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FUNDAMENTAL DETERMINANTS OF THE CANADIAN DOLLAR*

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Fundamental Determinants of the Canadian Dollar

"In other words, for cyclical as well as for more fundamental reasons, the prospects are good for a stronger Canadian currency."

Gordon Thiessen
Bank of Canada, 30 May 1997[1]

1. Introduction

The near-term prospects for the Canadian economy and the Canadian dollar in early 1997 looked very promising. Canada's current account balance had swung into surplus for the first time in eleven years; the federal government deficit had finally been eliminated; public sector debt was now on a clear downward track; world commodity prices had recovered from their 1992-93 lows; the private sector had just gone through a painful process of restructuring and downsizing; and inflation had remained steady at 1 to 2 per cent for more than five years.

While the Governor's exchange rate forecast may seem optimistic in retrospect, this positive outlook was shared by many other observers. Canadian interest rates at both ends of the yield curve had fallen below comparable U.S. rates, suggesting that investors believed the Canadian dollar would soon appreciate against the U.S. dollar and continue to strengthen for several years to come. Some noted analysts expressed concern that the Canadian dollar might strengthen too quickly, undermining Canada's new-found competitiveness and throwing the economy back into recession.

"Can Canada compete with a higher currency? Shrinking fiscal deficits and the country's first current account surplus in 11 years have put the canadian dollar on a tear. Even in the face of 300 bps of central bank easing, and deeply negative money market spreads to the US, the C$ staged a three cent rally over six months, before its recent retracement. If that momentum reasserts itself, C$ bulls may soon be pointing to 80 cents US as a fair evaluation of C$ fundamentals."

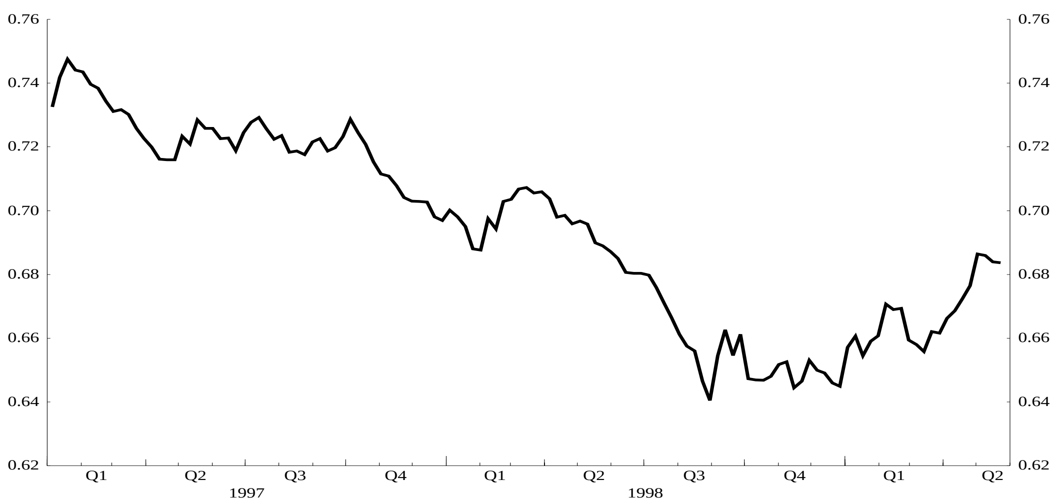
Jeff Rubin and Peter Buchanan
Wood Gundy, 3 December 1996[2]

1. Excerpted from "Flexible Exchange Rates in a World of Low Inflation," remarks by Gordon Thiessen, Governor of the Bank of Canada, to the FOREX '97 Conference in Toronto, 30 May 1997.

While there was widespread agreement among analysts and numerous forecasting groups that the Canadian dollar would soon appreciate, few of them shared Buchanan's and Rubin's concerns about the near-term growth prospects in Canada, or the world economy more generally. Both the IMF and the OECD predicted that growth in Canada would be higher than in any other G-7 country, reaching 3.5 per cent in 1997 and 3.3 per cent in 1998. World output was expected to grow by more than 4 per cent a year, and world trade was expected to increase by more than 9 per cent -- continuing a trend that had started in 1994.

In the event, none of these optimistic predictions came true. Although the Canadian economy did post respectable growth rates of 3.3 and 2.8 per cent in 1997 and 1998, respectively, these rates were not the highest of the G-7. (That honour belonged to the United States which grew by 3.9 per cent in both years.) The performance of the Canadian dollar was even more disappointing. It fell from an average level of U.S. 74 cents in the first quarter of 1997 to a record low of U.S. 63.1 cents in the third quarter of 1998, before rebounding to its current level of U.S. 68.5 cents -- roughly 8 per cent below its starting point (see Graph 1).[3]

Graph 1
Canadian $ vs U.S. $



Weekly Wednesday's (Average)

2. See Jeff Rubin and Peter Buchanan, "Do Fundamentals Justify An 80 Cent C$?" Wood Gundy Economics, Occasional Report #16, 3 December 1996.
3. Of course, were it not for the disappointing performance of the dollar Canada's real growth would have been much lower.

The reasons for the weakness of the Canadian dollar are easy to identify ex post, but few observers were able to predict them ex ante. A brief review of the reports and news letters that were published in the first half of 1997 reveals very few forecasters who anticipated either the sudden collapse in Asia or the "miraculous" performance of the U.S. economy. The IMF, the Governor of the Bank of Canada and messieurs Buchanan and Rubin can perhaps be forgiven, therefore, for not being more perspicacious than the rest of economics profession.

Canada, of course, was not the only industrial country to be affected by the Asian crisis and the resulting collapse in world commodity prices. Other countries, such as Australia and New Zealand, that had more extensive trade links with Asia and were more dependent on sales of raw materials, saw their currencies fall much further. These dramatic depreciations did not provide much comfort to analysts and investors who had counted on a stronger Canadian dollar, however; nor for the Canadian public at large, who awoke each day to find that their currency had hit a new low. Had it not been for the positive forecasts that had preceded this sudden downturn, and the proximity of the surging U.S. economy, the disappointment might not have been so great. There was a widespread sense during much of this period, that the Canadian dollar had fallen further than fundamentals alone could justify. Although some of this angst disappeared with the subsequent recovery of the Canadian dollar, the experience of the last two years has raised new concerns about the destabilizing effects of speculative behaviour in the foreign exchange market and led to calls for a new, more rigid, currency arrangement with the United States, including perhaps the introduction of a North American common currency.

The purpose of the present paper is to examine the behaviour of the Canadian dollar over the past two years and to determine the extent to which our dollar has been oversold or pushed below its "fair market value." The principal tool for our investigation is a simple exchange rate equation which was first developed at the Bank of Canada in the early 1990s. Extensive testing with the equation during the past nine years has shown that it is able to explain most of the broad movements in the dollar over the post-Bretton Woods period.

