Session 3:
Exchange Rates,
Currency Markets,
and Trade Flows

The Role of Chartists and Fundamentalists in Currency Markets: The Experience of Australia, Canada, and New Zealand

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Introduction

Almost 30 years have passed since the collapse of Bretton Woods, and hopes of resurrecting this system of pegged exchange rates have long since faded. Although many emerging markets continue to operate under a "soft fix," most industrial countries have opted for one of the two extremes—a freely floating or firmly fixed exchange rate.[1] Those at the flexible end of the spectrum have avoided serious difficulty, but have often worried about the excessive volatility and persistent misalignments that are thought to characterize this regime. For large, relatively closed economies, such as Japan and the United States, these erratic episodes are troublesome, but generally tolerable. For small, relatively open economies, such as Australia, Canada, and New Zealand, the prospective problems are much greater. Exports represent a much larger share of their GDP, and wide swings in the exchange rate could destabilize their domestic economies.

In a perfect world, monetary authorities would be able to distinguish between exchange rate movements caused by changing economic fundamentals and those driven solely by speculative whim. In cases where the movement appeared unjustified or excessive, steps could be taken to correct

1. Only four of the 20 original member countries in the OECD currently operate under an "intermediate" exchange rate regime.

* The authors would like to thank their colleagues for many helpful suggestions and to acknowledge the valuable assistance of Nathalie Lachapelle.

the situation. Unfortunately, the real world is far removed from this ideal state. In the case of small industrial countries, the identification problem that authorities face can be particularly difficult. Many of these countries are commodity exporters and are subject to sudden shifts in economic conditions. Fluctuations in world commodity prices, for example, may require a sharp appreciation or depreciation of the local currency. Efforts to resist these movements would only create additional problems and frustrate the re-equilibration process.

This paper looks at the post-Bretton Woods experience of Australia, Canada, and New Zealand and tries to determine whether past exchange rate movements have been consistent with economic fundamentals. The first half of the paper is devoted to estimating and testing simple error-correction models. Work by Amano and van Norden (1993) and Murray, van Norden, and Vigfusson (1996) has shown that most of the major movements of the Canadian dollar can be explained by four fundamental variables: the Canada-U.S. interest rate differential, the Canada-U.S. inflation differential, the real U.S. dollar price of energy commodities, and the real U.S. dollar price of non-energy commodities. One of the objectives of our paper is to apply similar models to Australia and New Zealand and to see if the same fundamental variables play an important role in explaining the behaviour of their currencies.

The second half of the paper approaches the problem from a somewhat different angle. It uses regime-switching models to capture the interaction of two different types of foreign exchange traders: chartists and fundamentalists. Chartists are assumed to operate on the basis of mechanical trading rules that are linked to past movements in the exchange rate, while fundamentalists, as the name suggests, pay greater attention to economic fundamentals. A number of alternative specifications are tested to gauge the relative importance of each group at different points in time. Vigfusson (1996) and Murray, Zelmer, and Antia (2000) have estimated regime-switching models for Canada and have uncovered some significant but surprising results. According to their estimates, fundamentalists have typically dominated foreign exchange markets during more turbulent periods, while chartists have been active during more tranquil periods.

This paper extends the earlier work on regime-switching models in three important ways. First, it applies the models to two additional currencies—the Australian and New Zealand dollars. Second, it tests a broader range of chartist trading strategies. Third, it estimates the models over a longer sample, which includes the recent crises in Asia, Latin America, and Russia.

The paper is organized as follows. Section 1 provides some background information on the Australian, Canadian, and New Zealand economies, as well as on the past behaviour of their currencies. The actions of the monetary authorities in each of these countries are also briefly described. Section 2 presents the error-correction models that have been developed for the three currencies and compares their performance with that of other exchange rate models. The results are used as inputs to the regime-switching models estimated in section 3. The implications of chartist and fundamentalist behaviour for official intervention in the foreign exchange market are reviewed in section 4. The paper concludes with a summary of the major results and suggestions for future research.

The results that we report are, for the most part, encouraging. They support a "fundamentalist" view of exchange rate determination and are consistent with the Canadian evidence reported earlier. Simple error-correction models are able to explain most of the persistent movements in the Australian, Canadian, and New Zealand dollars. In addition, there is evidence that fundamentalists, rather than chartists, are more active in foreign exchange markets during turbulent periods. Consequently, monetary authorities should be wary of intervening. Flexible exchange rates in Australia, Canada, and New Zealand are generally behaving as theory would predict and are often driven by strong fundamental forces. Any attempt to resist or reverse them is likely to be counterproductive and will simply impose additional costs on the domestic economy.

1 The Three Commodity Currencies

1.1 Background

Australia, Canada, and New Zealand have many common characteristics. All three have open and highly developed economies and rely on commodity exports for a significant portion of their international trade. Although Canada and Australia are obviously much larger than New Zealand, both in a geographical sense and in terms of their populations, most observers would still regard them as "small" from a macroeconomic perspective. With the exception of a few primary products, such as lamb, nickel, and gold, they are unlikely to exert much influence on world demand or supply. They are essentially price-takers.

The population of New Zealand, for example, was only 3.8 million in 1999. Its GDP, expressed in U.S. dollars, was $50 billion, and resource-based commodities accounted for more than 60 per cent of its total exports.[2] These figures clearly represent one extreme, but capture the essential features of all three economies. Canada's population was 30.5 million in 1999 or roughly 10 times the size of New Zealand's, while its GDP was US$650 billion. The U.S. population, in turn, was more than 10 times that of Canada, and the United States clearly dominated all three countries, individually and collectively, in terms of the influence it could exert on the world economy.

Another important feature of Australia, Canada, and New Zealand, from the standpoint of our study, is that all three countries operate under a flexible exchange rate. The movements in each currency vis-à-vis the U.S. dollar are shown in Figure 1. The line representing the Canadian dollar begins in June 1970, just after Canada decided to leave Bretton Woods. The lines for the Australian and New Zealand dollars begin in January 1985 and January 1987, respectively, roughly one to two years after each of these countries moved to a floating-rate system.

The three currencies display considerable volatility and have drifted downwards over time, consistent with the weakness in world commodity prices during this period (see Figure 2). As one might expect, the trade-weighted exchange rate for each country is slightly less variable than its bilateral U.S. dollar rate; however, the two series are highly correlated. The similarity between the trade-weighted and bilateral rates is not so surprising in the case of Canada, since 85 per cent of Canada's exports go to the United States. In the case of Australia and New Zealand, however, one might have expected more divergence. The U.S. share of Australian and New Zealand exports is only 10 per cent and 14 per cent, respectively. The fact that the two series follow such similar time paths is indicative of the number of other trading partners in the Asian region that have elected to peg their currencies, either explicitly or implicitly, to the U.S. dollar.

For convenience, the rest of the analysis is conducted using bilateral exchange rates. The statistical properties of the bilateral and trade-weighted exchange rates are very similar, and preliminary testing using both measures suggests that the results are essentially the same. While a trade-weighted exchange rate might be preferred on theoretical grounds, there is reason to believe that the bilateral rate actually provides a more reliable measure of each country's competitive position. Analyses conducted by Australian academics and by the Reserve Bank of New Zealand (RBNZ) indicate that the trade-weighted indexes understate the importance of the United States for their two economies (see Brook 1994 and Karfakis and Phipps 1999).

2. The numbers reported here were taken from the IMF's *International Financial Statistics*, September 2000.

Figure 1
Bilateral exchange rates for Australia, Canada, and New Zealand

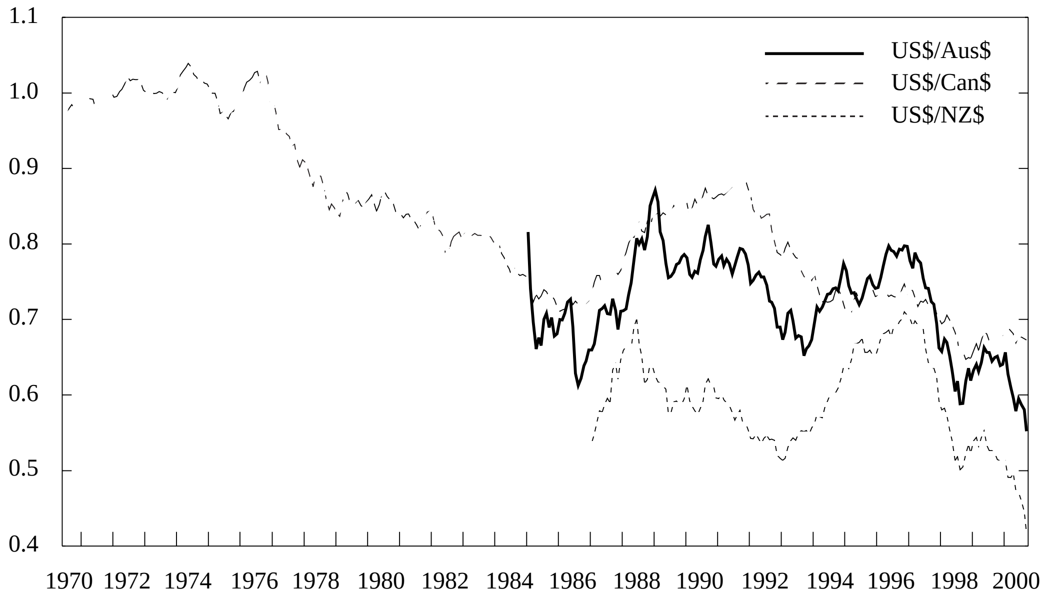
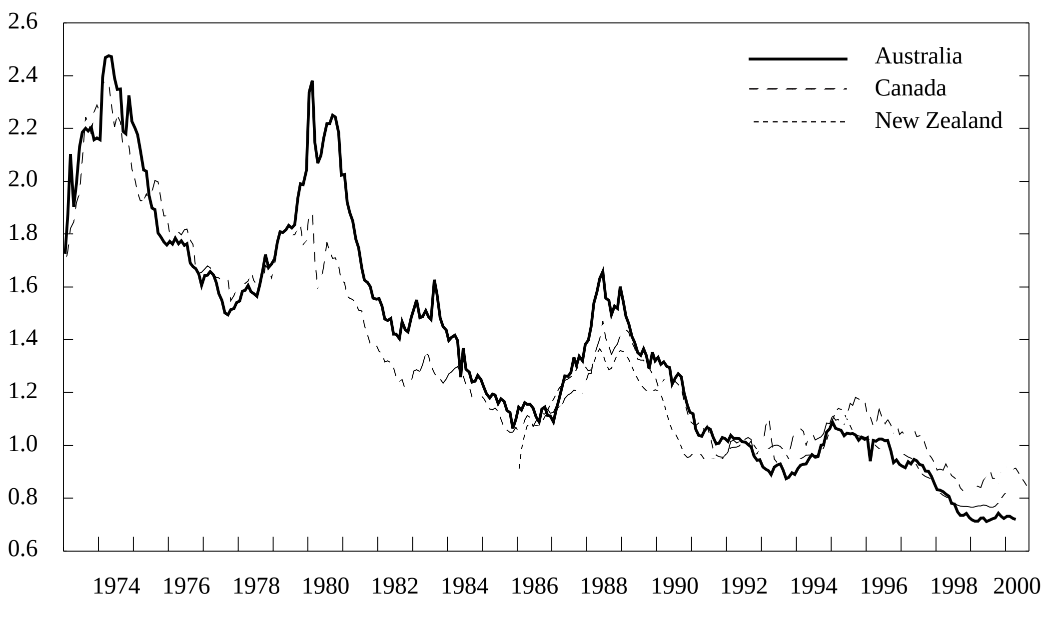


Figure 2
Real non-energy commodity prices for Australia, Canada, and New Zealand



International trade is often denominated and carried out in U.S. dollars even when both parties reside outside of the United States. The same is true for most international financial transactions.

1.2 The Asian financial crisis

The Asian financial crisis[3] provides a dramatic example of how sensitive the Australian, Canadian, and New Zealand dollars are to movements in world commodity prices. Although sales to Asia represent less than 8 per cent of Canada's total exports, the resulting decline in world commodity prices caused the Canadian dollar to depreciate by approximately 12 per cent over the 1997–98 period. The effect on the Australian and New Zealand dollars was even more pronounced. Asia is a much more important trading partner for Australia and New Zealand than it is for Canada, and resource-based commodities represent a larger share of their total exports. As a result, both exchange rates depreciated by about 25 per cent.

The monetary authorities in all three countries understood that a sizable depreciation of their currencies was probably unavoidable. They did not appreciate the severity of the situation, however, until the crisis was well underway. They also questioned whether markets could be trusted to perform the sort of re-equilibrating function they were supposed to, without significant overshooting. The sharp depreciations that each currency experienced in the first few months of the crisis seemed much larger than circumstances warranted. All three central banks, therefore, decided to intervene in an effort to moderate, if not reverse, some of the excessive exchange rate movement.

