon^c_t \sim N(0, \sigma^2_c).$$

The two transition equations are based on a stationary Markov chain in which the probability of being in regime r given last period's regime is constant over time.[12]

$$p\,(r_t | r_{t-1}) = \Phi\,(\alpha_f) \tag{7}$$

$$p\,(r_t | r_{t-1}) = \Phi\,(\alpha_c), \tag{8}$$

where $p(r_t)$ is the probability of being in regime r. The objective of the portfolio manager, as represented by the Markov model, is to maximise the log likelihood function

$$LLF = \sum_{t=1}^{T} \sum p(r_t)\, d\,(s_t | r_t), \tag{9}$$

where $d(s_t| r_t)$ is the normal density function of the regime's residual.

12 Alternative specifications based on variable transition probabilities are reported in Vigfusson (1995).

3.2 Empirical results

The equilibrium value of the exchange rate in the fundamentalist forecasting equation is estimated[13] using daily bilateral exchange rate data from January 1983 to December 1992, with the terms-of-trade based exchange rate[14] as the fundamentalist forecast of the equilibrium exchange rate, a constant and a short-term interest rate differential:

$$\Delta s_t = f + \theta(\tilde{s}_{t-1} - s_{t-1}) + \beta i_{t-1} + \varepsilon_t^f \,. \tag{10}$$

The chartist trading strategy is proxied by two moving averages: a short-term moving average and a long-term moving average. Whenever the 14-day (short-term) moving average of exchange rates exceeds the 200-day (long-term) moving average, the chartist buys the currency. If the 14-day moving average is lower than the 200-day moving average, the currency is sold. The chartists' forecast, like those of the fundamentalists, are also conditioned by an interest rate differential and a constant:

$$\Delta s_t = c + \psi_{14} ma_{14} + \psi_{200} ma_{200} + \Gamma i_{t-1} + \varepsilon_t^c , \tag{11}$$

where f and c are constants, and i is the interest rate spread on Canadian and US 30-day commercial paper. The estimated coefficients are shown in Table 16.

Table 16

Parameter estimates for the Markov switching model

(sample period: daily data, January 1983 to December 1992)

	f	θ	β	σ_f	α_f	
Fundamentalists	0.0001 (2.729)*	0.0119 (2.243)	0.0002 (0.381)	0.0018 (26.371)	1.2656 (10.076)	
	c	ψ_{14}	ψ_{200}	Γ	σ_c	α_c
Chartists	0.0002 (1.573)	0.0070 (2.381)	- 0.0079 (- 2.677)	- 0.0007 (- 4.000)	0.0007 (33.634)	1.6784 (17.704)

* t-statistic is shown in parentheses under the parameter estimate.

Most of the coefficients are statistically significant and correctly signed (the only insignificant coefficient is the interest rate term in the fundamentalist equation). Test statistics on the score matrix evaluated at the above parameter estimates (White, 1995) suggest that ARCH errors are no longer a problem (as was the case with the equation estimated in Section 2), and likelihood ratio tests indicate that the only restriction accepted by the equations is one that imposes equal but oppositely signed coefficients on the two moving average terms.

The coefficients α_f and α_c measure the degree of persistence in the chartist and fundamentalist regimes. The resulting long-run probabilities for each regime are 0.31 and 0.69, respectively, indicating that the chartist regime dominates the market about twice as often as the fundamentalist regime. This result is consistent with the survey evidence of Allen and Taylor (1992), who found that market participants used chartist strategies about 90% of the time for short-term forecasts (up to one week) and regarded chartism "at least as important as fundamentals" roughly 60% of the time.