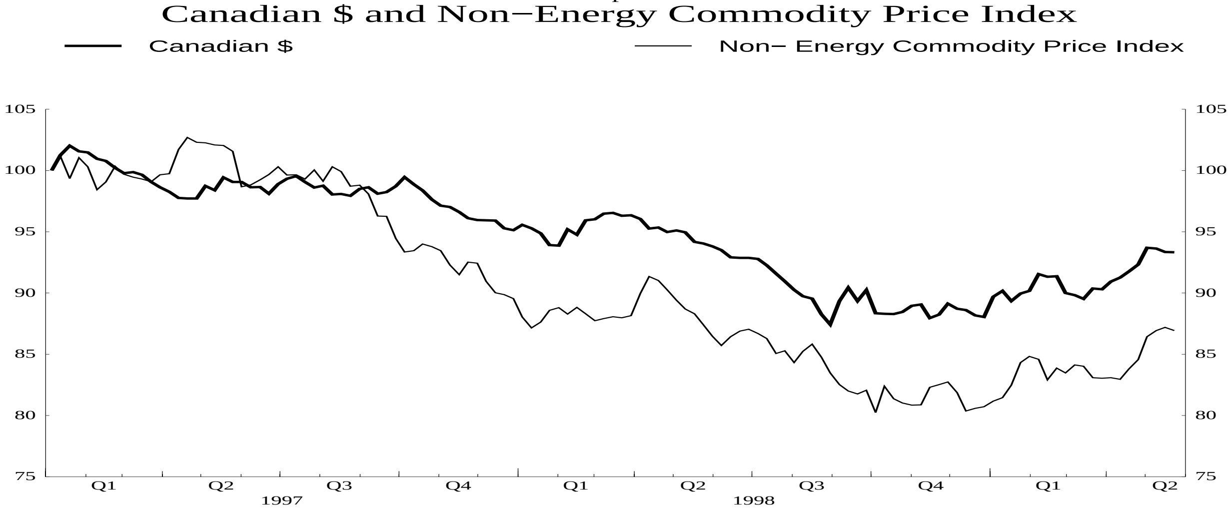
The rest of the paper is organized as follows. Section 2 begins with a brief review of recent economic developments in Canada and the world economy, and compares the performance of the Canadian dollar with that of several other currencies. Section 3 describes the basic exchange rate equation that we use in our analysis, and reports the results of a number of simulations designed to measure the degree to which the dollar has been undervalued. Section 4 extends the analysis by adding two new variables to the equation -- differences in productivity and public debt in Canada and the United States -- to see if they improve its explanatory power. The role of speculative bubbles and destabilizing currency traders is investigated in Section 5 with the aid of regime switching model. The final section of the paper provides a short summary of the main results and some suggestions for future work on the exchange rate equation.

While some evidence of overshooting is detected in the results reported below, a careful review of previous periods suggests that such episodes are not unusual and that any difference between the actual and predicted values of dollar are generally short lived. Most of the weakness that has been observed in the Canadian dollar over the past two years can be explained by two or three independent variables. Moreover, the dollar's current value of U.S. 68.5 cents is very close to the fitted values generated by our original equation. The addition of other variables has no significant effect on the performance of the equation, and there is little evidence of destabilizing speculation. In short, the Canadian dollar is exactly where it should be (or at least close to it).

2. Recent Economic Developments

According the latest IMF estimates, the world economy grew by just 2.5 per cent in 1998, and is expected to grow by only 2.3 per cent in 1999.[4] These rates, assuming they are realized, would be the lowest that the IMF has recorded since the 1991 recession. They would also be significantly lower than the 3.4 per cent pace that was recorded over the 1980-90 period, in the midst of the Latin American debt crisis. World trade, which typically grows at about twice the rate of world GDP, expanded by only 3.3 per cent in 1998, compared to 9.9 per cent in 1997. World commodity prices, which had reached a local peak in early 1996, declined by more than 20 per cent between the first quarter of 1997 and the end of 1998, and have increased only modestly in the last four months as a result of higher oil prices (see Graph 2).

Graph 2
Canadian $ and Non−Energy Commodity Price Index

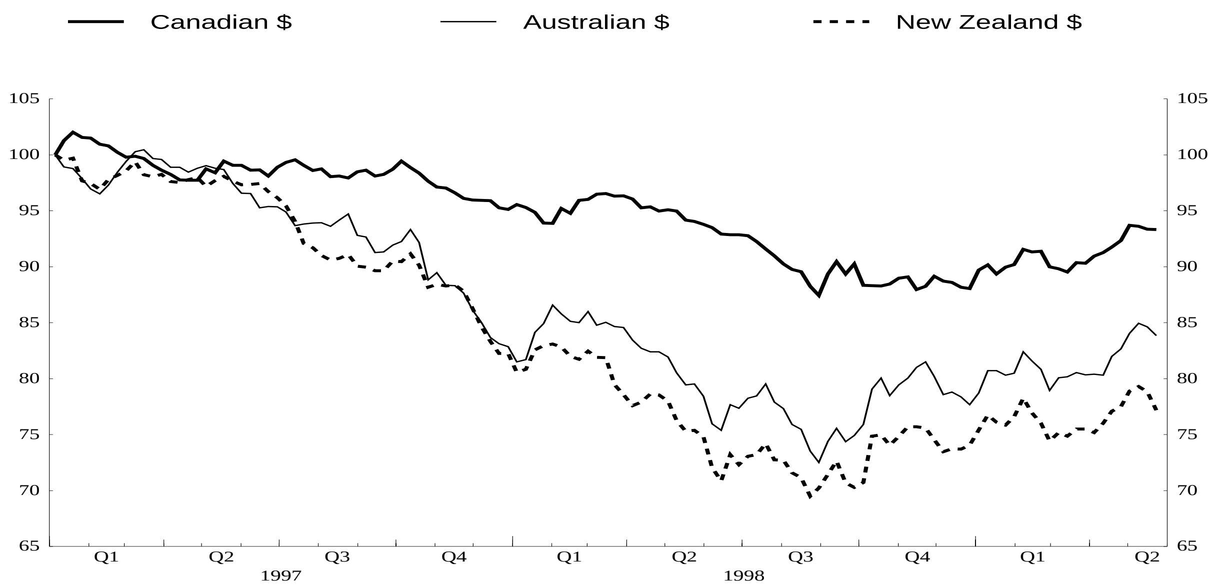


Weekly Wednesday's (Average) − Jan. 8, 1997 = 100

4. IMF World Economic Outlook, May 1999.

The implications of all of these movements for a small, open economy like Canada are clear, especially if it is heavily dependent on commodity exports. A sharp deterioration in our terms of trade, lower real growth and a weak currency were all an inevitable consequence of the Asian crisis. While the Canadian dollar depreciated by more than 15 per cent from its peak in early 1997 to its historic trough in late 1998, other industrial countries saw their currencies fall much further against the U.S. dollar (see Graph 3). The Australian dollar, for example, depreciated by 27 per cent, while the New Zealand dollar lost more than 30 per cent of its value in U.S. dollar terms. These more dramatic declines are understandable given Australia's and New Zealand's stronger trade connections with Southeast Asia and the larger shares of their exports that are devoted to raw materials. In addition, they did not benefit to the same degree as Canada from a strong U.S. economy.

Graph 3
Exchange Rates vs U.S. $



Weekly Wednesday's (Average) – Jan. 8, 1997 = 100

Canada nevertheless went through a difficult period. Over 35 per cent of our exports are still commodity based, and a much larger share of our GDP is exported than either Australia or New Zealand. While real output growth in 1997 and 1998 did not live up to earlier expectations, it was still among the highest of the G-7 and would have been much lower were it not for the sizable depreciation of our dollar. New Zealand, which initially tried to offset the stimulative effects of its weaker currency with higher interest rates, saw its output decline by 2.1 per cent in 1998. Australia and Canada, which adopted more accommodative monetary policy stances, saw their economies grow by 4.7 per cent and 2.8 per cent.