The Reserve Bank of Australia (RBA) relied exclusively on sterilized intervention and entered the market on only two or three occasions. Interest rates were left unchanged throughout the crisis period. The authorities were worried about the level of the Australian dollar, as well as the speed with which it was falling, but were not prepared to tighten monetary conditions to help support it. Their objective was simply to provide some resistance to the speculative momentum that had developed and to introduce an element of two-way risk in foreign exchange markets. The RBA was careful to time its actions so that its intervention would have maximum effect. It was also willing to risk large amounts of money. If the currency continued to decline after the intervention exercise was complete, the authorities took it as a sign

3. The term "Asian financial crisis" is used rather loosely throughout the text to refer to all the financial crises that occurred over the 1997–99 period. They include the collapse of several economies in Southeast Asia in 1997–98, as well as the collapse of the Russian and Brazilian economies in 1998 and 1999.

that the move was fundamentally driven and should not be resisted with any additional action.

The RBNZ had similar concerns about the sharp depreciation of its dollar, but reacted differently. It believed that sterilized intervention was ineffective and had not engaged in any traditional intervention activity since 1985. Its primary objective during the early stages of the crisis was to prevent domestic monetary conditions from becoming too loose, and it reacted to the depreciation by aggressively raising official interest rates. Once the RBNZ realized how severe the crisis was, it moved quickly to lower interest rates, but not before the economy had fallen into a deep recession.

The Bank of Canada pursued a policy track that was midway between those of the RBA and the RBNZ. Official interest rates were raised through the latter half of 1997 and again in the summer of 1998, but were reversed before they had any significant impact on economic activity. Intervention in foreign exchange markets was also employed on occasion; however, the amounts involved were modest by Australian standards and were typically followed by more serious monetary policy medicine (i.e., official interest rate adjustments). While the Bank of Canada suspected that the Canadian dollar might have overshot its long-run equilibrium value, its main concern throughout this period was to ensure that exchange-market developments did not destabilize domestic interest rates and push monetary conditions much higher than the economic situation would justify. The Bank hoped that by raising official rates a modest amount, and by offering some resistance through foreign exchange intervention, it could pre-empt a more significant jump in market interest rates.

The fact that the Australian, Canadian, and New Zealand dollars have remained close to the low levels that they reached in 1997–98 (and, in some cases, have fallen below them) suggests that the exchange rate movements observed during the Asian crisis were probably warranted. The error-correction models presented in section 2 are designed to see if this is the case and to determine what factors might have been responsible for the dramatic depreciations.

2 Fundamental Determinants of the Exchange Rate

2.1 The basic error-correction model

The error-correction models that are estimated in this section for Australia, Canada, and New Zealand are based on an equation that was first developed by Amano and van Norden in the early 1990s. Although the original equation contained only four explanatory variables, it was able to track most of the major movements in the Canadian dollar over the 1973M1–92M2 period. It also appeared remarkably stable. All of its coefficients were statistically significant and (for the most part) sensibly signed. It was also able to forecast future exchange rate movements with greater accuracy than a random walk (i.e., it passed the Meese-Rogoff test).

Subsequent testing of this model has confirmed that its superior performance was not an accident or an econometric fluke. It continues to track movements in the Canadian dollar with surprising accuracy and has become an important part of the Bank of Canada's internal forecasting exercise.

The basic Amano-van Norden equation can be written as follows:

$$\Delta \ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c \ln(comtot)_{t-1} - \beta_e \ln(enetot)_{t-1}) + \Upsilon intdif_{t-1} + \varepsilon_t, \quad (1)$$

where: *rfx* = real US$/C$ exchange rate,
comtot = real non-energy commodity terms of trade,
enetot = real terms of trade for energy,
intdif = C-US interest rate differential.

The dependent variable, rfx, is the real value of the US$/C$ exchange rate, where the nominal exchange rate has simply been deflated by the consumer price index (CPI) for each country. (Previous work has indicated that it does not make much difference whether the GDP deflator or the CPI is used for this purpose.) The terms of trade for non-energy commodities, $comtot$, is taken from the Bank of Canada's commodity price index and includes all the major non-energy commodities that Canada produces, weighted according to their relative importance.[4] It is deflated by the U.S. CPI to convert it into a real price variable. The same procedure is used to calculate $enetot$, but only energy-related commodities are included in the index. The final explanatory variable is the C-US interest rate differential, $intdif$, which is designed to capture the effects of changes in Canadian and U.S. monetary policies on the value of the real exchange rate. It was originally modelled as the difference between the short-term and long-term interest rate spreads in Canada and the United States:

$$intdif = (i_l^{c} - i_s^{c}) - (i_l^{us} - i_s^{us}).$$

More recently, however, the variable has been replaced by the short-term interest rate differentials for the two countries ($intdif = (i_c^s - i_{us}^s)$), since the regression results are essentially the same with either specification.

4. Appendix 1 describes the composition of the non-energy commodity price index, as well as the energy price index.

Representative results for the error-correction model are shown in Table 1, estimated with quarterly data over two different sample periods.[5] The parameters display very little movement as the sample is extended, and they retain their statistical significance. Since upward movements in the real exchange rate are associated with appreciations (and downward movements with depreciations), the positive signs on *comtot* and *intdif* indicate that higher prices for non-energy commodities and higher C-US interest rate differentials cause the Canadian dollar to strengthen. Higher energy prices, in contrast, cause it to weaken. While the last effect was not expected when the equation was first estimated, it has proven to be a remarkably robust result. Canada is a small, but significant, net exporter of energy products, and one might have anticipated a positive sign on *enetot*. Various theories have been proposed to explain this anomalous result, but the most convincing relates to Canada's use of energy products. Most Canadian industries, not to mention Canadian households, are intensive users of oil, natural gas, and other energy products. Indeed, recent statistics suggest that Canadians use 50 per cent more energy per dollar of GDP than do Americans. This is an inevitable consequence of Canada's harsh climate and its industrial base, which tends to specialize in energy-intensive production processes. Higher oil prices, such as we are witnessing at the moment, raise the value of our energy exports, but the additional costs that Canada's other industries incur more than offset these gains. The Canadian dollar is, therefore, forced to depreciate in response to the deterioration in our competitive position and the decline in our net worth.

Dynamic simulations of the error-correction model, estimated over the period 1973Q1 to 1999Q4, reveal how well the equation performs (see Figure 3). The simulation begins with the actual value of the exchange rate, but in all subsequent periods its level is determined solely by the estimated parameters and the values of the independent variables. No updating of the dependent variable is allowed. (To facilitate comparisons between the actual and predicted values of the exchange rate, *rfx* has been converted back into nominal terms, using the Canadian and U.S. consumer price indexes.)

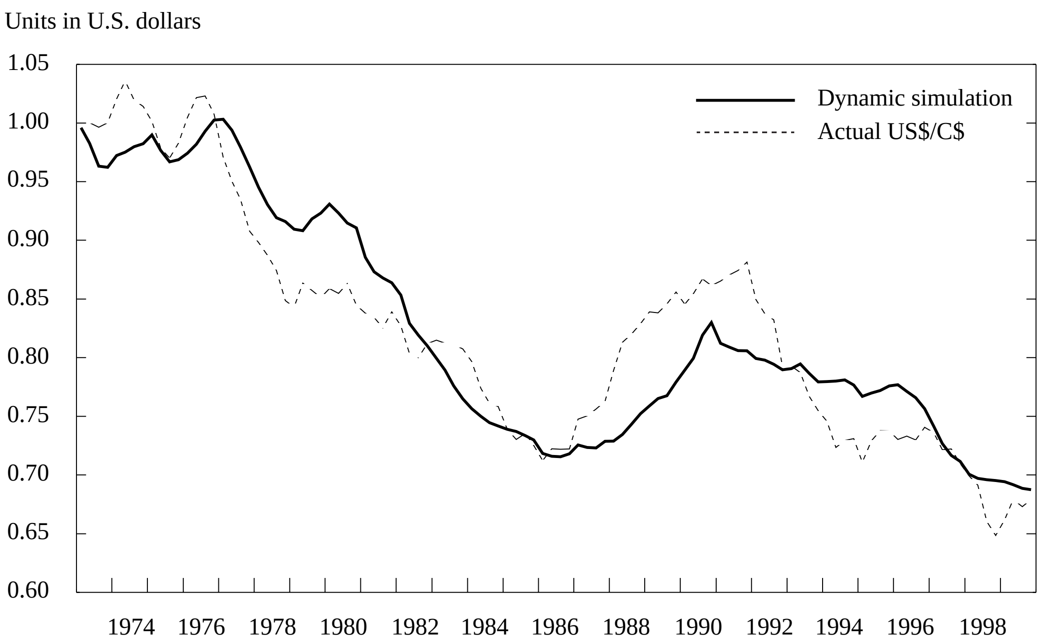
While significant differences can be observed between the actual and predicted values of the exchange rate, they are usually eliminated (or at least reduced) within a short period of time. The most important factor contributing to the impressive performance of the equation is the separate recognition given to energy and non-energy price effects. Previous attempts to model the Canadian dollar used a definition of world commodity prices that

5. Appendix 2 defines all of the variables that were used in this study and describes the data series from which they were drawn.

Table 1
Error-correction model for the Canadian dollar
Equation (1)

Sample period	1973Q1 to 1990Q4		1973Q1 to 1999Q4	
Variable	**Coefficient**	***P*-value**	**Coefficient**	***P*-value**
Adjustment	–0.16	0.00	–0.11	0.00
Constant	–0.29	0.00	–0.43	0.00
Real non-energy commodity ($comtot_{t-1}$)	0.24	0.00	0.41	0.00
Real energy ($enetot_{t-1}$)	–0.15	0.00	–0.09	0.03
Interest rate differential ($intdif_{t-1}$)	0.49	0.00	0.58	0.00
$\overline{R}^2$	0.23		0.16	

Figure 3
Dynamic simulation for the Canadian dollar
Equation (1)



combined these two effects. As is evident from the regression results, however, the two variables affect the Canadian dollar in very different ways.

The present specification was uncovered only after a great deal of searching, and many different variables and functional forms were tested before Amano and van Norden arrived at this equation. The fact that it has continued to perform so well, several years after it was developed, attests to its reliability, as well as to the exhaustive series of econometric tests that the authors used to verify its properties in 1992.

The four-step procedure that Amano and van Norden followed is documented in their original paper and has been replicated with Australian and New Zealand data in the next two sections of this paper. The first step involves the use of unit-root tests to check for stationarity; the second applies the Johansen-Juselius procedure to determine the number of cointegrating vectors in the data. The third step checks for weak and strong forms of exogeneity and determines whether a simple error-correction model is likely to yield efficient and consistent parameter estimates. The final step tests the residuals of the model for AR (autoregressive) and (autoregressive conditional heteroscedastic) ARCH-type behaviour.

These tests have been applied to the latest version of equation (1) for Canada and have also been used to develop exchange rate equations for Australia and New Zealand. (See Appendix 3 for a more detailed description of the results.) The main features can be summarized as follows and typically hold for all three models.

The two commodity price variables in each equation are generally non-stationary and are integrated of order 1—the same order as the dependent variable, rfx. The interest rate differential, in contrast, is stationary and is therefore placed outside the error-correction term, influencing the short-run movements of the exchange rate but not its long-run behaviour. The Johansen-Juselius tests usually indicate the presence of a single cointegrating vector among the non-stationary variables, although a second cointegrating vector is also found to be marginally significant in some cases. Subsequent testing typically indicates that the first vector includes the exchange rate and that the second vector (if one exists) involves the two commodity price terms.

The results of the exogeneity tests are sensitive to the number of lags included in the estimated equations but often reveal one-way causality running from commodity prices to the exchange rate. Two-way causality, running between exchange rates and commodity prices, is also observed on occasion. Simultaneity is unlikely to pose a problem with regard to the estimation of our equations, since the explanatory variables always enter with a lag. The residuals for the final version of each equation are generally well behaved and, with the exception of the equation for New Zealand, do not appear to suffer from AR or ARCH-type problems. (Some autocorrelation was observed in the New Zealand equation and could not be corrected in the time available. The results for this exchange rate should be interpreted, therefore, with an extra degree of caution.)

2.2 An error-correction model for the Australian dollar

The regression results for the Australian dollar are shown in Table 2. The estimated error-correction model is essentially the same as that for Canada but with two important differences. The first involves the commodity price variables, which have been redefined to reflect the composition of Australia's exports (see Appendix 1); the second relates to the short-term interest rate differential, which is now expressed in real, as opposed to nominal, terms:

$$\Delta \ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c \ln(comtot)_{t-1}$$
$$-\beta_e \ln(enetot)_{t-1}) + \Upsilon intdif_{t-1} + \varepsilon_t , \quad (2)$$

where: *rfx* = real US$/A$ exchange rate,
comtot = real non-energy commodity terms of trade,
enetot = real energy terms of trade,
intdif = real A-US interest rate differential = $(i_a{}^s - i_{us}{}^s)$.