13 The model was estimated using the Bank of Canada's regime-switching procedures (1995).

14 Daily fitted values were generated with a cubic spline.

What is perhaps most important in these results, however, is the fact that chartists not only dominate the market on a typical trading day, but do so on occasions when the exchange rate is relatively stable and displays low variance. Fundamentalists, in contrast, tend to dominate on fewer occasions, and only when rates are moving in a more volatile manner. One interpretation of this surprising outcome is that fundamentalists come into the market only when the rate has deviated significantly from its equilibrium value and requires a correction. Turbulent conditions are therefore associated with equilibrating adjustments, which tend to reverse the cumulative errors made by the chartists.

Chart 9 describes the probability of being in the fundamentalist regime along with the level of the exchange rate. (The probability of being in the chartist regime is just one minus the probability of being in the fundamentalist regime.) Periods with a high probability of being in the fundamentalist regime are not very frequent and do not last for very long, while periods with a low probability of being in the fundamentalist regime (high probability of being in the chartist regime) are more frequent and last for much longer.

For Chart 10, exchange rate changes were sorted by size and placed in bins of uniform size (25 observations each). For each bin, the average probability of being in the fundamentalist regime was calculated. The results are plotted with the bins ranked in ascending order of size of change. As shown here, the fundamentalists only dominate when there are large changes in the exchange rate. For small changes the chartists are found to be the dominant group.

The implications of this for intervention policy and the choice of exchange rate system are examined in the next section. Although strong evidence of speculative behaviour has been uncovered, it is typically associated with periods of relative stability and low volatility in the market. Turbulent conditions, in contrast, are related to the actions of fundamentalists restoring the equilibrium value of the exchange rate.