The Asian crisis and the policy reaction functions of different central banks were not the only factors influencing exchange rate movements over this period. Nor were small, open, commodity-based economies the only ones to be affected by large depreciations. The Japanese yen, which had been suffering well before the crisis, fell by an additional 23 per cent in mid-1998, while the major European currencies declined by almost 16 per cent. Although reduced net exports to Asia played an important role in each of these depreciations, they can be credited as much to the amazing strength of the U.S. economy as they can to the weakness of the domestic economies in Japan and Europe. While the Asian crisis represented a significant negative shock for most industrial countries, the softer world commodity prices and the flight to quality that it triggered actually helped support U.S. growth. This asymmetric response to the Asian shock meant that few world currencies appreciated against the U.S. dollar over this period.

As the previous discussion suggests, Canada's experience through the 1997-1998 period was neither unique nor more extreme than that of many other countries. Some depreciation of the Canadian dollar was inevitable given the deterioration in our terms of trade relative to those of the United States. The only remaining question is whether the depreciation was in some sense too large. The next section tries to answer this question by isolating the unexpected component of the dollar's decline with the aid of the Bank of Canada's exchange rate equation.

3. Basic Exchange Rate Equation

The Bank of Canada's exchange rate equation is a simple error-correction model, first developed by Robert Amano and Simon van Norden in 1991. The dependent variable is the real Can-U.S. exchange rate and the three independent variables that are used to explain its movements include: the energy terms of trade, the commodity terms of trade (ex-energy), and the real Can-U.S. interest rate differential. The equation can be written as follows:

$$\Delta \ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c comtot_{t-1} - \beta_e enetot_{t-1}) + \Upsilon intdif_{t-1} + \varepsilon_t \qquad (1)$$

where: *rfx* = real Can-US exchange rate
comtot = non-energy commodity terms of trade
enetot = energy terms of trade
intdif = Can-US interest rate differential

The dependent variable, *rfx*, is simply the nominal Can-U.S. exchange rate deflated by either the CPI or the GDP price index. The choice of deflator makes little difference to the behaviour of the real exchange rate since the CPI and GDP price indices tend to move in a very similar manner over the time horizons relevant for our study. The energy terms of trade, *enetot*, and the commodity terms of trade,*comtot*, are obtained by dividing the U.S. dollar price of energy and the U.S. dollar price of non-energy commodities by the U.S. GDP deflator. The effects of Canadian and U.S.

monetary policy on the real exchange rate are proxied by *intdif*, which is defined as the differential between Canadian and U.S. short-term interest rates.[5]

$$intdif = (i_{st}^{ca} - i_{st}^{us})$$

(a) Unit Root and Cointegration Tests

It is not surprising that commodity prices and Can-U.S. interest rate differentials would play an important role in the determination of the Can-U.S. exchange rate. Canada is a large net exporter of commodities and benefits from an increase in world commodity prices, while the United States is a large net importer of commodities and is hurt by an increase in commodity prices. As a result, the terms of trade for the these two countries typically move in opposite directions. The high degree of capital mobility and asset substitutability between Canada and the United States also imply that investment flows and the Can-U.S. exchange rate are very sensitive to changes in the real interest rate differential. It is important to note, however, Amano and van Norden arrived at the simple specification shown in equation (1) only after testing over a much larger set of explanatory variables. The fact that the relationship has remained stable for the past nine years and retained its explanatory power is remarkable, especially for an exchange rate equation, and is testament to the important influence that the three variables exert on the movements of our dollar.

Amano and van Norden began their search for a new and more reliable exchange rate equation by testing the dependent variable for stationarity. Their results showed that the real exchange rate was non-stationary in levels and was characterized by a unit root. Similar tests conducted over a somewhat longer sample period for the purposes of this paper confirm the earlier results. Based on the Augmented Dickey-Fuller tests shown in Table 1, we cannot reject the null hypothesis of a unit root for *rfx*.

The fact that the dependent variable has a unit root is significant for two reasons. First, cointegration techniques have to be used in the analysis to avoid drawing incorrect and misleading inferences from the regression equations. Second, only variables that are also integrated of order one, I(1), can play a role in determining the long-run behaviour of the real exchange rate.

Unit root tests conducted on the three explanatory variables of the equation suggest that only *enetot* and *comtot* are I(1), while *intdif* is stationary in levels. This is why only the first two variables appear in the error-correction term and *intdif* is left outside the parentheses, influencing the short-term dynamics of the real exchange rate but not its long-run value.

5. In the original Amano-van Norden paper, the energy and commodity terms of trade were deflated by the price of U.S. manufactured goods. The interest rate differentialwas defined as the spread between long-term and short-term interest rates in the United States less the spread between long-term and short-term interest rates in Canada.

Table 1
Tests for Unit Roots
1973Q1 to 1997Q4

Variable	**No. of Lags**	**ADF[a]**
RFX	3	-1.040
COMTOT	5	-1.801
ENETOT	3	-1.360
INTDIF	6	-3.28
5% critical value		-2.89
10 % critical value		-2.58

a. ADF = Augmented Dickey-Fuller

If *enetot* and *comtot* are to play a critical role in determining the value of *rfx*, however, it is not sufficient simply to show that they have a unit root. One also has to show that the dependent variables and the prospective explanatory variables are linked by stable long-run relationship or, in other words, are cointegrated. Although several different approaches can be used to test for cointegration, the most popular and reliable technique is the Johansen-Juselius test which applies maximum likelihood methods to estimate a full vector-autogressive system of equations. The results of this test over the sample period 1973Q1 to 1997Q4 are shown below in Table 2.

Table 2
Johansen - Juselius Tests for Cointegration
on RFX, COMTOT and ENETOT*

No. of cointegrating vectors under the null hypothesis	**λ^{max} statistic**	**5% critical value**
Fewer than 1	32.88	15.59
Fewer than 2	9.47	9.52
Fewer than 3	2.76	2.86
Test for weak exogenity	**LR test**	**Chi-square critical value**
RFX	2.93	3.84
COMTOT	8.96	3.84
ENETOT	4.42	3.84

Note: * no. of lags for J-J test = 20

Based on the λmax statistics only one cointegrating vector was identified at the 5 per cent critical value. There is no guarantee, however, that this vector links *enetot* and *comtot* to *rfx*. It is possible that the two explanatory variables are cointegrated with one another, and have nothing to do with movements in *rfx*. To check for this possibility, a separate test was run just on *enetot* and *comtot*. Since no cointegrating vector was identified (see Table 3), it would appear that the two explanatory variables are only related to *rfx* and manage to capture most of the permanent innovations in the dependent variable. In addition, since the explanatory variables were found to be weakly exogenous, any estimation and inference that is conducted on the single equation (1) will be equivalent to estimation of the full system of equations in which *enetot* and *comtot* are treated as separate dependent variables.[6] One need not worry, therefore, about feedback from the exchange rate to commodity prices.