The sample period runs from 1985Q1 to 1999Q4. Although the Australian dollar began floating in December 1983, the starting point for the regression has been shifted by approximately four quarters to allow the exchange rate to adjust to the new regime. As the reader can see, all the parameters (except for the constant term) are statistically significant and have their expected signs. Higher Australian interest rates and higher non-energy prices cause the currency to strengthen, while higher energy prices cause it to weaken—just as they do in Canada. In this case, however, the depressing effect of *enetot* is less surprising, since Australia is a significant net importer of oil, and most of the variation in *enetot* has been related to the price of oil.[6]

The dynamic simulation for the Australian dollar is shown in Figure 4. Some overshooting of the exchange rate is observed over certain periods, but the difference between the actual and predicted values is seldom very large. The Australian dollar appears to have been overvalued in the two years immediately preceding the Asian crisis, for example, but then falls below its "fair market value" once the crisis begins to take hold.

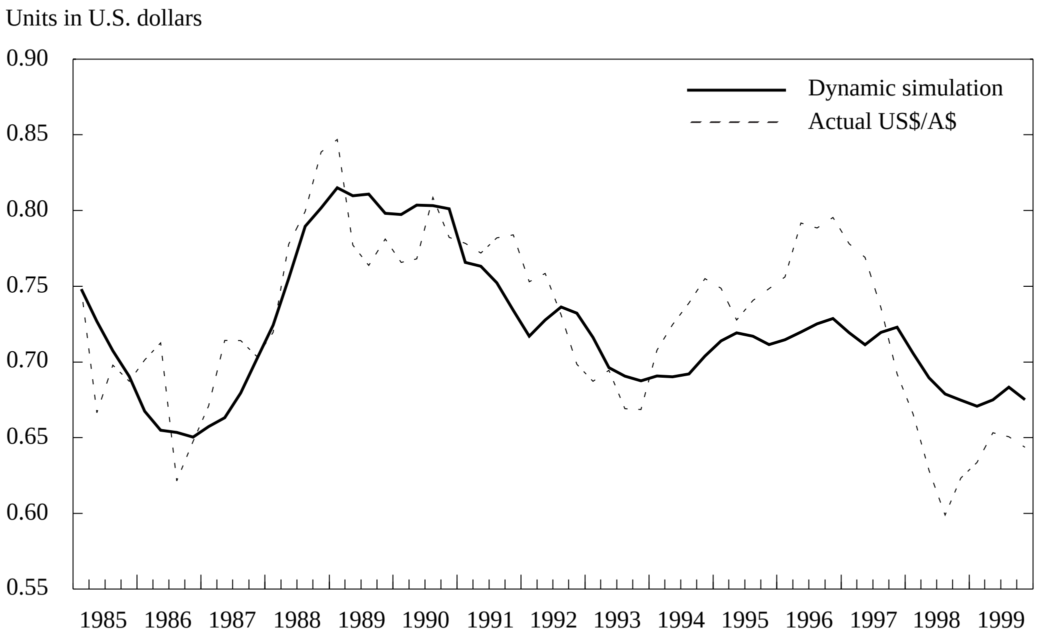
Table 3 reports the results for an alternative specification, based on some of the articles and working papers that have been published on the Australian dollar. (See, for example, Gruen and Wilkinson 1991, Karfakis and Phipps 1999, Koya and Orden 1994, and Tarditi 1996.) Most of these models give a

6. Australia is, nevertheless, a modest net energy exporter. Sales of coal, coke, and other mineral fuels totalled A$9 billion in 1999, while imports of fuels and lubricants equalled roughly A$8 billion.

Table 2
Error-correction model for the Australian dollar
Equation (2)

Variable	Coefficient	*P*-value
Adjustment	–0.29	0.00
Constant	–1.11	0.02
Real non-energy commodity $(comtot_{t-1})$	0.69	0.00
Real energy $(enetot_{t-1})$	–0.55	0.00
Real interest rate differential $(intdif_{t-1})$	0.53	0.04
$\overline{R}^2$	0.21	

Figure 4
Dynamic simulation for the Australian dollar
Equation (2)



prominent role to the terms of trade, as distinct from world commodity prices, and also include the price of gold as a separate explanatory variable.

Attempts to replicate these published results were often unsuccessful, and these efforts failed to uncover any specification that outperformed the error-correction model described above. The new variables were statistically insignificant, and many of the alternative models did not appear to be cointegrated when the sample was extended to include more recent data. The results reported below are taken from one of the more promising models and provide a benchmark with which to judge the results from equation (2).

Table 3
Alternative error-correction model for the Australian dollar
Equation (3)

Variable	Coefficient	*P*-value
Constant	–0.03	0.54
Real exchange rate (rfx_{t-1})	–0.03	0.74
Real gold price (US$/oz.) ($gp_{t-1}$)	0.00	0.01
Terms of trade (tot_{t-1})	–0.11	0.10
Real interest rate differential ($intdif_{t-1}$)	–0.00	0.97
ΔTerms of trade (Δtot_{t-1})	0.002	0.99
$\bar{R}^2$	0.10	

$$\Delta rfx = \beta_0 + \beta_r rfx_{t-1} + \beta_g gp_{t-1} + \beta_t \ln(tot)_{t-1} + \beta_i intdif_{t-1} + \beta_t \Delta \ln(tot)_{t-1} + \varepsilon_t, \quad (3)$$

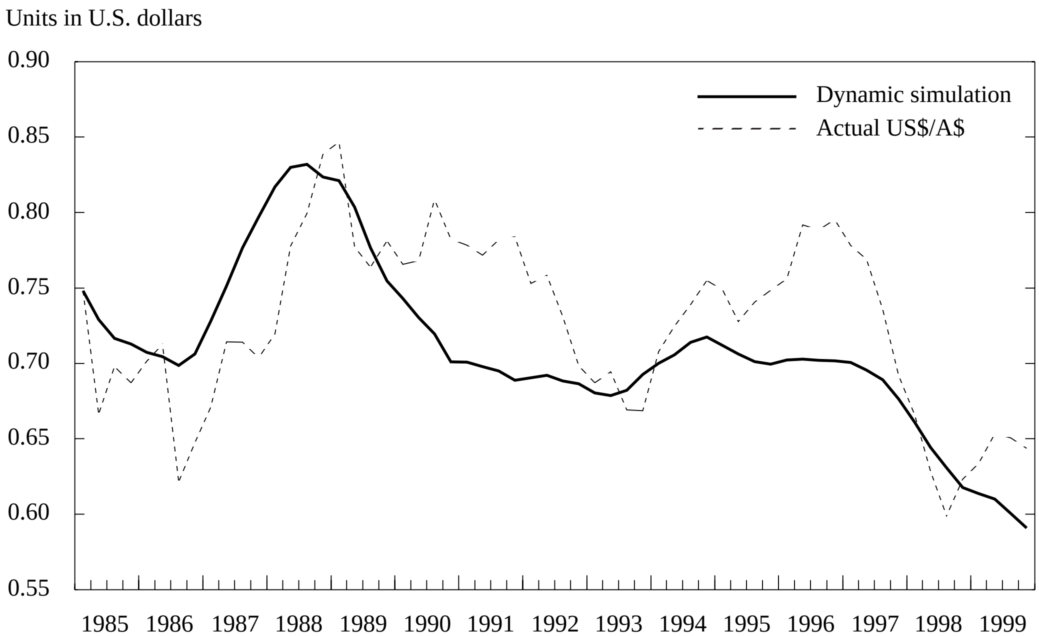
where: rfx = real US\$/A\$ exchange rate,
gp = real gold price,
tot = terms of trade,
$intdif$ = real A-US interest rate differential = $(i_a^l - i_{us}^l)$.

The price of gold, the terms of trade (expressed in levels), and the interest rate differential are not statistically significant. The dynamic simulation (plotted in Figure 5) also exhibits a much weaker relationship to the actual exchange rate than was observed in Figure 4.

2.3 An error-correction model for the New Zealand dollar

The basic error-correction model described above is also able to track the major movements in the New Zealand dollar. As with the Australian dollar, certain modifications have to be made to reflect differences in the composition of New Zealand's exports and the sensitivity of the New Zealand dollar to different market interest rates. The non-energy price variable has been redefined according to the trade weights shown in Appendix 1, and two interest rate variables have been added to the equation—one for the differential on long-term interest rates and another for the differential on short-term interest rates. Tests on a restricted version of the model, which imposed a common coefficient on the two interest rate terms, were decisively rejected. (Since initial results with equation (4) suggested that the

Figure 5
Alternative dynamic simulation for the Australian dollar
Equation (3)



energy-price term did not have any explanatory power, it was dropped in subsequent runs.)

$$\Delta \ln(rfx) = \alpha(\ln(rfx)_{t-1} - \beta_0 - \beta_c \ln(comtot)_{t-1}) + \Upsilon intdif_{1,t-1} + \Phi intdif_{2,t-1} + \varepsilon_t , \quad (4)$$

where: rfx = real US$/NZ$ exchange rate,
$comtot$ = real non-energy commodity terms of trade,
$intdif_{1,2}$ = real NZ-US interest rate differentials $= (i_s^{nz} - i_s^{us}) ; (i_l^{nz} - i_l^{us})$.

The sample period begins in 1987Q1, approximately two years after New Zealand decided to float, and ends in 1999Q4. Parameter estimates and test statistics for the final model are shown in Table 4. The results are broadly similar to those in Tables 1 and 2. All the parameters are statistically significant and have their expected signs. The speed of adjustment is somewhat slower than in the Canadian or Australian equations, however, and changes in *comtot* seem to have a much stronger effect on the New Zealand dollar.

Table 4
Error-correction model for the New Zealand dollar
Equation (4)

Variable	Coefficient	*P*-value
Adjustment	–0.11	0.04
Constant	–3.46	0.02
Real non-energy commodity *($comtot_{t-1}$)*	0.62	0.04
Real short-term interest rate differential *($intdif_{t-1}$)*	0.58	0.04
Real long-term interest rate differential *($intdif_{t-2}$)*	–0.79	0.01
$\overline{R}^2$	0.27	

The correspondence between the actual and predicted values of the equation, shown in Figure 6, is not as close as that observed in Figures 3 and 4, but the general pattern is similar. The period immediately preceding the Asian crisis is again associated with an overvalued exchange rate, as judged by the equation, while the period following the crisis is characterized by an undervalued exchange rate.

Since few articles and working papers appear to have been published on the New Zealand dollar, it is difficult to test the performance of our error-correction model against other specifications. One of several experiments that we tried involved replacing the variable for non-energy commodity prices with one for the terms of trade. Koya and Orden (1994) found evidence of a long-run cointegrating relationship between the terms of trade and the New Zealand dollar. However, a similar specification produced insignificant results and a somewhat weaker fit when their model was tested with more recent data (see Table 5 and Figure 7).

$$\Delta 1n(rfx) = \alpha(1n(rfx)_{t-1} - \beta_0 - \beta_c 1n(tot)_{t-1}) + \Upsilon intdif_{1,t-1} + \Phi intdif_{2,t-1} + \varepsilon_t, \qquad (5)$$

where: *rfx* = real US$/NZ$ exchange rate,
tot = terms of trade,
$intdif_{1,2}$ = real NZ-US interest rate differentials
$= (i_s^{nz} - i_s^{us})\,;\,(i_l^{nz} - i_l^{us})$.