Chart 9

Exchange rate and probability of fundamentalist regime

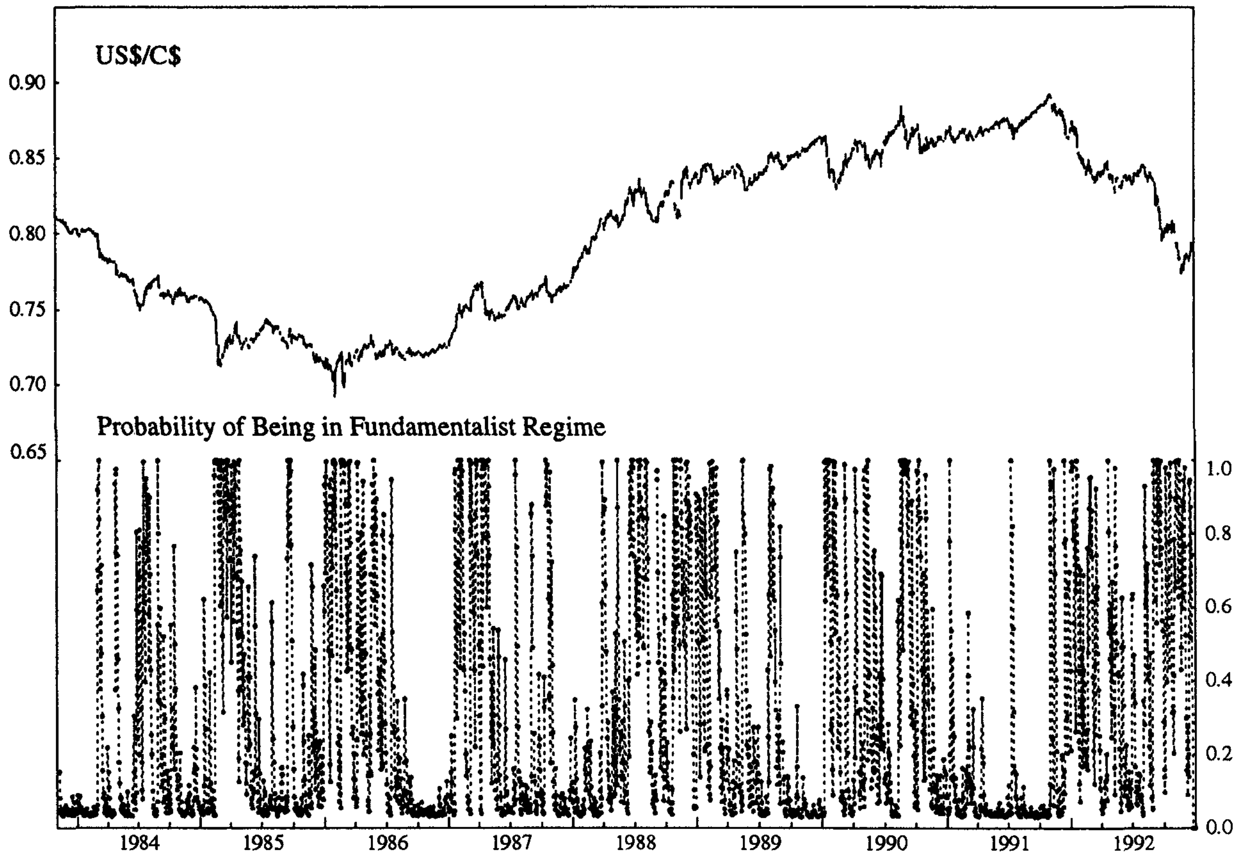
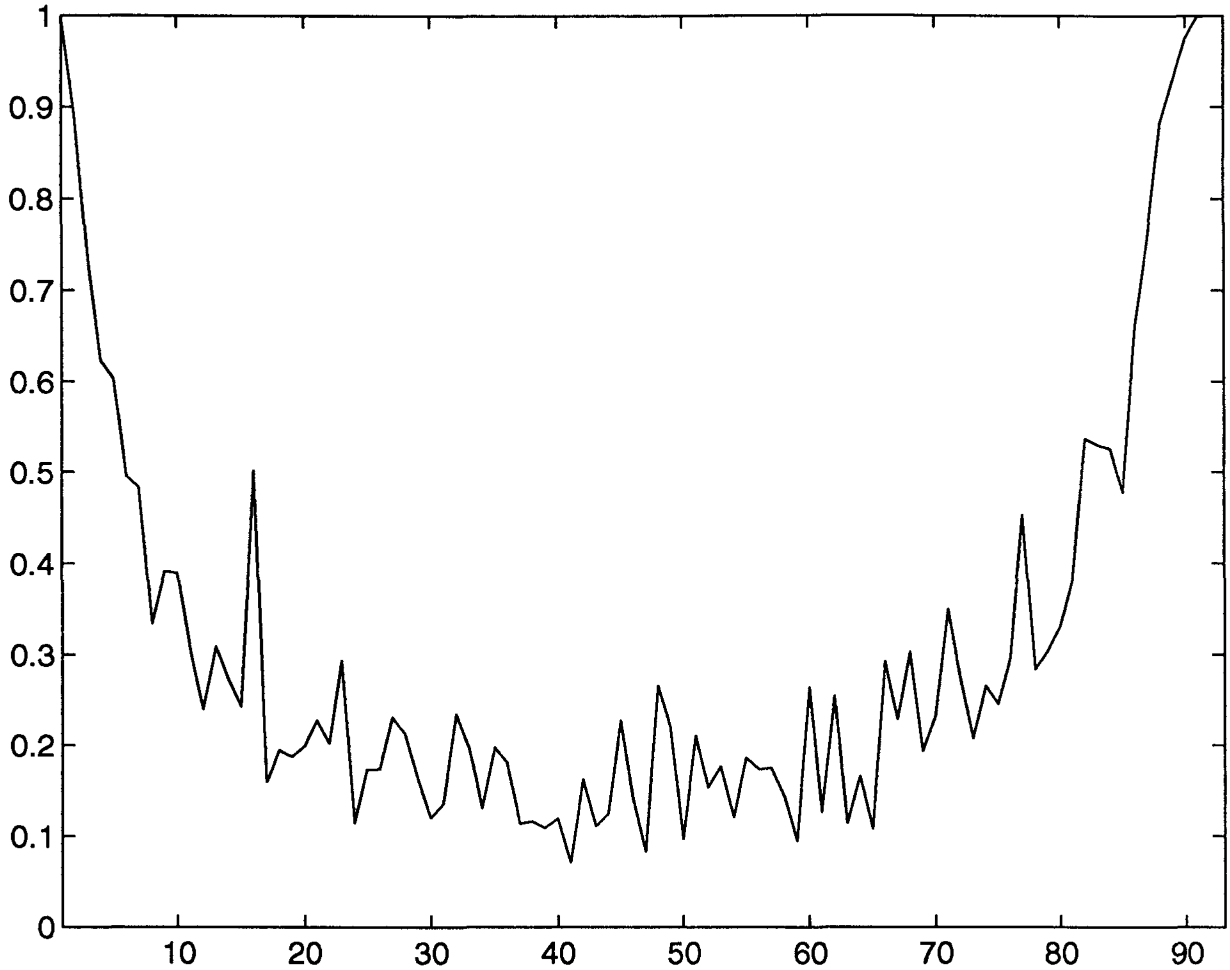