6. Weak exogeniety is tested at the bottom of Table 2 with the Chi-square statistic.

Table 3
Johansen - Juselius Tests for Cointegration
COMTOT and ENETOT*

No. of cointegrating vectors under the null hypothesis	**λ^{max} statistic**	**5% critical value**
Fewer than 1	6.34	9.52
Fewer than 2	4.45	2.86

Note: * no. of lags for J-J test = 15

(b) Regression Results

Representative results for the basic model estimated over four different sample periods are shown in Table 4. As the reader can see, most of the parameters are statistically significant and have their expected signs. Since the dependent variable is defined in a way that associates downward movements in the exchange rate with appreciations and upward movements with depreciations, the results suggest that increases in *comtot* and *intdif* cause the exchange rate to strengthen, while increases in *enetot* cause it to weaken. While the latter may seem counter-intuitive, and was not expected when Amano and van Norden first ran their regressions, it has proven to be a relatively robust result. Indeed, it was only when energy and non-energy commodities were separated into two variables, and allowed to affect *rfx* in different ways, that the equation was able to work. Earlier results, based on single commodity price variable which combined the two effects, were disappointing.

The way that this unexpected result is rationalized is by noting that Canada is only a marginal net exporter of energy products, but has other industries which are very energy intensive. As a consequence, the benefits realized from larger energy exports when the price of energy increases are more than offset by the costs borne by other Canadian industries, which suffer a loss of competitiveness.

The only other mildly disturbing feature of the regression results is the long implied adjustment lag, α, associated with changes in commodity prices. Although long lags are not unusual in simple reduced-form models of this kind, the mean adjustment lag in equation (1) is approximately 4 quarters. One normally assumes that the response time would be much shorter for an asset price variable such as *rfx*. The more gradual response to commodity price movements that is found here may suggest that agents wait to see if the change is permanent before factoring it into the exchange rate completely.

Table 4
Standard Exchange Rate Equation

Variable	1973Q1 - 1986Q1	1973Q1 - 91Q3	1973Q1 - 96Q1	1973Q1 - 98Q4
Speed of adjustment	-0.198	-0.167	-0.141	-0.127
	(-3.251)[1]	(-3.917)	(-4.149)	(-3.810)
Constant	2.419	1.807	2.728	3.013
	(4.585)	(5.306)	(7.566)	(7.822)
COMTOT	-0.454	-0.368	-0.524	-0.574
	(-4.794)	(-5.713)	(-6.558)	(-6.441)
ENETOT	0.059	0.119	0.070	0.058
	(1.442)	(2.916)	(1.769)	(1.339)
INTDIF	-0.540	-0.519	-0.604	-0.580
	(-2.442)	(-3.105)	(-3.682)	(-4.075)
$\overline{R}^2$	0.218	0.227	0.204	0.196
Durbin-Watson	1.197	1.159	1.265	1.320

Note: [1] t-statistic

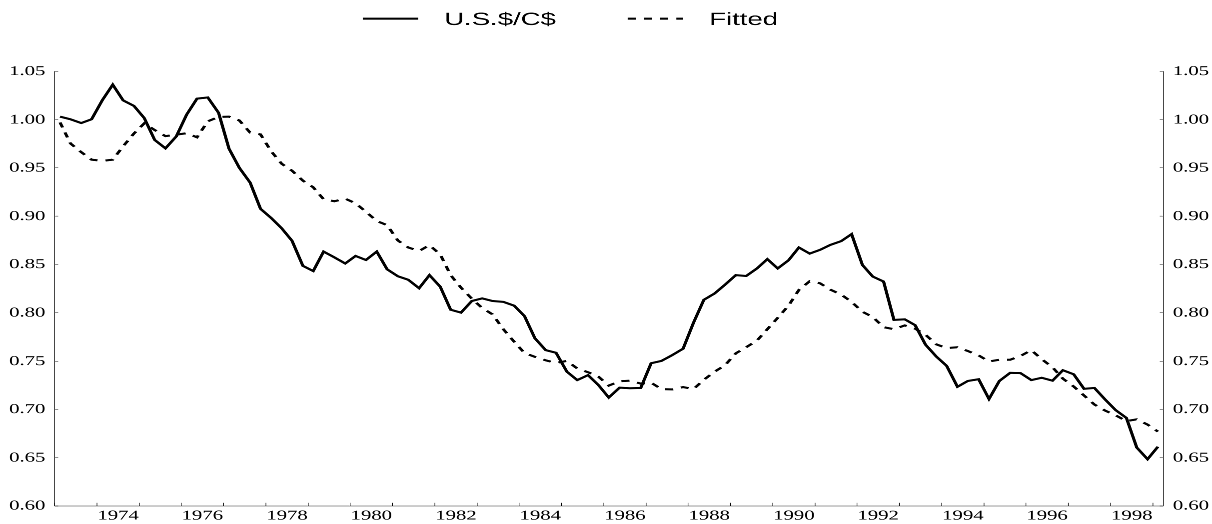
Aside from these two anomalies, the performance of the basic equation is impressive. It is able to explain over twenty per cent of the monthly variation in the real exchange rate; its parameters are (for the most part) sensibly signed and significant; and the relationship is remarkably robust. Very little movement is observed in the parameters across the four sample periods.[7] Tests of the model's ex ante predictive power also indicate that it is able to beat a random walk (See the original Amano and van Norden (1992) paper.) While it may seem that we are damning the model with faint praise, the performance of this equation is very good by the standards of most exchange rate equations.

7. A series of rolling Chow tests, which are reported in a separate appendix, confirm that the parameter estimates seldom wander outside a 5 per cent confidence band.

(c) Simulations

A dynamic simulation, using parameter estimates drawn from the 1993Q1 to 1998Q4 period, is shown in Graph 4. In order to facilitate comparisons between the actual and predicted values of the exchange rate, *rfx* was converted into a nominal exchange rate by adjusting the series for changes in the Canadian and U.S. GDP deflators.

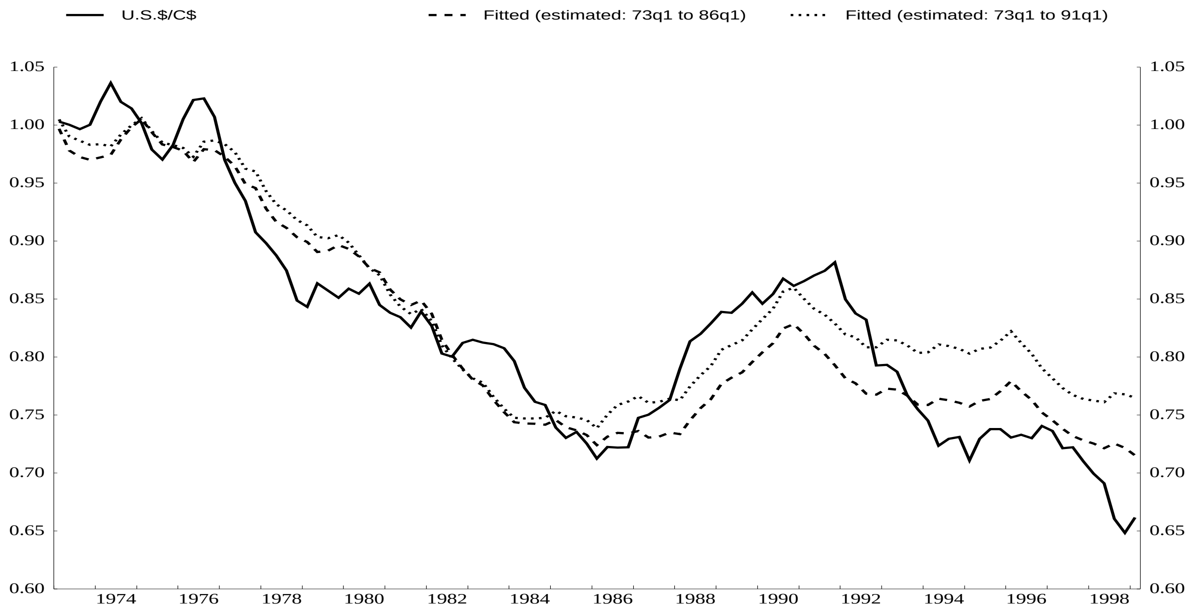
Graph 4
Dynamic Simulation – basic model