Based on the results reported above, it would appear that a simple error-correction model is able to explain most of the major movements in all three currencies. Nevertheless, episodes of apparent overshooting and excess volatility are observed in some of the dynamic simulations. Whether this is an indication that other fundamental forces are at work, or simply that destabilizing speculators have been active in the market, is unclear. Many

Figure 6
Dynamic simulation for the New Zealand dollar
Equation (4)

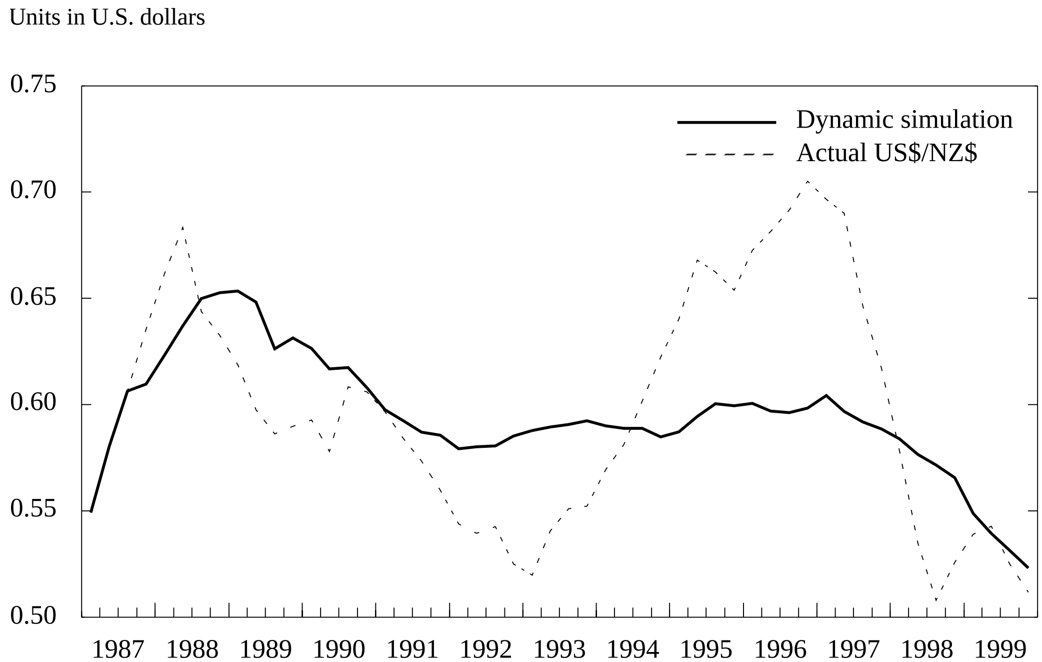


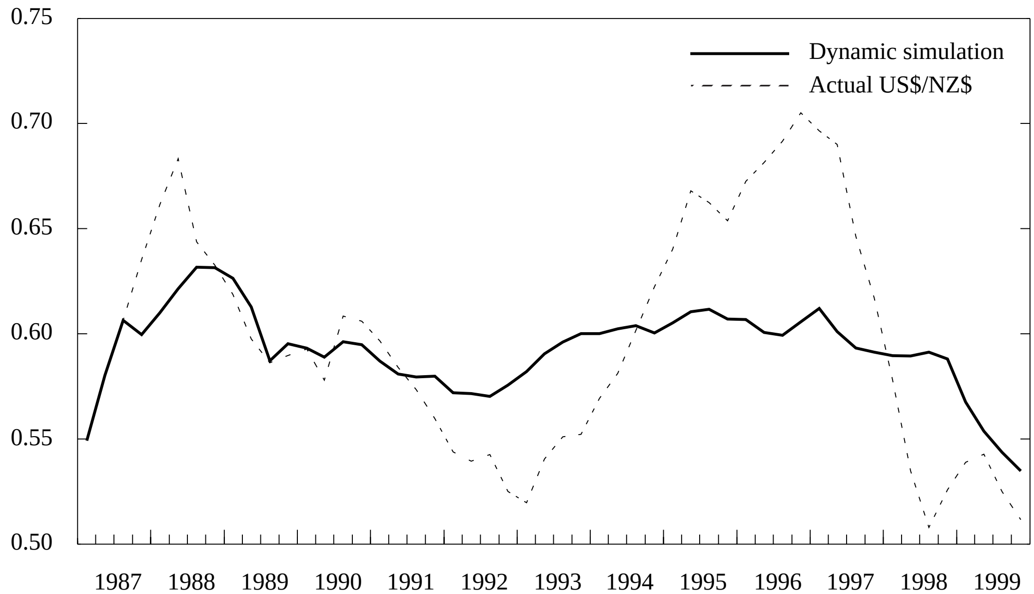
Table 5
Alternative error-correction model for the New Zealand dollar
Equation (5)

Variable	Coefficient	*P*-value
Adjustment	–0.08	0.10
Constant	–0.78	0.00
Terms of trade *(tot_{t-1})*	2.35	0.24
Real short-term interest rate differential *($intdif_{t-1}$)*	1.05	0.00
Real long-term interest rate differential *($intdif_{t-2}$)*	–1.30	0.00
$\overline{R}^2$	0.24	

knowledgeable observers are convinced that foreign exchange markets are dominated by chartists and other technical traders, who have little regard for economic fundamentals and who are concerned only with following the latest market trend. The next section of the paper attempts to capture chartists' behaviour in a simple regime-switching model, and to determine whether they have exerted an important influence on the three currencies.

Figure 7
Alternative dynamic simulation for the New Zealand dollar
Equation (5)

Units in U.S. dollars



3 Regime-Switching Models

The regime-switching models presented in this section assume that there are two types of agents in the foreign exchange market: chartists and fundamentalists. The exchange rate that we observe at any time, t, depends on which group is dominant.[7] Portfolio managers receive advice from both groups and must decide whose recommendations to follow. Chartists, as noted earlier, are assumed to base their recommendations on past movements of the exchange rate. They try to identify emerging trends and turning points in the market and urge portfolio managers to buy or sell a particular currency whenever certain thresholds have been crossed. Fundamentalists realize that exchange rates are subject to destabilizing short-run pressures, but they believe that fundamental forces will eventually push rates back to their long-run equilibrium values. They try to forecast future exchange rate movements with a simple macro model and a few key economic variables.

7. Frankel and Froot (1988) were the first economists to develop a formal model of this process.

The maximization problem that portfolio managers face can be written as follows:

$$LLF = \sum_{t=1}^{t} \sum_{t=1}^{t} \rho(s_t) d(e_t | s_t). \tag{6}$$

Equation (6) is a log-likelihood function, and $\rho(s_t)$ is the probability of being in state *s* at time *t*, where *s* represents either a chartist or a fundamentalist regime. Portfolio managers are assumed to weight the forecasts of chartists and fundamentalists in such a way that their chances of correctly predicting the future value of the exchange rate at each point in time are maximized. The expected value of the nominal exchange rate at time *t* is simply:

$$E\Delta e_{t+1} = \omega_t E\Delta e^f_{t+1} + (1 - \omega_t) E\Delta e^c_{t+1}, \tag{7}$$

where: $E\Delta e$ = expected change in *e*,
e = log of the nominal exchange rate,
f, c = superscripts indicating fundamentalist and chartist forecasts,
ω = weight assigned to the fundamentalist forecast.

The equations that chartists and fundamentalists use to forecast changes in the exchange rate can be written as:

$$\Delta e^f_t = \lambda^f + \phi(\tilde{e}_{t-1} - e_{t-1}) + \gamma intdif_{t-1} + \varepsilon^f_t,$$

$$\varepsilon^f_t \sim N(0, \sigma^f_t), \tag{8}$$

where: $\tilde{e}$ = fundamentalist forecast of *e*,
ε^f_t = forecast error (normally distributed with a zero mean and variance $\sigma_t^{\ f}$),

and

$$\Delta e^c_t = \alpha^c + \psi(X) + \Gamma intdif_{t-1} + \varepsilon_t^{\ c},$$

$$\varepsilon^c_t = N(0, \sigma^c_t), \tag{9}$$

where: X = technical trading rule(s) used by chartists to forecast *e*,
ε^c_t = forecast error (normally distributed with zero mean and variance $\sigma_t^{\ c}$).

Equations (8) and (9) represent the two different states (or regimes) that are presumed to exist in exchange markets. The transition equations that calculate the conditional probability of being in a particular state (given last period's regime) are:

$$\rho(s_t = f | s_{t-1} = f) = \Phi(\alpha_f + \nu_f |s_{t-1} - \tilde{s}_t|), \tag{10}$$

and

$$\rho(s_t = c | s_{t-1} = c) = \Phi(\alpha_c + \nu_c |s_{t-1} - \tilde{s}_t|). \tag{11}$$

The log-likelihood function, the two forecasting equations, and the two transition equations represent the three essential inputs in our Markov regime-switching model. To estimate the model, however, specific functional forms must be substituted for equations (8) to (11). The fundamentalists in our Markov model are assumed to base their forecasts on the exchange rate equations that were developed in section 2. The technical trading rules that chartists use are drawn from the finance literature and are assumed to take one (or more) of the following three forms.

(i) The moving average cross (MAC). This trading rule is based on the behaviour of two moving averages—one calculated over a relatively short time horizon, the other over a somewhat longer interval. Whenever the short-run moving average crosses the long-run moving average from below, a buy signal is generated. (The opposite is true whenever it crosses from above.)[8] For the purposes of our model, the short-term moving average is calculated over a 14-day period (MA14), and the long-run moving average is calculated over a 200-day period (MA200).

(ii) The relative strength index (RSI). This index is used by technical traders to identify overbought and oversold market conditions and is calculated as follows:

$$RSI = 100 - (100/(1 + RS)), \tag{12}$$

where: RS = average number of "up closes" in a given period, divided by the average number of "down closes."

The structure of equation (12) ensures that the RSI will vary between a value of 0 and 100. Arbitrary thresholds, such as 30 and 70, are usually established within this range to identify buying and selling opportunities. (A value lower than 30, for example, might indicate a buying opportunity, while a value higher than 70 might indicate a selling opportunity.) While the RSI enjoys

8. Crosses from below are often called "golden crosses," while crosses from above are called "dead crosses."

considerable support among technical traders, it is known to produce false signals when markets are moving sharply upwards or downwards.

(iii) The moving average convergence and divergence indicator (MACD). The third trading rule is more complicated than the other two, but has become increasingly popular in recent years. The MACD is a combination of three exponentially smoothed moving averages. The first stage of the calculation is essentially the same as that of the MAC. A short-run moving average (such as 14 days) is subtracted from a long-run moving average (such as 200 days). The difference is then compared with a third line, known as "the signal," which is a short-run exponential average of the MAC. Once again, buy orders are associated with crosses from below, and sell orders are associated with crosses from above.

The transition equations that determine the probability of being in either a chartist or a fundamentalist regime are usually linked to the residuals in one of the forecasting equations. If the fundamentalist equation is used for this purpose, the probability of moving into the fundamentalist regime is assumed to increase with the size ε_t^f . The further the actual exchange rate is from the value predicted by fundamentalists, the more likely it is that the fundamentalist regime will be selected in the next period.

The Markov switching models that we report below are estimated with daily data, using an (expectations-step, maximization-step) EM algorithm and maximum-likelihood techniques (Gauss's maxlik package). The EM algorithm allows the model to approach the maximum much faster than the maxlik package but is slower to converge and does not provide any diagnostic statistics. Since some of the Australian and New Zealand data necessary to estimate the model are available only monthly or quarterly, daily versions of these time series have to be generated using a cubic spline.

3.1 Regime-switching results for Canada

Three different sets of results are reported for Canada. The first set, shown in Table 6, assumes that chartists operate on the basis of a simple MAC. All of the estimated coefficients in the model, with the exception of MA200, are correctly signed and statistically significant. The positive coefficients shown in the first row of Table 6 indicate that the Canadian dollar has a tendency to appreciate whenever the fundamentalist forecast of *e* exceeds its actual value (Fund) or when there is a positive interest rate differential (IRD). The positive sign in the second row, under MA14, suggests that chartists start buying the domestic currency whenever the short-run moving average begins to rise. Unfortunately, the same is also true of MA200. Theory would

Table 6
Parameter estimates for the Markov regime-switching model with the MAC trading rule, Canada (daily data)

Fundamentalist regime	**Constant**	**Fund**	**IRD**	σ^f		l_f
Estimates	4.67 e-07	0.0817	0.0006	0.0019		1.2995
P-value	0.49	0.03	0.04	0.00		0.00
Chartist regime	**Constant**	**MA14**	**MA200**	**IRD**	σ^c	l_c
Estimates	0.0001	0.0237	0.0052	–0.0006	0.0009	1.7016
P-value	0.01	0.07	0.11	0.00	0.00	0.00
	AR(1)	ARCH(1)	Test for higher-order Markov effects		Long-term probability	
Regime 1	0.09	0.54	3.4 e-64		0.31	
Regime 2	0.18	0.80	5.2 e-147		0.69	

predict that the sign on this variable should be negative, but instead it has a value of 0.0052 (although it is statistically insignificant).

Two other points worth noting concern the variance of the chartist and fundamentalist regimes and the long-run probability of being in one regime or the other. According to the figures shown under σ^f and σ^c, fundamentalist regimes in Canada tend to be far more volatile than the chartist regimes. Moreover, the long-run probability of being in a fundamentalist regime is only about half as large as the probability of being in a chartist regime. In other words, chartists appear to dominate the foreign exchange market on most trading days and especially during more tranquil periods. Fundamentalists, in contrast, have a much smaller presence, but typically dominate the market when conditions are more unsettled.