Chart 10

Average probability of being in the fundamentalist regime



Conclusion

Three main conclusions can be drawn from the empirical evidence reported above. The first is that excess volatility does not appear to be a serious problem for the Canadian dollar or for most other financial assets that we examined. Neither does volatility appear to be increasing through time. Any relationship that might exist between volatility and trade volumes would appear to be negative, therefore, with larger trade volumes generally improving market liquidity and helping to stabilise prices.

The second conclusion is that most of the wide swings that have been observed in exchange rates over the 1975-95 period can be explained by economic fundamentals, and originate on the real side of the economy as changes in the terms of trade and primary product prices. Persistent misalignments, in which asset prices become detached from economic fundamentals for an extended period of time, are rare and often related to an unusual or unfortunate sequence of events. Although the Canadian dollar has deviated on occasion from the levels that were predicted by the simple model described in Section 2, many of these episodes can be attributed to political developments and other risk-related factors that are not easily captured in the equation.

The third and final conclusion is that market turbulence may be a necessary by-product of stabilising speculative behaviour. While the Markov switching models examined in Section 3 were able to identify long periods during which chartists or noise traders seem to have dominated the exchange market, these periods were often more stable or quiescent than those dominated by fundamentalists. Chartists, using simple rules of thumb keyed off past exchange rate movements, lend a type of inertia force to the market which over time may cause rates to drift from their equilibrium values. Fundamentalists, in contrast, are more sensitive than chartists to shocks that cause the underlying exchange rate to shift, and enter the market periodically to correct the pricing errors of their chartist colleagues. These periods of correction are often characterised by greater volatility.

The policy implications that one draws from the results can also be divided into three groups. The first concerns the use of Tobin taxes and other forms of capital controls. Since the volatility that was reported in Section 1 was not judged to be inordinately high or increasing over time, it is difficult to make a convincing case for any of these remedies. This is true even if the restrictions could be applied in an effective and equitable manner. Indeed, to the extent they were effective, they would only reduce market liquidity and make asset prices more erratic.

The evidence presented in Section 1, as well as the encouraging model results reported in Section 2, also have implications for the choice of exchange rate regime. Arguments raised in support of pegged exchange rates and more ambitious forms of international policy coordination frequently assume that financial markets are inherently unstable and driven by reckless traders with no sense of fundamentals. The time series behaviour of exchange rates, bond prices and stocks over the past twenty-five years does not offer any evidence consistent with these views, however. It suggests instead that pegged exchange rate systems may actually be more volatile than flexible exchange rates in terms of their net impact on exchange rate and interest rate variability over time. More important perhaps were the results in Section 2, which demonstrated that most of the major swings in the Canadian dollar were predictable and consistent with economic fundamentals. The case for pegged exchange rates must therefore rest on other arguments, such as greater policy discipline and reduced transactions costs. These must be weighed against the advantages afforded by flexible exchange rates, usually cast in terms of increased monetary policy independence and greater insulation from external shocks.