Estimated from 73q1 to 98q4

The correspondence between the simulated values of the nominal exchange rate and its actual values is very close. Most of the broad movements in the exchange rate are captured by the three explanatory variables. Sizable deviations do appear on occasion, but they typically disappear after a short period of time. The 1993 to 1996 period is an example of this. While there may also have been an element of speculative overshooting in late 1998, the exchange rate has now returned to a value very close to what the equation would predict. It would be surprising, however, if such a simple formulation managed to capture all of the movements in the Can-U.S. exchange rate. Many potentially important economic variables have obviously been omitted, as well as political considerations, which could have had an important influence on the exchange rate over the first half of the 1990s. To give the reader some idea of how large the confidence bands around these predictions might be, two alternative simulations were run, based on parameter estimates taken from two sub-periods: 1973Q1 to 1986Q1 (when the exchange rate reached a local low) and 1973Q1 to 1991Q3 (when the exchange rate reached a local high).

Graph 5
Dynamic Simulation − basic model



Although it is intriguing to speculate about the factors that might account for the equation's forecast errors, it is also useful to examine the variables that have played a central role in explaining the movements of *rfx*. Table 5 provides a decomposition of the simulation shown in Graph 4, and indicates the relative contribution of each variable to changes in the actual Can-U.S. exchange rate.

Table 5
Relative Importance of the Explanatory Variables
1973Q1 - 1998Q4

Variable	Percentage share
COMTOT	56.20
ENETOT	1.85
INTDIFF	-6.52
Inflation	23.00
Lags	11.51
Other*	13.76
TOTAL	100.00

Note: * includes error term

Over the 1973Q1 to 1998Q4 period, the nominal bilateral exchange rate depreciated by roughly 44 per cent. Of this, more than 56 per cent was the result of a trend decline in the relative price of non-energy commodities; 23 per cent was caused by higher inflation in Canada than the United States (Purchasing Power Parity); 2 per cent came from higher energy prices; and 25 per cent was related to other unidentified factors (including the lagged adjustment term and the residual error). Real interest rate differentials provided an offsetting effect (i.e. an appreciation) of roughly 7 per cent.

4. An Extended Equation

The simulations reported in the previous section suggest that most of the movements in the exchange rate have been driven by two or three fundamental variables, and that one could predict the general direction of the exchange rate, if not its exact level, provided one had prior knowledge of these forcing variables. Nevertheless, independent of which simulation is chosen, the equation tends to over-predict the actual value of the exchange rate over most of the 1990s. Is there a chance that other explanatory variables might be uncovered that could help explain these discrepancies?

Amano and van Norden ended their estimations in 1992Q2. While the regressions in Table 4 extend their results to 1996Q4 and 1998Q4, no new variables have been added to the original equation. The same specification has simply been applied to more data. Although the new results are essentially unchanged vis-à-vis those of Amano and van Norden, the longer sample that we now have at our disposal might allow us to uncover some additional explanatory variables.

(a) Can-U.S. Differences in Productivity and Government Debt

Several new variables were examined as part of our effort to find a new and improved exchange rate equation -- some of which had been investigated earlier by Amano and van Norden. A complete list of the variables that were tested is contained in a companion paper written by David Tessier and Ramdane Djoudad, who have conducted a more exhaustive study of this issue.[8] Some of the variables that Tessier and Djoudad considered were (1) differences in Canadian and U.S. unemployment rates, (2) differences in Canadian and U.S. productivity, (3) differences in Canadian and U.S. government spending, (4) differences in Canadian and U.S. net foreign indebtedness, and (5) differences in Canadian and U.S. government debt.

Rather than reproduce all of the results of Tessier and Djoudad, we have decided to focus on two variables: the difference in Canadian and U.S. labour force productivity and the difference in Canadian and U.S. general government debt.

8. See David Tessier and Ramdane Djoudad, “Certaines évidences empiriques relatives à l’évolution du taux de change Canada/É.U.,” Bank of Canada, February 1999.

These variables are of particular interest, owing to public attention that they have attracted in recent months, and the results that we obtained were broadly similar to those that were reported by Tessier and Djoudad using a number of other variables.

(i) Productivity

Concern over lagging productivity in Canada has been at the centre of public debate since late last year when the OECD published a report suggesting that the level of labour productivity in our manufacturing sector was well below that in the United States and was growing at a much slower rate. Although the data on which these results were based have now been revised, and the productivity puzzle seems to have largely disappeared, it is worth testing to see if any evidence of a productivity slowdown can be detected in the exchange rate equation. Although the effects of a (relative) productivity improvement in Canada are in theory ambiguous, one would typically expect faster productivity growth to cause the exchange rate to appreciate. Canada is not a large enough producer to materially affect the world price of most commodities and is unlikely to suffer from immiserizing growth.

(ii) Government Debt

Higher government debt in Canada relative to that in the United States would generally be expected to lead to an exchange rate depreciation since we will eventually be forced to pay for our excess absorption with higher net exports. (This assumes that the counterpart of the higher domestic debt is higher foreign indebtedness.) In the short run, however, the net effect of higher government debt on the exchange rate is ambiguous. The positive demand shock generated by higher government spending and reduced taxes might be expected to put upward pressure on the exchange rate, in part through higher interest rates. On the other hand, if the level of the government debt approaches levels that raise concerns about our ability to service it, the positive Keynesian effect described above could easily be out-weighed by the higher risk premiums attached to domestic debt, causing interest rates to rise and the exchange rate to depreciate. Whether the statistical techniques employed below are able to disentangle these long-run and short-run effects, and the sudden changes in market sentiment that might occur once certain thresholds are breached, is unclear.

(b) Unit Root and Cointegration Tests

As with the original specification, it is important to determine whether the new variables, *debtdif* and *proddif*, are stationary or have unit roots. Tests based on the same Augmented Dickey-Fuller procedure that was used earlier indicate that both variables are I(1), and are therefore integrated of the same order as *rfx* (see Table 6).

Table 6
Tests for Unit Roots
1973Q4 to 1997Q4

Variable	No. of lags	ADF[1]
DEBTDIF	8	-1.288
PRODDIF	5	0.613
5% critical value		2.89
10% critical value		2.58

Note: [1]ADF = Augmented Dickey-Fuller

In order to improve the long-run explanatory power of the equation, it is also important that *debtdif* and *proddif* be cointegrated with *rfx*. When the Johansen-Juselius test is applied to the expanded variable list, a second cointegrating relationship is found. However, it is not obvious that the second vector indicates a long-run relationship between one or both of the new variables and the exchange rate. It is possible that the two new variables are linked to one another, and quite independent of the exchange rate. In order to test the nature of the relationship, separate cointegration tests were run on *debtdif* and *proddif*. The results are reported in Tables 7 and 8.