A simple way of characterizing the situation might be as follows. Most short-term activity in the foreign exchange market is guided by technical trading rules, which cause the exchange rate to drift steadily up or down. Once the exchange rate has moved a reasonable distance from its long-run equilibrium value, fundamentalists enter the market and (presumably) earn a profit by pushing it back towards $\tilde{e}$. While the fundamentalist regime is usually associated with increased volatility and disorderly market conditions, it would be a mistake for monetary authorities to intervene. As long as exchange rates are moving in the right direction, maintaining orderly markets should be a secondary consideration. Aggressive intervention would simply slow the re-equilibration process.

Figure 8 plots the actual movements of the Canadian dollar over the 1985–99 period against the probability of being in a fundamentalist regime. (The closer the spikes are to 1.0, the higher the probability of being in a

Figure 8
Probability of a fundamentalist regime, Canada, 1985–99

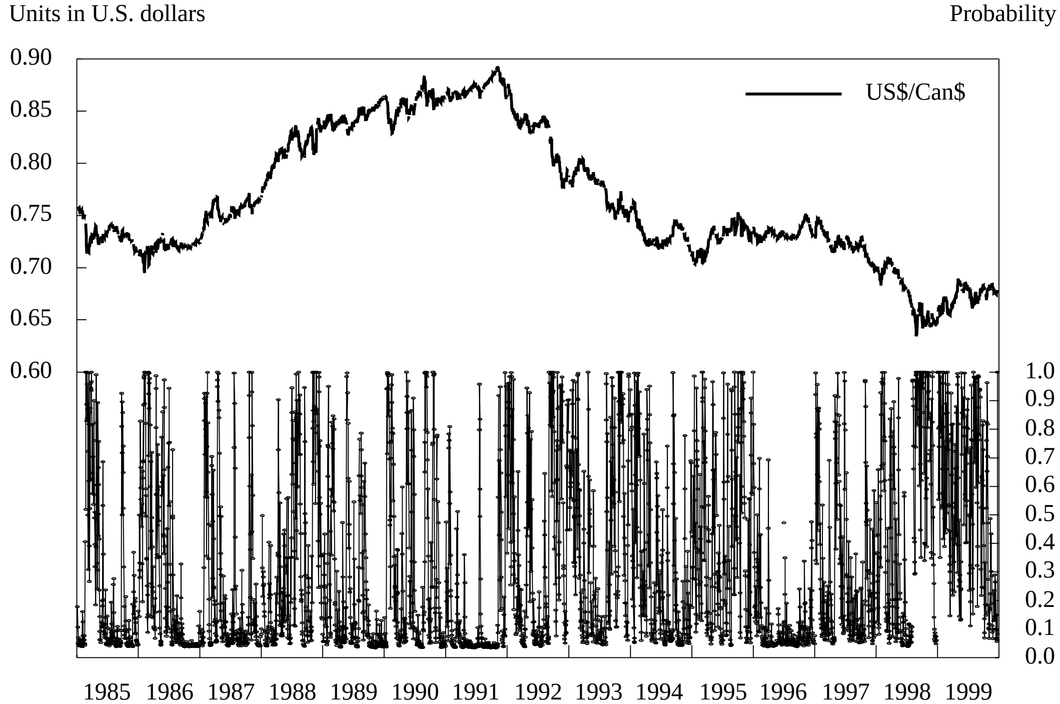


Figure 9
Probability of a fundamentalist regime, Canada, 1995–99

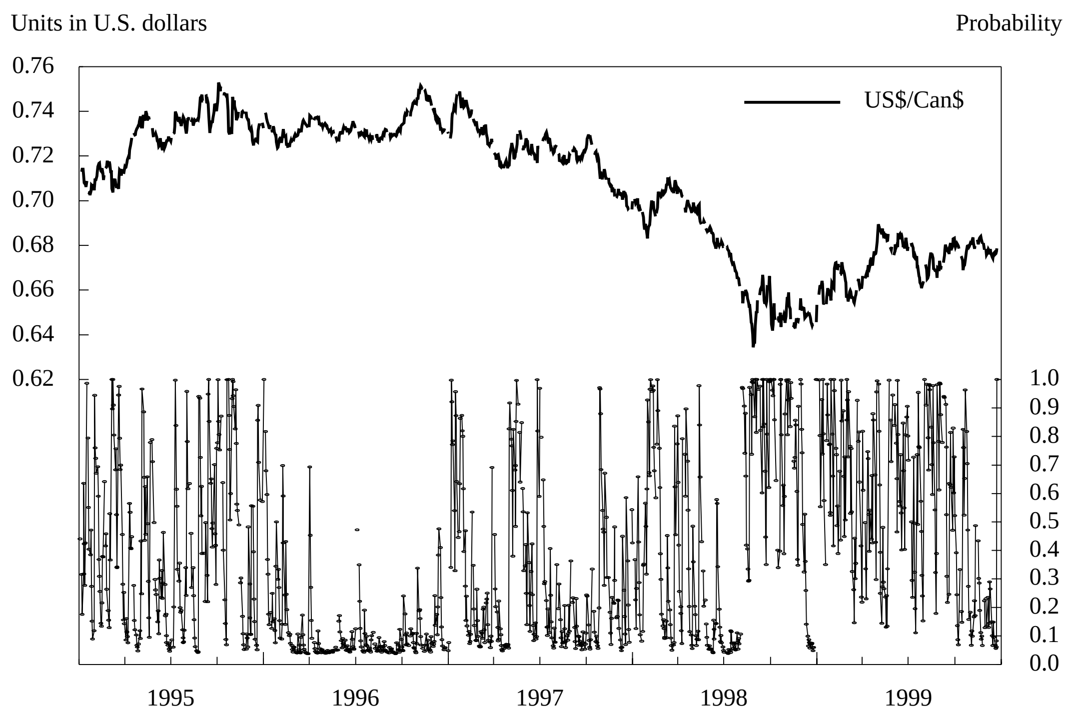


Table 7
Parameter estimates for the Markov regime-switching model with the MAC trading rule, Canada (cubic spline data)

Fundamentalist regime	**Constant**	**Fund**	**IRD**	σ^f	l_f	
Estimates	2.14 e-5	0.0163	–0.0009	0.0019	1.2585	
P-value	0.41	0.04	0.02	0.00	0.00	
Chartist regime	**Constant**	**MA14**	**MA200**	**IRD**	σ^c	l_c
Estimates	0.0001	0.0364	–0.0373	0.0005	0.0009	1.7120
P-value	0.32	0.00	0.10	0.00	0.00	0.00
	AR(1)	ARCH(1)	Test for higher-order Markov effects		Long-term probability	
Regime 1	0.11	0.91	3.63 e-57		0.29	
Regime 2	0.54	0.35	2.91 e-1130		0.71	

fundamentalist regime.) Figure 9 provides a more detailed view of the same series, plotted over the 1995–99 period. A quick glance at either graph confirms the story that was presented earlier. Sharp spikes in the fundamentalist regime are highly correlated with volatile movements in the exchange rate. This is particularly evident during the Asian crisis, but can also be seen on other occasions when the Canadian dollar experienced a significant depreciation. (Appreciations, on the other hand, tend to be more orderly.)

The Markov switching model estimated in Table 7 is very similar to the one in Table 6. The only difference is that some of the data for the fundamentalist forecasts have been generated with a cubic spline, whereas the results in Table 6 are based on actual daily data. All of the important parameters are essentially unchanged, except for the coefficient on MA200, which is now correctly signed and statistically significant at the 10 per cent level. The similarity of the results in Tables 6 and 7 provides some assurance that the estimates for Australia and New Zealand (reported below) have not been affected in any substantive way by the use of the cubic spline.

Table 8 repeats the exercise but replaces the MAC with two other trading rules, the RSI and the MACD. As in the earlier case, the coefficients are all correctly signed and statistically significant. The chartist regime still tends to dominate the market during more tranquil periods, and the long-run probability of being in a chartist regime has risen to 80 per cent. This last number is very close to that reported by Taylor and Allen (1992) in their survey of London foreign exchange traders and is also consistent with the sort of anecdotal evidence that is frequently heard concerning the use of technical trading rules. Taylor and Allen found that 90 per cent of all trading operations in London used some form of chartist or technical trading rule to

Table 8
Parameter estimates for the Markov regime-switching model with the RSI and MACD trading rules, Canada

Fundamentalist regime	**Constant**	**Fund**	**IRD**	σ^f	l_f	
Estimates	–0.0015	0.0050	0.0001	0.0022	1.1016	
P-value	0.00	0.00	0.08	0.00	0.00	
Chartist regime	**Constant**		**MACD**	**RSI**	σ^c	l_c
Estimates	6.05 e-06		–0.2914	–0.0003	0.0009	1.8184
P-value	0.43		0.00	0.00	0.00	0.00
	AR(1)	ARCH(1)	Test for higher-order Markov effects		Long-term probability	
Regime 1	0.14	0.85	3.99 e-53		0.20	
Regime 2	0.38	0.56	1.20 e-133		0.80	

Table 9
Parameter estimates for the Markov regime-switching model with the MAC trading rule, Australia

Fundamentalist regime	**Constant**	**Fund**	**IRD**	σ^f	l_f	
Estimates	–0.0004	0.0177	–0.0006	0.0040	1.1766	
P-value	0.02	0.02	0.28	0.00	0.00	
Chartist regime	**Constant**	**MA14**	**MA200**	**IRD**	σ_c	l_c
Estimates	–0.0003	0.0056	–0.0080	0.0009	0.0017	1.1671
P-value	0.00	0.00	0.00	0.00	0.00	0.00
	AR(1)	ARCH(1)	Test for higher-order Markov effects		Long-term probability	
Regime 1	0.29	0.26	3.6 e-53		0.28	
Regime 2	0.17	0.89	1.03 e-147		0.72	

Table 10
Parameter estimates for the Markov regime-switching model with the RSI and MACD trading rules, Australia

Fundamentalist regime	**Constant**	**Fund**	**IRD**	σ^f	l_f	
Estimates	–0.0004	0.0227	–0.0010	0.0044	1.2461	
P-value	0.03	0.02	0.10	0.00	0.00	
Chartist regime	**Constant**	**MACD**	**RSI**	**IRD**	σ^c	l_c
Estimates	–1.18 e-05	–0.2036	–0.0008	0.0004	0.0019	1.9457
P-value	0.41	0.00	0.00	0.14	0.00	0.00
	AR(1)	ARCH(1)	Test for higher-order Markov effects		Long-term probability	
Regime 1	0.19	0.34	1.5 e-33		0.20	
Regime 2	0.15	0.70	3.12 e-87		0.80	

help guide their activities, especially over short time horizons. As the time frame was extended, however, greater reliance was usually placed on fundamental analysis.

3.2 Regime-switching results for Australia

The regime-switching results for Australia are reported in Tables 9 and 10. They are broadly similar to those for Canada and will not be described in detail. The only difference between the two estimated models in Tables 9 and 10 is the assumption that has been made about the chartists' trading behaviour. Technical traders in Table 9 are assumed to use the MAC, while those in Table 10 rely on a mixture of the RSI and the MACD. The fundamentalist regime has a higher variance than the chartist regime in both models and is also more volatile than the fundamentalist regimes that were reported in any of the Canadian models. However, the long-run probability of being in a fundamentalist regime is generally somewhat lower than in Canada, especially for the MAC versions of the Markov switching model.

Figures 10 and 11, which have been plotted for Australia over the 1987–99 and 1995–99 periods, show results very similar to those reported for Canada. The spikes associated with a fundamentalist regime are usually linked to large downward movements in the exchange rate and are particularly evident during the more volatile periods of the Asian crisis.

3.3 Regime-switching results for New Zealand

The regime-switching results for New Zealand differ from those for Australia and Canada in only one minor respect (see Tables 11 and 12). Some evidence of ARCH-type errors is observed in the residuals for the chartist regimes. Allowing chartists to use different trading strategies does not seem to change the results in any significant way. Substituting the RSI and the MACD trading rules for the MAC reduces the probability of being in a fundamentalist regime but leaves most of the parameter values unchanged.

Figures 12 and 13 present the same story that we saw before, with fundamentalists clearly dominating the exchange market in more turbulent periods. Although the statistical properties of the models for New Zealand might cause some concern, the broad qualitative results reported for this country are unlikely to change once these problems have been corrected.