The third and final set of implications concerns the conduct of foreign exchange market intervention, and is in many ways the most intriguing and significant. Taken at face value, the Markov model presented in Section 3 would suggest that official sales and purchases of foreign exchange merely add to the inertia that is already present in markets owing to the actions of technical traders. Market turbulence, in contrast, is associated with fundamentalists and the restoration of equilibrium prices. In situations such as these, a case can be made for leaning with the wind rather than against it. Instead of resisting exchange rate changes, central banks should perhaps wait until markets have started to move and then assist the re-equilibration process by pushing rates in the same direction. Current intervention strategies are often based on the assumption that all exchange rate movements are bad and should be resisted. A more selective approach, based on the presumption that the market is innocent until proven guilty, might be a more appropriate operating rule.

The evidence reported above is necessarily partial, and should be interpreted with care. It nevertheless provides a useful counter to those who favour more restrictive and interventionist measures. At least in the case of the Canadian dollar, volatility would seem to be a "real" issue only in the sense that it is driven by real economic forces as opposed to speculative excesses. The problems that are associated with it, in contrast, appear to be more imaginary than real.

References

Amano, Robert and Jeff Gable (1994): "Statistical properties of daily Canada-US exchange rates: 1980-93", Bank of Canada manuscript.

Amano, Robert and Simon van Norden (1993): "A forecasting equation for the Canada-US dollar exchange rate", Proceedings of a Bank of Canada Conference, pp. 207-265.

Amano, Robert and Simon van Norden (1995): "Terms of trade and real exchange rates: the Canadian evidence", *Journal of International Money and Finance*, 14: pp. 83-104.

Amano, Robert and Simon van Norden (1995): "Exchange rates and oil prices", Bank of Canada Working Paper, pp. 95-8.

Backus, David (1984): "Empirical models of the exchange rate: separating the wheat from the chaff", *Canadian Journal of Economics*, 17: pp. 824-846.

Baillie, Robert and T. Bollerslev (1989): "The message in daily exchange rates: a conditional-variance tale", *Journal of Business and Economic Statistics*, 7: pp. 297-306.

Bollerslev, T. (1987): "Generalized autoregressive conditional hetroskedasticity", *Journal of Econometrics*, 31: pp. 307-327.

Bollerslev, T. (1978): "A conditionally hetroskedastic time series model for speculative prices and rates of return", *Review of Economics and Statistics*, 9: pp. 542-547.

DeGrauwe, Paul and Hans Dewachter (1992): "Chaos in the Dornbusch model of the exchange rate", *Kredit and Capital*, pp. 27-54.

DeGrauwe, Paul (1994): "Exchange rates in search of fundamental variables", Centre for Economic Policy Research Discussion Paper, No. 1073, December.

DeLong, J. Bradford, Andrei Shleifer, Lawrence Summers and Robert Waldman (1990a): "Noise trader risk in financial markets", *Journal of Political Economy*, 98: pp. 4.

DeLong, J. Bradford, Andrei Shleifer, Lawrence Summers and Robert Waldman (1990b): "Positive feedback strategies and destabilizing rational speculation", *Journal of Finance*, 45: pp. 379-95.

Dickey, David and William Fuller (1979): "Distribution of the estimators for autoregressive time series with a unit root", *Journal of the American Statistical Association*, 74: pp. 427-431.

Engel, Charles (1993): "Real exchange rates and relative prices", *Journal of Monetary Economics*, 32: pp. 35-50.

Engel, Charles and James Hamilton (1990): "Long swings in the dollar: are they in the data and do markets know it?", *American Economic Review*, September 80: pp. 689-713.

Engel, Charles (1994): "Can the Markov switching model forecast exchange rates?", *Journal of International Economics*, 36: pp. 151-165.