Table 7
Johansen - Juselius Tests for Cointegration
on RFX, COMTOT, ENETOT, DEBTDIF and PRODDIF*

No. of cointegrating vectors in the null hypothesis	**trace statistic**	**5% critical value**
Fewer than 1	88.76	55.44
Fewer than 2	45.36	36.58
Fewer than 3	12.22	21.63
No. of cointegrating vectors under the null hypothesis	**λ^{max} statistic**	**5% critical value**
Fewer than 1	43.40	27.62
Fewer than 2	33.15	21.58
Fewer than 3	9.29	15.59

Note: * no. of lags for J-J test = 8

Table 8
Johansen - Juselius Tests for Cointegration
on DEBTDIF and PRODDIF*

No. of cointegrating vectors under the null hypothesis	**trace statistic**	**5% critical value**
Fewer than 1	12.16	10.47
Fewer than 2	0.67	2.86
No. of cointegrating vectors under the null hypothesis	**λ^{max} statistic**	**5% critical value**
Fewer than 1	11.49	9.52
Fewer than 2	0.67	2.86

Note: * no. of lags for J-J test = 16

Based on the trace statistic and the λmax statistic, the two new variables appear to be related to one another as opposed to rfx. While there was not enough time to explore the nature of this relationship in any detail, it would not be surprising if the two were negatively correlated and if higher government debt was seen to cause lower productivity. David Tessier and Pierre St-Amant have shown in an earlier Bank of Canada Working Paper that higher trend rates of government spending in Canada than in the United States can explain much of the difference in our long-run rates of unemployment. Although higher employment does not necessarily translate into higher productivity, productivity is known to be pro-cyclical and increased government regulation and spending are often believed to reduce potential output productivity.

(c) Regression Results

The cointegration tests reported above suggest that any results one might obtain from the extended model should be treated with caution. Nevertheless, it is still interesting to see how they compare with those of Table 4. The three new equations that were tested can be written as:

$$\Delta\ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c comtot_{t-1} - \beta_e enetot_{t-1} - \beta_d debtdif_{t-1}) + \Upsilon intdif_{t-1} + \varepsilon_t \quad (2)$$

where: debtdif = Can. government debt to GDP ratio less US government debt to GDP ratio;

$$\Delta \ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c comtot_{t-1}) - \beta_e enetot_{t-1} - \beta_p proddif_{t-1}) + \Upsilon intdif_{t-1} + \varepsilon_t \qquad (3)$$

where: proddif = Can.-US labour productivity differential; and

$$\Delta \ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c comtot_{t-1}) - \beta_e enetot_{t-1} - \beta_d debtdif_{t-1} - \beta_p proddif_{t-1}) + \Upsilon intdif_{t-1} + \varepsilon_t. \qquad (4)$$

The first thing to note from Table 9 is that while *debtdif* often enters the equation with the expected positive sign (i.e. higher debt leads to a weaker exchange rate), it is seldom significant. Indeed, the only period in which it has a t-statistic greater than 2.0 is 1973Q1 to 1986Q1, when Canada's debt was growing but still lower than that of the United States. The productivity variable, in contrast, is significant at the 10 per cent level in all four sample periods, but always has the wrong sign (i.e. higher relative productivity leads to a weaker exchange rate). (see Table 10) When both variables are entered simultaneously, they become highly significant over the last two sample periods, but *proddif* still has the wrong sign. Interestingly, none of the other variables in the original equation is affected, though their t-statistics are sometimes higher.

Table 9
Standard Exchange Rate Equation with Government Debt

Variable	1973Q1 - 1986Q1	1973Q1 - 91Q3	1973Q1 - 96Q1	1973Q1 - 97Q4
Speed of adjustment	-0.300	-0.147	-0.162	-0.156
	(-3.278)[1]	(-3.295)	(-4.156)	(-4.173)
Constant	1.781	2.541	2.089	2.235
	(3.983)	(3.719)	(3.472)	(3.631)
COMTOT	-0.297	-0.515	-0.402	-0.430
	(-3.251)	(-3.710)	(-3.448)	(-3.588)
ENETOT	0.032	0.1033	0.090	0.083
	(1.031)	(2.182)	(2.145)	(1.987)
INTDIF	-0.465	-0.476	-0.627	-0.566
	(-2.035)	(-2.771)	(-3.735)	(-3.981)
DEBTDIF	0.804	-0.587	0.302	0.180
	(2.014)	(-1.290)	(1.159)	(0.706)
$\overline{R}^2$	0.238	0.243	0.205	0.207
Durbin-Watson	1.148	1.230	1.238	1.311

Note: [1] t-statistic

Table 10
Exchange Rate Equation with Productivity

Variable	1973Q1 - 1986Q1	1973Q1 - 91Q3	1973Q1 - 96Q1	1973Q1 - 97Q4
Speed of adjustment	-0.281	-2.07	-0.144	-0.147
	(-5.017)[1]	(-5.347)	(-4.258)	(-4.468)
Constant	2.400	2.740	3.478	3.307
	(7.258)	(8.521)	(5.859)	(6.306)
COMTOT	-0.477	-0.529	-0.653	-0.622
	(-7.787)	(-8.367)	(-5.535)	(5.905)
ENETOT	0.106	0.080	0.037	0.043
	(3.559)	(2.932)	(0.936)	(1.146)
INTDIF	-0.622	-0.411	-0.565	-0.645
	(-3.234)	(-2.715)	(-3.392)	(-4.474)
PRODDIF	1.059	1.015	0.618	0.414
	(3.994)	(4.044)	(1.812)	(1.790)
$\overline{R}^2$	0.429	0.415	0.230	0.234
Durbin-Watson	1.637	1.563	1.326	1.369

Note: [1] t-statistic

Table 11
Exchange Rate Equation with Government Debt and Productivity

Variable	1973Q1 - 1986Q1	1973Q1 - 91Q3	1973Q1 - 96Q1	1973Q1 - 98Q4
Speed of adjustment	-0.262	-0.216	-0.211	-0.199
	(-3.25)[1]	(-5.100)	(-5.374)	(-5.178)
Constant	2.568	2.580	2.162	2.206
	(3.879)	(6.222)	(4.917)	(4.801)
COMTOT	-0.520	-0.491	-0.401	-0.412
	(-3.277)	(-6.075)	(-4.781)	(-4.666)
ENETOT	0.118	0.084	0.081	0.801
	(2.365)	(3.055)	(2.701)	(2.552)
INTDIF	-0.844	-0.417	-0.557	-0.685
	(-3.141)	(-2.732)	(-3.484)	(-4.847)
DEBTDIF	-0.205	0.137	0.782	0.637
	(-0.309)	(0.560)	(3.640)	(2.932)
PRODDIF	1.183	1.031	0.898	0.605
	(2.363)	(4.217)	(3.564)	(3.205)
$\overline{R}^2$	0.418	0.409	0.296	0.273
Durbin-Watson	1.672	1.559	1.366	1.367