Table 11
Parameter estimates for the Markov regime-switching model with the MAC trading rule, New Zealand

Fundamentalist regime	**Constant**	**Fund**	**IRD1**	**IRD2**		σ^f	l_f
Estimates	–0.0005	0.0255	–0.0025	0.0058		0.0048	1.0619
P-value	0.04	0.10	0.21	0.05		0.00	0.00
Chartist regime	**Constant**	**MA14**	**MA200**	**IRD1**	**IRD2**	σ^c	l_c
Estimates	–0.0004	0.0060	–0.0076	0.0070	–0.0071	0.0016	1.6531
P-value	0.05	0.20	0.15	0.00	0.02	0.00	0.00
	AR(1)	ARCH(1)	Test for higher-order Markov effects			Long-term probability	
Regime 1	0.18	0.06	1.15 e-45			0.25	
Regime 2	0.20	0.43	3.36 e-132			0.75	

Table 12
Parameter estimates for the Markov regime-switching model with the RSI and MACD trading rules, New Zealand

Fundamentalist regime	**Constant**	**Fund**	**IRD1**	**IRD2**		σ^f	l_f
Estimates	–0.0004	0.0251	–0.0049	0.0086		0.0049	1.0393
P-value	0.08	0.06	0.20	0.03		0.00	0.00
Chartist regime	**Constant**	**RSI**	**MACD**	**IRD1**	**IRD2**	σ^c	l_c
Estimates	–0.0001	–0.0007	–0.2724	0.0069	–0.0075	0.0016	1.6636
P-value	0.05	0.00	0.00	0.01	0.03	0.00	0.00
	AR(1)	ARCH(1)	Test for higher-order Markov effects			Long-term probability	
Regime 1	0.14	0.06	6.75 e-38			0.24	
Regime 2	0.34	0.13	1.78 e-126			0.76	

4 Implications for Foreign Exchange Market Intervention

Taken at face value, the results from sections 2 and 3 would seem to suggest that monetary authorities should be extremely cautious about intervening in foreign exchange markets. Most of the observed movements of the Australian, Canadian, and New Zealand dollars appear to have been driven by economic fundamentals as opposed to destabilizing speculation, and there is very little evidence of significant overshooting. Official intervention is usually undertaken with a view to maintaining orderly markets and keeping exchange rates close to their equilibrium values. But if exchange rates seldom deviate from their equilibrium values, and market volatility is

Figure 10
Probability of a fundamentalist regime, Australia, 1987–99

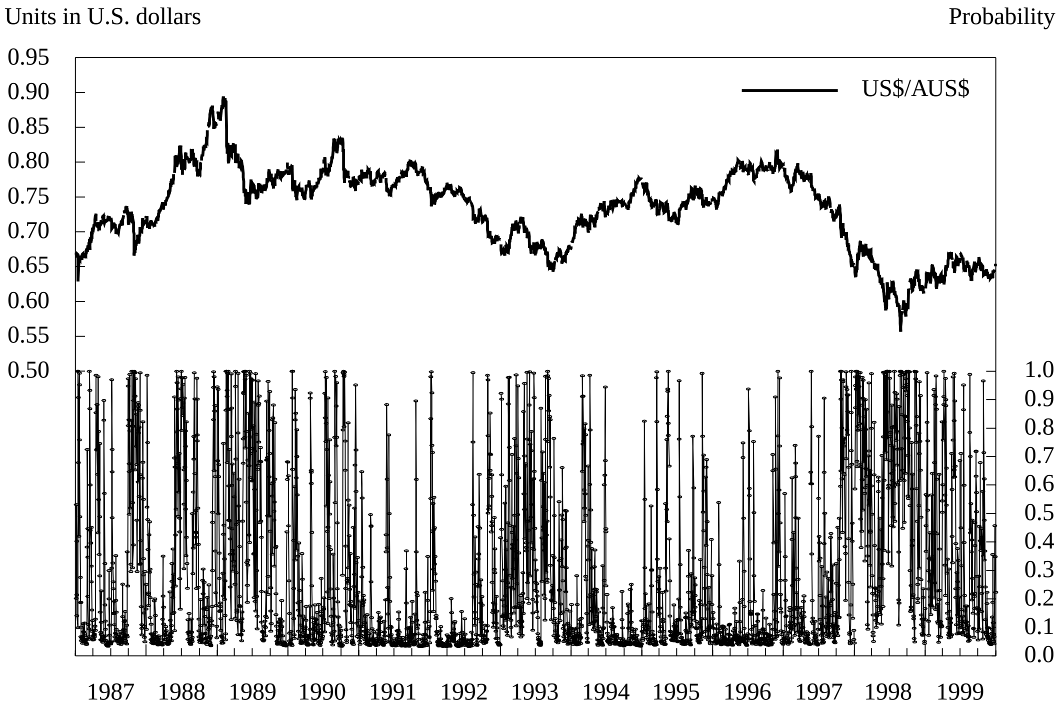


Figure 11
Probability of a fundamentalist regime, Australia, 1995–99

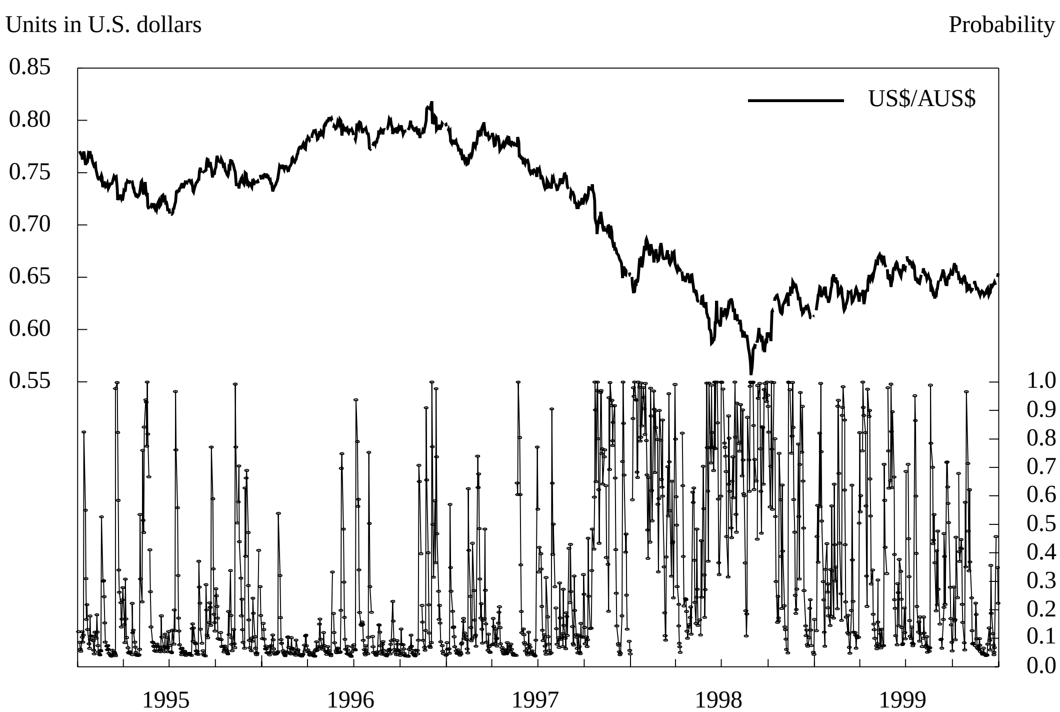


Figure 12
Probability of a fundamentalist regime, New Zealand, 1987–99

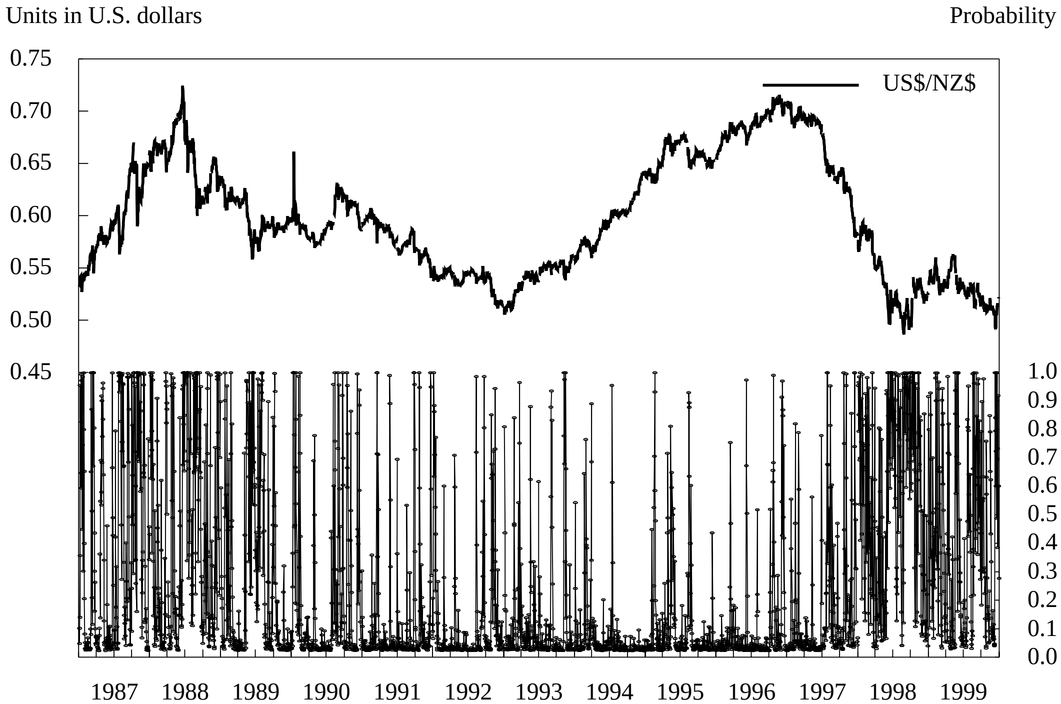
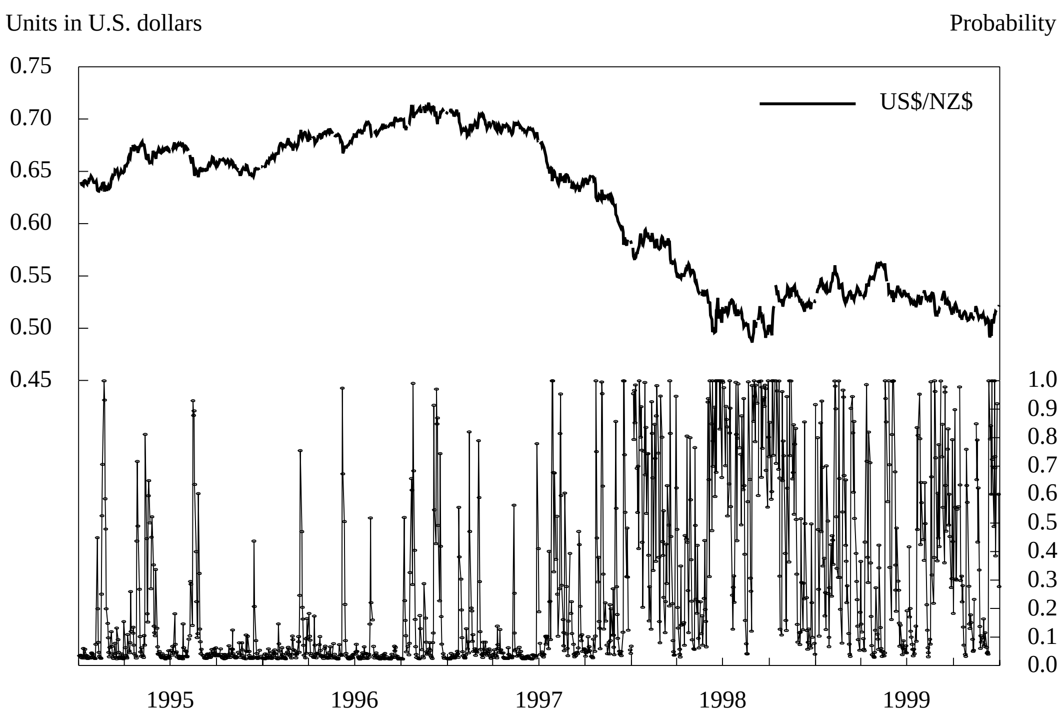


Figure 13
Probability of a fundamentalist regime, New Zealand, 1995–99



typically associated with the stabilizing activities of fundamentalists, these arguments would appear to lose most of their validity. A more relaxed, laissez-faire attitude towards intervention would seem to be called for in the case of these three currencies.

Of the three intervention strategies reviewed in section 1, those of the RBA appear to have offered the least resistance to exchange rate movements. Intervention was initiated on only two or three occasions during the Asian crisis, and less importance was attached to defending the external value of the currency. The Australian authorities generally assumed that their currency was moving for a reason and were not prepared to take any offsetting action. The evidence from section 3 indicates, however, that even this more light-handed touch may have had unfortunate consequences. To the extent that fundamentalists rather than chartists were more active in the Australian market during these turbulent periods, the Australian interventions may have inadvertently delayed necessary adjustments in the exchange rate.

