NEMO: An Equation for the Canadian Dollar

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Introduction

Bank of Canada staff have often found it useful, in evaluating the economic outlook, to check the predictions of a Canada-US real exchange rate equation that was originally developed by Robert Amano and Simon van Norden (1993) for RDXF, an earlier Bank of Canada macroeconomic model. This equation, which we call CPE (for Commodity Price Exchange rate), is built around a long-run relationship between the bilateral real exchange rate and real commodity prices, split between energy and non-energy components.[1] Short-run dynamics are captured by Canada-US nominal interest differentials and changes in relative government debt/GDP ratios. Significant differences between the actual and predicted value of the Canada-US nominal exchange rate, based on dynamic simulations, are

1. The traditional Keynesian RDXF (Research Department Experimental Forecasting) model was replaced by a new, forward-looking Quarterly Projection Model (QPM) in late 1993. CPE was initially developed by Amano and van Norden (1993, 1995), but was subsequently modified a number of times. Variants of CPE have figured prominently in various Bank of Canada studies: Murray, van Norden, and Vigfusson (1996); Murray (1999); Djoudad, Gauthier, and St-Amant (2001); Murray, Zelmer, and Antia (2000); and Murray, Djoudad, Chan, and Daw (2001).

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usually interpreted as temporary misalignments, which have a bearing on the conduct of monetary policy.

CPE has raised a number of questions, however. For instance, it implies that higher energy prices weaken the Canadian dollar, despite the fact that Canada is a net exporter of energy-related products and that the United States is a large net importer. Laidler and Aba (2001) argue that energy commodity prices played a limited role in determining the real exchange rate after the 1970s. In effect, estimated over the 1975–99 period, CPE fails to find a significant role for energy prices (see Appendix 2). And CPE cannot account for the sharp appreciation of the Canadian dollar in 2003.

In this paper, building on previous experience with CPE, we estimate a nominal bilateral exchange rate equation, which we call NEMO (Nominal Exchange rate MOdel).[2] Loyal to the Bank's traditions in this regard, our approach is a pragmatic one, based on experimenting with a small set of explanatory variables that have been related to the exchange rate in the literature.[3]

Our best version of NEMO incorporates two long-run fundamentals of the nominal exchange rate fully adjusted for national prices (or real exchange rate): real non-energy commodity prices and labour productivity differentials with the United States. This relationship is augmented by nominal variables to capture short-run dynamics: Canada-US short-term interest rate differentials, the evolution of the US dollar relative to other currencies, and a measure of risk perception in international markets. NEMO tracks the historical data well, both in sample and out of sample and can account for the sharp appreciation of the Canadian dollar in 2003.

Our main message is that NEMO can account for most of the Canadian dollar's movements since 1975. Two exceptions stand out: late 1998 when the dollar came under strong speculative pressure in the wake of the LTCM (Long-Term Capital Management) debacle, and the autumn of 2001 (and most of 2002) in the wake of terrorist acts in New York and Washington.

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2. Our focus on the nominal exchange rate comes from findings early in the project that relaxing the constraints on relative price dynamics, which are part and parcel of a real exchange rate equation, significantly helped to explain the movements of the nominal exchange rate.

3. There is a long-standing tradition in the empirical exchange rate literature of linking the exchange rate to a few key macroeconomic variables or "fundamentals." NEMO may be classified as a BEER equation. BEER stands for Behavioural Equilibrium Exchange Rate. The "equilibrium" label refers to the fact that the exchange rate reflects estimated historical linkages with the fundamentals. It does not mean that the estimated exchange rate from the single-equation model is necessarily at a value that would close the output gap. For a review of BEER and related concepts, see MacDonald (1999 and 2000).

The implication of our findings for monetary policy is that the monetary authorities in their deliberations should assume that the Canadian dollar reflects economic fundamentals, except in extraordinary circumstances when exchange markets are obviously disrupted.

The outline of our paper is as follows. After discussing candidate variables (section 1), we establish the statistical properties of the variables and the conditions that allow us to adopt a single-equation approach (section 1.1). We then report our estimation results (section 1.2), as well as robustness and predictability tests (section 1.3). In section 2, we discuss possible interpretations of the effect of productivity differentials on the exchange rate and conclude in section 3 with leads to further research.

1 Finding NEMO

1.1 Specification

Like CPE, NEMO is an error-correction model (ECM). NEMO is built around a long-run cointegrating relationship between the nominal exchange rate, a proportional change in relative prices, and a set of other long-run fundamentals. Short-run dynamics are captured mainly by Canada-US short-term interest rate differentials and other nominal variables.