Engle, Robert (1982):"Autoregressive conditional hetroskedasticity with estimates of the variance of the United Kingdom inflation", *Econometrica*, 50: pp. 987-1007.

Engle, Robert and Charles Granger: (1987): "Cointegration and error correction: representation, estimation and testing", *Econometrica*, 55: pp. 251-276.

Frankel, Jeffrey and Kenneth Froot (1988): "Chartists, fundamentalists and the demand for dollars", *Greek Economic Review*, 10: pp. 49-102.

Froot, Kenneth and Kenneth Rogoff (1994): "Perspectives on PPP and long-run real exchange rates", N.B.E.R. Working Paper, No. 4952, December.

Froot, Kenneth, Michael Kim and Kenneth Rogoff (1995): "The law of one price over 700 years", N.B.E.R. Working Paper, No. 4952.

Gable, Jeff, Simon van Norden and Robert Vigfusson (1995): "Analytical derivatives for Markov-switching models", Bank of Canada Working Paper, pp. 95-7.

Goodhart, Charles (1988): "The foreign exchange market: a random walk with a dragging anchor", *Economica*, 220: pp. 437-460.

Huizinga, John (1987): "An empirical investigation of the long-run behaviour of real exchange rates", *Carnegie-Rochester series on Public Policy*, 27: pp. 149-215.

Johansen, S. and K. Juselius (1990): "Maximum likelihood estimation and inference on cointegration with application to the demand for money", *Oxford Bulletin of Economics and Statistics*, 52: pp. 169-210.

Johnson, David (1992): "Unit roots, cointegration and purchasing power parity: Canada and the United States 1970-1991", in *The Exchange Rate and the Economy*, Proceedings of a Bank of Canada Conference, pp. 133-198.

Kwiatkowski, D., P. Phillips, P. Schmidt, and Y. Shin (1992): "Testing the null of stationarity against the alternative of a unit root: how sure are we that economic time series have a unit root?", *Journal of Econometrics*, 54: pp. 159-178.

Lafrance, Robert (1988): "Technical note: measuring Canada's international competitiveness", *Bank of Canada Review*, September, pp. 17-32.

Lafrance, Robert and Simon van Norden (1995): "Exchange rate fundamentals and the Canadian dollar," *Bank of Canada Review*, Spring, pp. 17-33.

MacDonald, Ronald and Mark Taylor (1992): "Exchange rate economics: a survey", IMF Staff Papers, 39: pp. 1-57.

Meese, Richard and Kenneth Rogoff (1983): "Empirical exchange rate models of the seventies: do they fit out of sample?", *Journal of International Economics*, 14: pp. 3-24.

Meese, Richard and Kenneth Rogoff (1988): "Was it real? The exchange rate interest rate relation, 1973-1984", *Journal of Finance*, 43: pp. 933-948.

Ng, Serena and Pierre Perron (1994): "Unit root tests in ARMA models with data dependent methods for the selection of lag length", *Journal of the American Statistical Association*, 90: pp. 268-281.

Phillips, P. and Pierre Perron (1988): "Testing for a unit root in time series regressions", *Biometricka*, 75: pp. 335-346.

Stephenson, Donald R. and Robert Lafrance (1990): "Capital flows, exchange rates and monetary policy: the Canadian experience", *International Capital, Flows, Exchange Rate Determination and Persistent Current-Account Imbalances*, BIS, June, pp. 61-81.

Taylor, Mark and Helen Allen (1992): "The use of technical analysis in the foreign exchange market", *Journal of International Money and Finance*, 11: pp. 304-314.

White, Halbert (1994): *Estimation, inference, and specification analysis*, Econometric Society Monographs, Cambridge University Press.

Vigfusson, Robert (1995): "Switching between chartists and fundamentalists: a Markov regime-switching approach," Bank of Canada manuscript.