The RBNZ pursued a much more aggressive strategy than the RBA over most of the sample period. Through the first half of the 1990s, exchange rate adjustments were viewed as a way of controlling domestic inflation. Official interest rates would be raised or lowered whenever inflation threatened to move outside the RBNZ's target bands. These interest rate changes were expected to strengthen or weaken the exchange rate and, owing to the open nature of the New Zealand economy, exert a direct influence on consumer prices. The RBNZ soon realized, however, that attempts to control the short-run behaviour of the CPI through regular adjustments in the exchange rate could lead to problems of instrument instability. A new monetary policy strategy was introduced, therefore, based on the monetary conditions index (MCI). According to this strategy, the RBNZ would establish a medium-term path for the MCI, designed to keep the domestic economy in balance. Official interest rates were used to rebalance the index any time an unexpected shift in the exchange rate pushed the MCI off course. Fundamental shocks, which required a change in the exchange rate and a new MCI track, would not be resisted, but portfolio shifts and other unsettling disturbances would be automatically offset. Unfortunately, the RBNZ was inclined to treat most shocks as portfolio shifts. Consequently, more resistance was offered at the start of the Asian crisis than was probably warranted. The evidence from the Markov switching models for New Zealand suggests that this was not an unreasonable assumption on most trading days, since the long-run probability of being in a chartist regime is typically much higher than being in a fundamentalist regime. During volatile periods, however, the reverse is true. With the benefit of hindsight, it is easy to see that most of the exchange rate movements during the Asian crisis were based on economic fundamentals and should have been accommodated (or perhaps reinforced) rather than resisted.

The Bank of Canada, as noted earlier, typically reacted with greater vigour than the RBA, but with less enthusiasm than the RBNZ. It used a combination of sterilized intervention and interest rate adjustments to respond to exchange rate movements through much of the sample period. Although sterilized intervention was often undertaken according to a fixed rule, interest rate adjustments were always applied in a more discretionary manner. In periods of evident instability, such as the Asian crisis, the objective was often to guard against tighter rather than easier monetary conditions. Official interest rates would occasionally be raised in response to a sharp depreciation of the Canadian dollar, even when the movement appeared justified. These adjustments in the Bank Rate were designed to calm financial markets by offering some support for the currency, thereby preventing an even larger increase in market interest rates. The issue of chartists versus fundamentalists—and which regime was dominant at different points in time—was essentially irrelevant. As long as an exchange rate movement was regarded as potentially destabilizing, some offsetting action was deemed necessary.

In retrospect, it appears that the exchange rate movements in Australia, Canada, and New Zealand were often driven by fundamental forces, and less resistance would have been appropriate. It is impossible to know, however, what would have happened if different intervention strategies had been followed. Controlled experiments cannot be conducted in macroeconomics. Ultimately, these actions must be based on judgment and gut instinct. The evidence in sections 2 and 3 should be regarded as simply suggestive, therefore—a modest caution against more aggressive and frequent foreign exchange market intervention.

Conclusion

The main objective of this paper was to examine the recent behaviour of the Australian, Canadian, and New Zealand dollars, and to determine whether there was any evidence of significant overshooting and instability. Simple error-correction models were developed and tested in the first part of the paper. The results suggested that all three currencies were sensitive to changes in world commodity prices and that a few fundamental variables could account for most of the observed movements in each of these currencies over the post-Bretton Woods period.

The second part of the paper examined the activities of chartists and fundamentalists in foreign exchange markets. Regime-switching models were constructed and used to determine the relative importance of these two groups at different points in time. The results for all three currencies were once again very similar. While there was strong evidence of chartist-type behaviour throughout the 1985–99 period, most of the erratic movements in the Australian, Canadian, and New Zealand dollars seem to have been driven by fundamentalists. Chartists were responsible for most of the trading activity in foreign exchange markets, but tended to dominate markets during more tranquil periods. Fundamentalists, on the other hand, appeared to enter the market in a more selective and episodic manner and exerted a greater influence during more turbulent times.

While these results were not expected when the study was undertaken, they are consistent with earlier work by Amano and van Norden (1993); Vigfusson (1996); Murray, van Norden, and Vigfusson (1996); and Murray, Zelmer, and Antia (2000). Our main conclusion is that most exchange rate movements in Australia, Canada, and New Zealand are benign and should not be resisted. They are usually driven by economic fundamentals and represent necessary market corrections. Efforts to smooth exchange rate movements through sterilized intervention and interest rate adjustments are unlikely to be successful, therefore, and may simply reduce market efficiency and stability.

Future research by the authors will concentrate on the following topics. First, we would like to correct the statistical problems associated with the equations for New Zealand. The results that we obtained for the "kiwi" were encouraging and similar to those for the other two currencies. Additional work will be required, however, before these results can be used with any confidence. Second, we would like to improve the performance of our error-correction models by including additional explanatory variables in each equation. Our objective in this paper was not to find the best specification for each currency, but rather to identify a small set of fundamental variables that seemed to work in all three cases. There is no reason to believe that the three or four fundamental variables that were identified in section 2 exhaust all useful possibilities. Third, it would be interesting to test a somewhat larger set of chartist trading rules in our regime-switching models. The parameter estimates for the MAC, RSI, and MACD trading rules were all statistically significant and give us some assurance that the results are reasonably robust. (Those with more experience in this area may still be unconvinced, however.) Fourth, the software used to estimate the regime-switching models in section 3 can be extended to capture the effects of more than two regimes. Some of the test results reported above suggest that Markov models allowing three or more states might provide a better representation of real-world behaviour.

Appendix 1

Table A1.1
Composition of non-energy commodity price indexes

Canada	%	Australia	%	New Zealand	%
Barley	1.8	Barley	2.4	Kiwi fruit	3.7
Canola	2.0	Rice	0.8	Wholemeal MP	10.6
Corn	1.2	Sugar	5.8	Skim MP	3.7
Wheat	8.5	Wheat	13.2	Apples	3.1
Beef	9.4	Beef	9.0	Fish	6.7
Hogs	4.9	Cotton	3.3	Casein	6.7
Cod	0.01	Wool	17.9	Butter	6.5
Lobster	0.5	Gold	19.4	Cheese	8.3
Salmon	0.6	Aluminum	8.9	Beef	9.4
Gold	4.3	Copper	3.1	Lamb	12.5
Silver	0.9	Zinc	1.8	Wool	7.7
Aluminum	4.6	Nickel	2.5	Skins	1.6
Copper	4.5	Iron ore	10.6	Aluminum	8.3
Nickel	3.7	Lead	1.3	Sawn timber	4.6
Zinc	4.2			Logs	3.5
Potash	2.0			Pulp	3.1
Sulphur	1.4				
Lumber	13.8				
Newsprint	12.8				
Pulp	18.9				
TOTAL	100		100		100

Table A1.2
Composition of energy commodity price indexes

Canada	%	Australia	%	New Zealand	%
Crude oil	62.3	Crude oil	15.7	Crude oil	100
Natural gas	29.9	Natural gas	11.1		
Coal	7.8	Coal	73.2		
TOTAL	100		100		100

Appendix 2

Exchange rates

— monthly exchange rates from International Financial Statistics (IFS)
— daily exchange rates from Bank of Canada internal database

Consumer price indexes (all items)

— Canada (Statistics Canada)
— United States (Data Resources Limited/McGraw-Hill)
— Australia (OECD main economic indicators)
— New Zealand (OECD main economic indicators)

Interest rates (monthly or quarterly)

— Canada, 90-day prime corporate paper rate (Statistics Canada)
— United States, 90-day commercial paper rates (Statistics Canada)
— United States, T-bill rate: discount on new issues of three-month bills (IFS)
— United States, long bond: 10-year constant maturities (IFS)
— Australia, 90-day bank-accepted bills (OECD main economic indicators)
— Australia, long bond: secondary market yields on non-rebate bonds with maturity of 10 years. Yields are calculated before brokerage and on the last business day of the month (IFS).
— New Zealand, 90-day bank bills (OECD main economic indicators)
— New Zealand, long bond: rate on the five-year “benchmark” bond, a specific bond selected by the Reserve Bank to provide a representative five-year government bond rate (IFS)

Commodity prices

— Canada, non-energy commodity price index (Statistics Canada)
— Canada, energy price index (Statistics Canada)
— Australia, non-energy commodity price index (used weights from the RBA and constructed a non-energy index by re-weighting). Price data used for commodities were IFS, and the Bank of Canada internal database was used for barley.
— Australia, energy commodity price index (used weights from the RBA and constructed an energy index by re-weighting). Price data used for commodities were from IFS and Bank of Canada internal database for the following commodity: natural gas.
— New Zealand, non-energy commodity price index (memorandum: Australia and New Zealand Banking Group Limited (ANZ) commodity price index). The New Zealand dollar index was converted to US$ by using the quarterly average of the NZ$/US$ exchange rate.

Gold price

— *Globe and Mail Report on Business* (US$/oz.)

Exports

— Canada (IFS)
— Australia (IFS)
— New Zealand (IFS)

Imports

— Canada (IFS)
— Australia (IFS)
— New Zealand (IFS)

Industrial production

— United States (OECD main economic indicators)

Appendix 3

Unit-root tests

Two different tests were used to check for stationarity in the *rfx*, *comtot*, *enetot*, and *intdif* time series—the Adjusted Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. The optimal lag length for each test was selected according to the procedure suggested by Campbell and Perron (1991).

Table A3.1
Unit-root tests, Canada[a]

Period	1973Q1 to 1999Q4	
	ADF[a]	PP[a]
comtot	–2.1305	–1.2382
enetot	–1.5932	–2.0210
rfx	–1.6066	–0.8871
$intdif_1$	–1.8371	–2.9433**

a. **: 5%.

Table A3.2
Unit-root tests, Australia[a]

Period	1973Q1 to 1999Q4		1985Q1 to 1999Q4	
	ADF	PP	ADF	PP
comtot	–1.4300	–1.1578	–1.4178	–0.8115
enetot	–1.3076	–0.9929	–1.4680	–2.2432
rfx	–2.2239	–1.5182	–2.6095*	–1.6454
intdif[b]	–2.9813**	–8.0578**	–2.6006*	–4.5726**
intdif[c]	–2.6736*	–8.4870**	–3.2509**	–4.9839**

a. *: 10%, **: 5%.
b. $intdif_1$ — real T-bill differential.
c. $intdif_2$ — real long-term differential.

Table A3.3
Unit-root tests, New Zealand[a]

Period	1987Q1 to 1999Q4	
	ADF	**PP**
comtot	–2.2126	–1.1130
rfx	–1.9207	–2.3387
intdif[b]	–6.9396**	–7.0041**
intdif[c]	–3.9392**	–6.8980**

a. **: 5%.
b. $intdif_1$ — real T-bill differential.
c. $intdif_2$ — real long bond differential.

The PP test results for Australia, Canada, and New Zealand cannot reject the presence of a unit root in *rfx*, *comtot*, and *enetot*. The same is true for the ADF test results, except for *rfx* in Table A3.2 over the period 1985Q1–99Q4. When the sample is extended back to 1973Q1, however, the results for both tests are consistent.

Although some variability is observed in the test statistics for the *intdif* terms in Tables A3.1 to A3.3, the unit-root hypothesis can usually be rejected. The one exception is the ADF test for Canada.

Cointegration tests

Cointegration was tested with the Johansen-Juselius procedure, using the max and trace test statistics.

Table A3.4
Cointegration tests

	Canada 1973Q1–1999Q4		Australia 1985Q1–1999Q4		New Zealand 1987Q1–1999Q4	
r =	**max**	**trace**	**max**	**trace**	**max**	**trace**
0	22.88**	35.16**	20.69*	37.63**	18.23**	21.82**
1	7.25	12.27	10.81	16.94	3.59	3.59
2	5.02	5.02	6.13	6.1		
	P-value		*P*-value		*P*-value	
LM(1)	0.92		0.62		0.62	
LM(4)	0.29		0.30		0.30	

a. **: 5%.

The existence of less than one cointegrating vector can be rejected for all three countries. Further testing suggests that it includes each of the non-stationary variables (*rfx*, *comtot*, and *enetot*).

Specification tests for the error-correction models

LM tests were used to check for first- and second-order autocorrelation, and the ARCH tests were used to check for autoregressive conditional heteroscedasticity.

Table A3.5
Specification tests for error-correction models, *p*-values

	Canada 1973Q1–1999Q4	Australia 1985Q1–1999Q4	New Zealand 1987Q1–1999Q4
LM(1)	0.62	0.92	0.49
LM(2)	0.84	0.32	0.42
ARCH(1)	0.63	0.64	0.57
ARCH(2)	0.86	0.40	0.52

Note: These tests were done using a model that included a lagged dependent variable.

None of the test statistics indicates a problem in the three error-correction models. While some signs of higher-order autocorrelation were observed in the case of New Zealand (not shown in Table 5), the residuals reported here were all well-behaved.