Note: [1] t-statistic

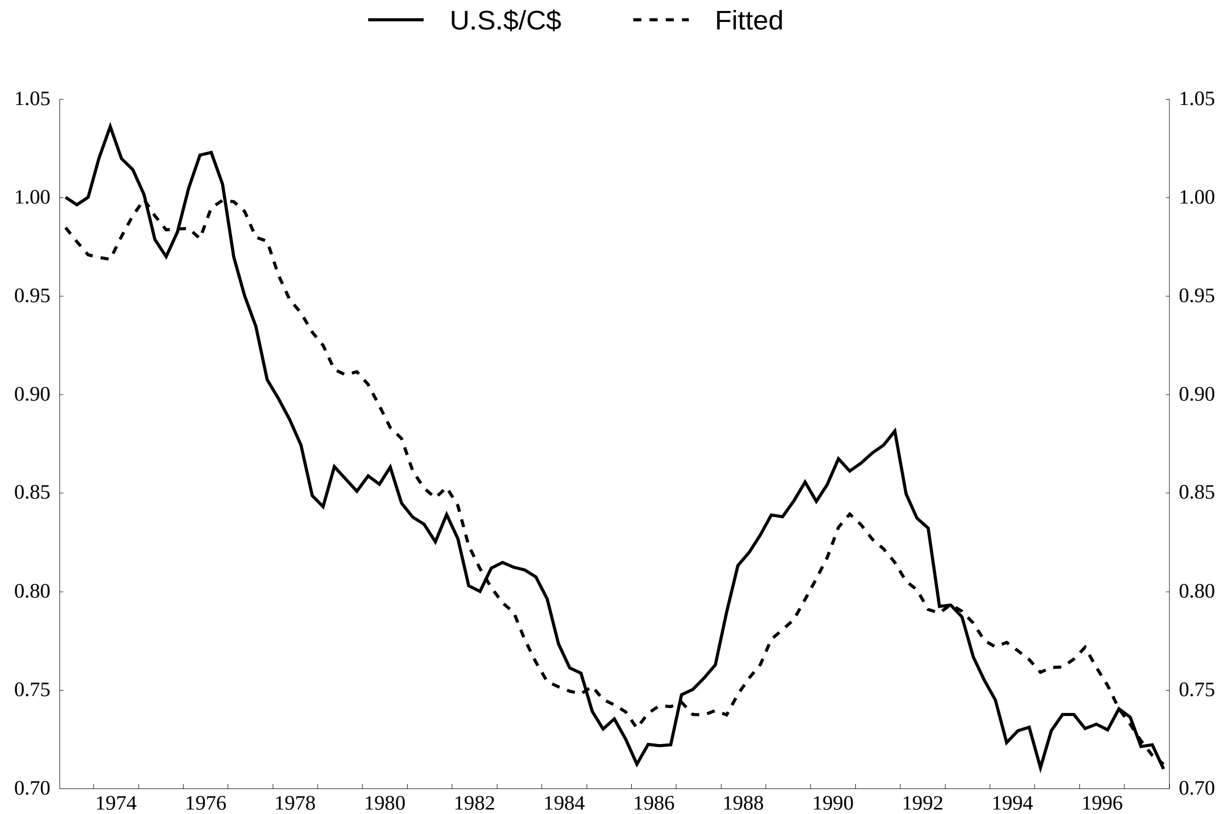
(d) Simulations

Graphs 6, 7 and 8 compare the actual value of the nominal Can-U.S. exchange rate and the simulated value from the original equation with those of equations (2), (3) and (4). Unfortunately, the simulations have to end in 1997Q4, since the debt and productivity variables are not available for 1998. The extra variables seem to improve the performance of the equation; however, the overshooting that was noted in earlier simulations over much of the 1990s is still evident.

Differences in national debt and labour productivity do not seem to provide the missing link that we were looking for. Neither do they represent a very reliable addition to the basic model that we first examined. Perhaps the answer lies in the activities of noise traders and other speculative agents who, popular wisdom suggests, regularly cause otherwise stable relationships to become disconnected from fundamentals.