In more formal terms:

$$\Delta e_t = \phi(e_{t-1} - p_{t-1} - \Pi X_{t-1}) + \Gamma \Delta Z_t + \varepsilon \quad (1)$$

e: logarithm of the nominal Can$/US$ exchange rate;
p: logarithm of the ratio of Canada/US GDP deflators;[4]
X: set of long-run fundamentals;
ΔZ: set of short-run dynamics;
ϕ is the adjustment coefficient; Π and Γ are vectors of coefficients; and
ε: error term.

In the long run, the bilateral exchange rate will adjust to fully account for Canadian and US inflation differentials and underlying fundamentals that are likely to affect aggregate demand and the trade balance. Thus, we impose (and confirm by tests) a unit coefficient on the price differential

4. We use GDP deflators rather than CPI, because the real exchange rate ultimately balances aggregate demand and supply in an open economy. Thus, prices should be considered from a production, rather than a consumption, perspective.

(p).[5] In other words, in the long run, the real exchange rate $(e-p)$ will adjust to its fundamentals (X).

For the long-run fundamentals, we looked to the major components of Canada's international trade: commodities and manufactured goods. (Variable definitions and sources are listed in Appendix 1.) Commodity prices are quite volatile when compared to prices of manufactured goods, and this volatility is likely to be reflected in real exchange rate movements. Higher prices for commodities that Canada exports represent a positive terms-of-trade shock that requires a real appreciation to re-establish equilibrium. The relationship between the real exchange rate and real non-energy commodity prices (*com*) is evident in the data (Figure A3.3). Given previous findings with CPE, we did not see a role for energy commodity prices.

In the case of manufactured goods, which represent the greater part of traded goods between Canada and the United States, relative productivity (*pmg*) growth should be an important factor. There are two ways to look at the effect of productivity on the exchange rate. The first is a relative supply effect. In a two-country model, the country that experiences higher relative productivity growth will incur a real depreciation, since this is required to increase sales abroad. This assumes that firms are not price-takers in international markets (or that price elasticities for exports are not infinite). An alternative interpretation is the Balassa-Samuelson hypothesis or BSH (Balassa 1964; Samuelson 1964).[6] This hypothesis states that countries where productivity growth in the traded goods sector, relative to other sectors, is greater than that of their trading partners, will experience a real appreciation over time. The reason is that wages in the more productive economy, and therefore prices, will rise faster to reflect the productivity increases.[7]

5. How much prices adjust is not considered in this paper. While not conclusive, a comparison of the variances of the nominal exchange rate (0.0163) and of the relative prices (0.0016), over the 1975–99 period, suggests that the nominal exchange rate was responsible for most of the real exchange rate adjustment that was required by the fundamentals. Consequently, the bilateral nominal and real exchange rates tend to move together (Figures A3.1 and A3.2).

6. BSH assumes that: (i) labour is the only factor of production; (ii) labour is mobile between sectors within a country, such that wages are equalized across sectors within a country; (iii) shares of non-traded goods are the same in both economies and constant over time; and (iv) purchasing-power parity (PPP) holds in the short run for traded goods.

7. In more formal terms, if we define labour productivity at home (abroad) in traded goods as $JT(JT^*)$ and correspondingly labour productivity in the aggregate economy as $JA(JA^*)$ and the following ratio: $\Lambda = [JT/JA][JT^*/JA^*]^{-1}$, then BSH says that an increase in Λ implies a real appreciation. In effect, the aggregate economy can be viewed as a proxy for non-traded goods (i.e., non-manufacturing), since the manufacturing sector accounts for about 20 per cent of GDP in Canada and in the United States.

For the short-run dynamics, we consider initially interest rate differentials (*i*), changes in relative GDP as a cyclical proxy (Δgdp), as well as changes in the effective US dollar nominal exchange rate (Δusd), excluding Canada.[8] The interest rate ratio is lagged one period to reduce the risk of simultaneous equations bias. To the extent that a US-dollar depreciation reflects the process of global adjustment, the Canadian dollar will also tend to appreciate. As for the relative cyclical variable (Δgdp), the presumption is that relatively stronger growth in Canada will result in an appreciation of the Canadian dollar (to counteract aggregate demand pressures).

We also examine, in a second stage, the possible contribution of selected financial market variables, such as the US current account deficit as a proportion of nominal GDP (*uca*), Canadian versus US stock market prices (*sm*), international risk premiums (*yus*), and the Canadian-US federal government fiscal deficit differential (*df*).[9] As these factors will encourage capital flows into Canada, we expect interest rate spreads in Canada's favour and relatively better performance of Canadian stock markets to appreciate the Canadian dollar. Factors that are also considered favourable for the Canadian dollar, by reducing the currency premiums, are a lower international risk premium, a relatively better fiscal balance in Canada than in the United States, and a worsening of the US current account balance (which implies the need for a US-dollar depreciation).