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Discussion

Gregor Smith

The impressive study by Djoudad, Murray, Chan, and Daw examines two statistical models of the real exchange rate. The first model, which is linear and uses quarterly data, can be written as:

$$\Delta r(t) = \beta o - \alpha[r(t-1) - \beta c(t-1)] + \gamma i(t-1) + \varepsilon(t),$$

where my simple notation has *r* as the log real exchange rate, *c* as a vector of real commodity prices, and *i* as the interest differential.

I will focus on the statistical and policy aspects of their work, and leave the interpretation of the effects of the two commodity prices to others. Features of their specification and results include the following.

(i) This model is written as a forecasting equation, not as a conventional error-correction mechanism, so its good fit is remarkable. However, if the goal is to explain past movements in the real exchange rate, then the use of current-period regressors might well lead to an even better fit.

(ii) The results for Canada display the forward premium anomaly: $\gamma > 0$, so a high interest rate currency tends to appreciate.

(iii) The authors find that *r* and *c* are cointegrated, with slow adjustment.

(iv) The equation is quite stable over time for Canada.

(v) The equation fits better for Australia than do the equations constructed at the Reserve Bank of Australia. Finding an equation that fits for one country over time is an accomplishment. But successfully fitting the same form of equation for other countries is that much more striking.

Perhaps this resilient statistical model could also be tried on small open economies that have adopted a fixed nominal exchange rate with their largest trading partner, since it applies to the real exchange rate. Possible candidates are Canada in the 1960s or the Netherlands.

While the authors' equations fit very well indeed, I do have a suggestion about the reporting of their findings. Their Figures 3 to 7 illustrate dynamic simulations, which show persistent gaps between the actual real exchange rates and the simulated values. But dynamic simulations use a strange information set. In predicting $r(t)$, one uses $c(t-1)$ and $i(t-1)$, but $r(0)$. This information set appears to artificially exclude the recent history of the real exchange rate.

To clearly see the effect of this reporting style, I created a simple simulation and generated data in the following way:

$$\Delta r(t) = 0.3 - 0.14[r(t-1) - c(t-1)] + 0.2\Delta c(t) + 0.7\varepsilon(t),$$

$$c(t) = 0.9c(t-1) + \eta(t),$$

with $\varepsilon(t)$ and $\eta(t)$ pseudo-standard normal. In this simulation laboratory, we know exactly what error-correction mechanism to fit. When I fitted this same form of equation to 100 simulated observations, I found an R-squared and an adjustment speed similar to those in the data. And there was no significant residual autocorrelation, just as the authors found in the historical data.

Figure 1 shows the simulated data (thin line) and the fitted values (thick line), and the fit is very good. Figure 2 shows the impression created by a dynamic simulation, which uses recent observations on the variable *c*, but only the starting value for *r.* Again, the thin line indicates the actual values, while the thick one now shows the dynamic simulation. My point is that the persistent differences between the two lines in Figure 2 are artifacts of the use of dynamic simulation. They are not evidence of bubbles, overshooting, or missing chartists. The underlying cause of this persistence is that multi-step forecast errors are autocorrelated, even if one-step forecast errors are not.

The second model the authors examine is nonlinear and estimated in daily data. I think of this, partly, as a specification test. If the model linking the real exchange rate to fundamentals also works well at the daily frequency, the added possibility of switching to moving averages will not matter statistically. But the authors find that this added feature does matter and that there are many switches, with the moving averages dominating during quiet periods. This is a significant discovery, because they have good daily data on the fundamentals (commodity prices and interest rates) in the Canadian case, yet the chartist variables remain important.

Figure 1
ECM fitted values
(thick line)

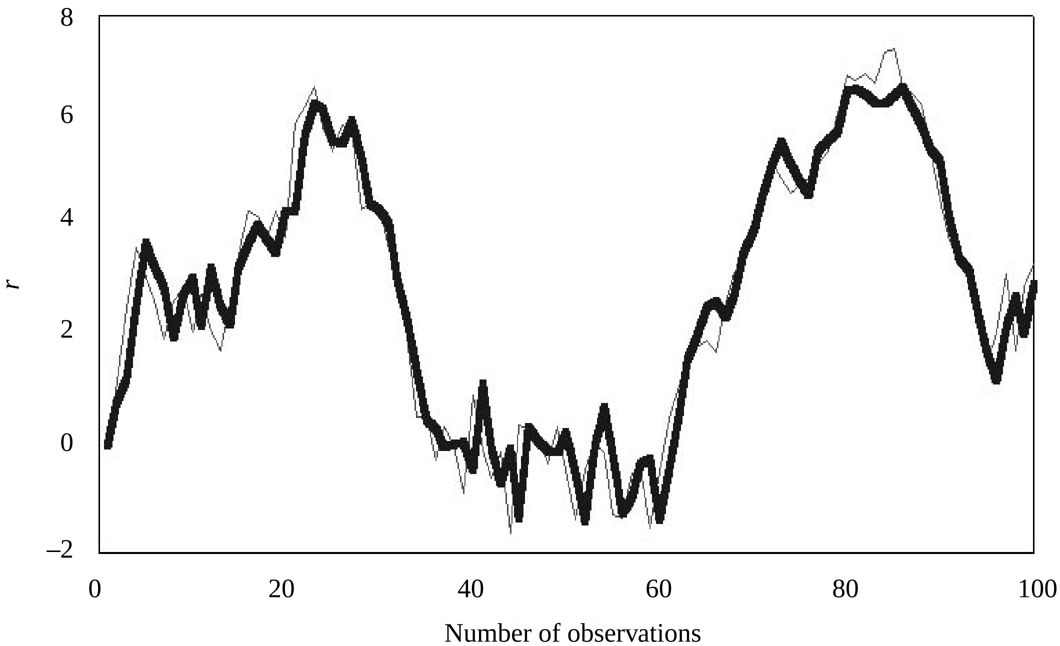
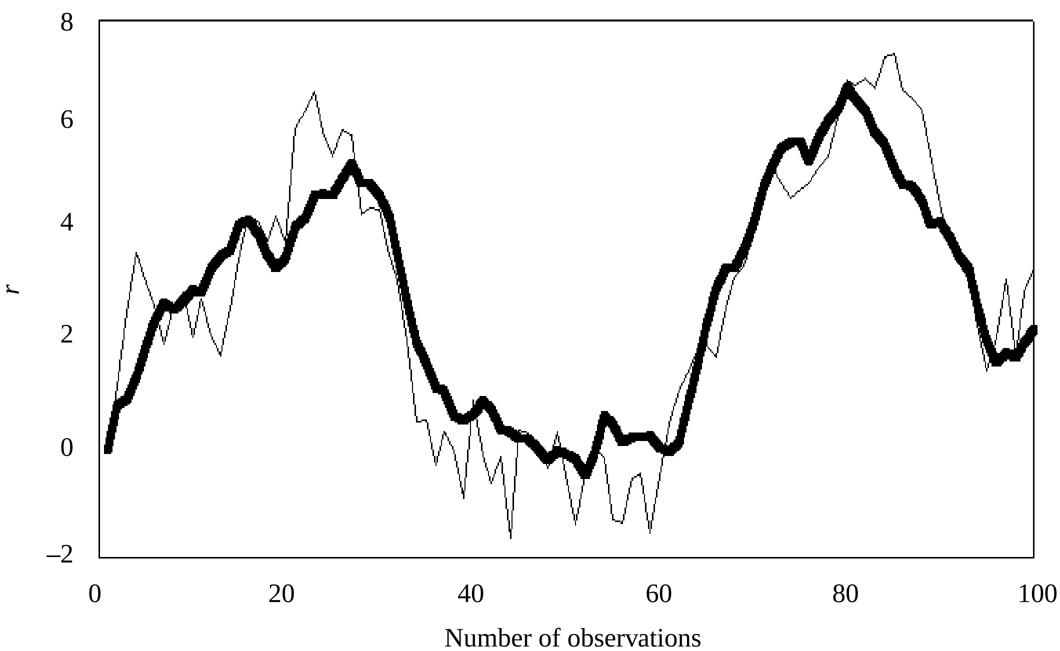


Figure 2
Dynamic simulation
(thick line)



The next step in this research could be the creation of a model in which several types of traders, along with the central bank, participate simultaneously in the foreign exchange market. Such a model might not lead to a simple econometric equation, but its predictions could be studied by simulation.

My final comments relate to policy. The authors suggest that many of the swings in real exchange rates are driven by commodity prices and thus are not signals of the need for intervention. But the international interest rate differential is included in both types of models (and both regimes) they consider. Since the differential is a rough indicator of the policy stance, it is clear that policy does matter, and that it can speed or slow adjustment to the path warranted by commodity prices alone. So, while the authors stress what policy should not do, I think their findings may also shed light on some of what policy has done historically.

For example, in their data for Canada, the correlation between the real exchange rate, $r(t)$, and the interest rate differential, $i(t)$, is 0.45. Meanwhile, the correlation between their estimate of $r(t) - \beta c(t)$ and $i(t)$ is much higher: 0.70. Here I have used their estimates of β, and the vector $c(t)$ includes both commodity prices that they include in their model.

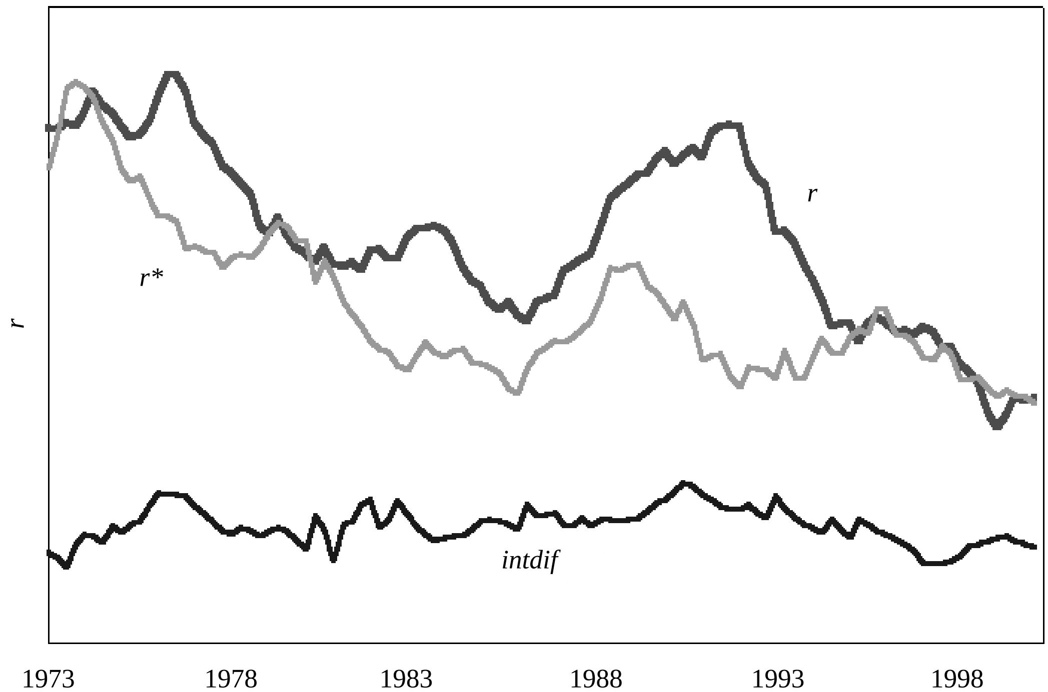
Another way to report this finding is to graph the log real exchange rate along with the linear combination of commodity prices with which it is cointegrated and to show the interest differential in the same graph. Figure 3 does this for Canada. Please note that this figure uses the historical data, with dates shown on the horizontal axis. The combination of commodity prices is labelled *r**, while the interest differential is labeled *intdif*.

Figure 3 has two interesting features. First, the real exchange rate seems to have been adjusting from above towards the path warranted by real commodity prices. In their data definitions, an increase in *r* is an appreciation. Therefore, the figure suggests that the Canadian dollar has generally been overvalued. Perhaps this pattern is natural in a time of declining commodity prices, but it is worth noting anyway.

The other feature is that periods when the real exchange rate was above the path given by commodity prices were periods when the interest differential was high. Simply put, that creates the impression that monetary policy was slowing down the adjustment of the real exchange rate to its long-run path during these periods.

I am not describing a history of Canadian monetary policy, and the authors certainly aren't, either. The goal of policy has not been to smooth the adjustment of the real exchange rate to shocks, and *intdif* is not a pure measure of policy. But this role for *intdif* may make it difficult to argue that

Figure 3
Canadian real exchange rate
(with long-run fundamentals)



movements in the real exchange rate are driven largely by commodity prices. Gerlach and Smets (2000) have also interpreted statistical evidence to suggest that Canadian monetary policy has reacted to the exchange rate.

I suggest that this correlation might tell us something about the effects of past monetary policy. And perhaps historical data on sterilized intervention could be included in these statistical models to determine whether it, too, has affected these real exchange rates.

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