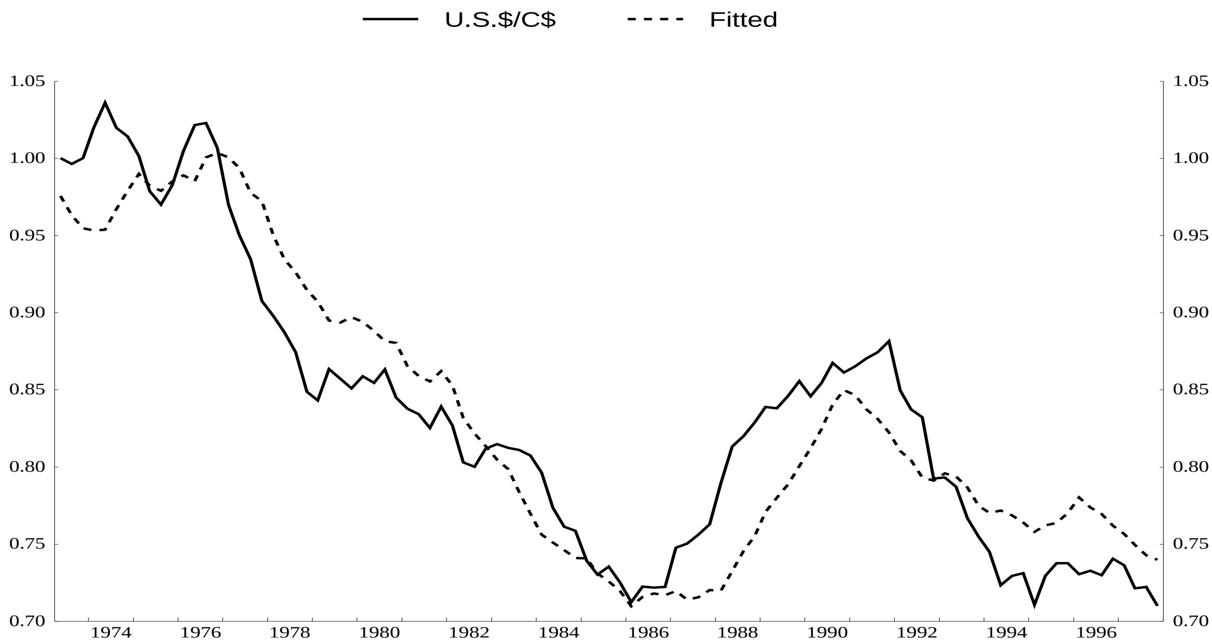
Graph 6

Dynamic Simulation − with debt



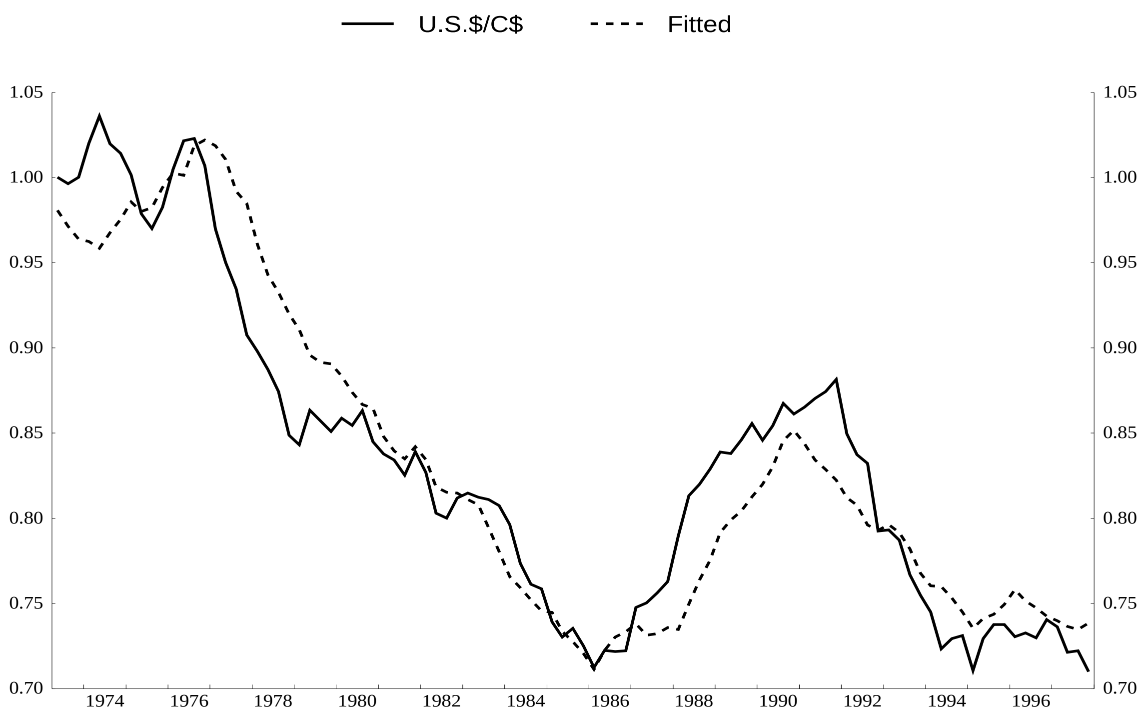
Graph 7

Dynamic Simulation − with productivity



Graph 8

Dynamic Simulation − with productivity and debt



6. Excess Volatility and Speculative Bubbles

Chartists and noise traders are typically cast as the villains in any discussion of sudden or unwanted exchange rate movements. This is not to suggest that the stories are untrue, or that speculative activity does not on occasion cause the exchange rate to move in an excessive or misguided manner; simply that there are very few credible tests of this proposition. Absent a reliable model of the exchange rate that could tell us exactly where the currency should be at every point in time, it is impossible to make anything other than informed guesses about whether or not the exchange rate has deviated from its fundamentals and what might have caused it.

Robert Vigfusson, an economist at the Bank of Canada, developed a model of chartists and fundamentalists in 1996 based on a Markov-switching procedure. The equation described in Section 4 was used as a proxy for the exchange rate that would have been observed if the market were dominated by traders guided solely by fundamentals. Chartists, in contrast, were assumed to operate in response to simple rules-of-thumb, designed to detect shifts in market momentum and the creation of new support levels or trends in the exchange rate. The exchange rate that was observed at any point in time, therefore, was outcome of complex interactions between the fundamentalists, who tried to keep the exchange rate close to its equilibrium value, and chartists, who had no regard for fundamentals but believed that they could make money anticipating the trends.

This interaction was captured in the following equation in which the expected change in the exchange rate was modelled as a weighted average of the expectations of these two groups:

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

where: $E\Delta s$ = expected change in s
s = log of the nominal Can.-US exchange rate
f, c = superscripts indicating fundamentalists and chartists
ω = weight assigned to fundamentalists

and the equations describing their behaviour were written as:

$$\Delta s^f_t = \alpha^f + \phi(s_{t-1} - \tilde{s}_{t-1}) + \gamma intdif_{t-1} + \varepsilon^f_t \qquad (6)$$

where: $\tilde{s}$ = fundamentalists forecast of s
α^f = a constant

$$\Delta s_t^c = \alpha^c + \psi_{14} ma_{14} + \psi_{200} ma_{200} + \Gamma intdif_{t-1} + \varepsilon_t^c \qquad (7)$$

where: ma_{14} and ma_{200} = moving averages used by the chartists to forecast changes in *s*

α^c = *a constant*

The variables guiding the fundamentalists have already been discussed in detail in the earlier sections. The only change that was introduced for purposes of Vigfusson's test was to convert the data to a daily frequency using a cubic spline. The chartists' equation assumes following simple (but not unrealistic) behaviour pattern. Whenever the 14-day (short-term) moving average of exchange rates exceeds the 200-day (long-term) moving average, the chartists buy the currency. If the 14-day moving average is lower than the 200-day moving average, the currency is sold.[9]

The transition equations in the Markov-switching process that link the two groups of agents and assign a probability of being in regime *f* or *c* (i.e. fundamentalists or chartists) were:

$$\rho(R_t | R_{t-1}) = \Phi(\alpha_f) \qquad (8)$$

$$\rho(R_t | R_{t-1}) = \Phi(\alpha_c) \qquad (9)$$

where: $\rho(R_t)$ is the probability of being in regime R.

and the objective of the portfolio manager, as represented by the Markov model, was to maximize the log-likelihood function:

$$LLF = \sum_{t=1}^{t} \sum_{t=1}^{t} \rho(R_t) d(s_t | R_t) \qquad (10)$$

where: $d(s_t | R_t)$ = the normal density function of the regime's residual

A detailed discussion of the results can be found in Vigfusson (1996) or in Murray et al. (1996). They can summarized as follows:

First, all of the variables in both the chartists' and fundamentalists' equations had their expected signs and were statistically significant.[10] Second, chartists appeared to dominate the market about 70 per cent of the time, while

9. While this might seem overly simplistic, it is modelled after practices that are actually followed in the market.

10. *Enetot* had a positive (perverse) sign, but this was expected from our earlier regressions.

fundamentalists only dominated the market 30 per cent of the time. Third, periods of "excess" volatility in the exchange market were typically dominated by fundamentalists, not chartists, who tried to push the exchange rate back to its equilibrium. Chartists, it seems, lent a certain inertial force to the market, which generally caused the exchange rate to move in a stable but not necessarily appropriate manner. In time, once the exchange rate had deviated significantly from its equilibrium value, fundamentalists would enter the market and realize profits by correcting the rate.

While time limitations have not allowed us to replicate this exercise with more recent data, the main message of the earlier work is that periods of volatility are not necessarily associated with instability and exchange rate overshooting. They may be the result of re-equilibrating forces trying to correct earlier mispricing of the exchange rate. It could be a mistake, therefore, to blame speculators for any sharp movements in *rfx*.

7. Conclusion

The empirical results reported in Sections 4 and 5 do not provide any new or convincing evidence of exchange rate misbehaviour over the most recent period. Neither do they suggest that our currency was always fairly priced. While the simulations typically shown that the Canadian dollar was underpriced, one should be careful about placing too much confidence in any exchange rate equation. Precise judgements of this kind are beyond our ability. In any event, the most significant result is not the extent to which our currency might have been undervalued, but rather the large share of the Canadian dollar's movements that could be explained by three or four fundamentals. For whatever comfort it provides, the basic equation indicates that the current value of the exchange rate is close to (albeit slightly below) its equilibrium value, given the fundamentals currently in place.

Our future work in this area will concentrate on two topics. The first involves a more comprehensive search for alternative explanatory variables, with a view to including them in the basic equation as factors explaining the short-term dynamics of the exchange rate as opposed to its long-term behaviour. (More specifically, they will likely lie outside the error-correction term rather than inside it.) The second will involve an extension of Robert Vigfusson's work to see if his earlier results still obtain, and if speculation might not have contributed to the episode late last summer when the Canadian dollar appeared to overshoot its fundamentals and be subject to destabilizing expectations.

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