To allow for testing the robustness of the equation and to limit the temptation of data mining, the sample period, 1975Q1 to 1999Q4 or 100 observations, was chosen a priori. The starting point was chosen to allow markets to settle down after the major shocks that were experienced in 1973. They include the large, unexpected oil-price shock in the autumn of 1973, the breakdown of the Bretton Woods pegged exchange rate arrangement in 1973, and a structural break in trend productivity in industrial countries around 1973. In our judgment, too many factors were at play in 1973–74 to get a good grasp on exchange rate fundamentals. The end point was chosen to allow for four years of post-sample experience in order to assess the

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8. We also considered the contemporaneous inflation differential, i.e., Δp. We discarded this variable, however, for two reasons. First, its coefficient was of the wrong sign (higher inflation in Canada pointed to an appreciation of the Canadian dollar), which we could not explain to our satisfaction. Second, we wanted to avoid the risk of simultaneous equations bias.

9. The relatively more favourable performance of stock markets across the border seems to be reflected in a lower Canadian dollar since the mid-1980s (Figure A3.8). The US current account deficit as a proportion of US nominal GDP also seems to parallel the evolution of the bilateral exchange rate in the sense that growing deficits are associated with a stronger US dollar in bilateral terms (Figure A3.9).

forecasting performance of the equation. The relevant data for the explanatory variables are plotted in Figures A3.3 to A3.11.[10]

1.2 The error-correction framework: testing stationarity, cointegration, and weak exogeneity

First, we need to ascertain the order of integration of the variables to ensure that our estimated equations are balanced.[11] To do this, we use the modifications of the augmented Dicky-Fuller (1979) (ADF) and the Phillips-Perron (1988) (PP) tests that have better finite-sample properties. Elliott, Rothenberg, and Stock (1996) suggest detrending the variables via a generalized least squares (GLS) regression before performing the ADF test. Ng and Perron (2001) also apply the GLS procedure to detrend the variables and modify the PP tests statistics using a method suggested by Stock (1999) that corrects for possible size distortions in the presence of negative moving-average errors. We perform both tests under the general-to-specific sequential testing procedure suggested by Campbell and Perron (1991). Reported in Table A3.1, the results indicate that series *e*, *com*, *pmg*, *usd*, *p*, and *yus* appear to have a unit root, while *i* appears to be mean stationary.

Second, we need to determine whether the I(1) variables of interest *e*, *p*, *pmg*, and *com* are cointegrated. The Engle-Granger (1987) method applies a unit-root test to the residuals of the candidate cointegrating vector. Our tests suggest that we cannot reject the null hypothesis of no cointegration at the 10 per cent level using the appropriate critical values (Table A3.2).[12] The Engle-Granger method, however, lacks power in identifying short-term dynamics. One solution to this problem is to use an ECM test, which is based on the Granger representation theorem that says there is an error-correction representation for every cointegrating relationship. Boswijk and Franses (1992) and Boswijk (1994) propose such a test. A single conditional ECM is estimated under three assumptions: (i) there is at most one

10. Following the conference, we updated the data in the figures from 2003Q4 to 2004Q3.
11. Formally, a variable is said to be an integrated series of order d, denoted I(d), if it can be represented by a stationary and invertible autoregressive moving-average (ARMA) process once it has been differenced d times. The variable is also said to have d unit roots.
12. The standard Dickey-Fuller tables from the unit-root tests may only be used if values of the cointegrating vector are imposed. Since the error term is estimated from a process that minimizes the sum of squared residuals, the cointegration test would be biased towards finding a stationary process using the standard Dicky-Fuller distribution. One consideration affecting the distribution of the appropriate critical values is the number of I(1) variables in the cointegrating relationship. Although four variables define our cointegrating relationship, a unit coefficient for *p* is imposed. Thus, our equation reduces to estimating a three-variable cointegrating relationship defined by $(e_t - p_t) = \Pi X_t + \varepsilon$ from equation (1) and applying the unit-root tests on the estimated residuals.

cointegrating vector; (ii) the variables of interest (here *p*, *pmg*, and *com*) are weakly exogenous; and (iii) the residuals are normally distributed.[13] A Wald-type test is performed to measure the significance of the long-run relationship in the ECM. The results indicate that a cointegrating relationship exists at the 5 per cent level (Table A3.2).

Our final test for cointegration is the system approach of Johansen and Juselius (1990), which has the advantage of determining the number of cointegrating vectors while making no assumptions of exogeneity. Moreover, we can test assumptions specified in equation (1). We begin by estimating an unrestricted vector autoregressive (VAR) system of equations with variables *e*, *p*, *pmg*, and *com*. The results point to the presence of a single cointegrating vector (Table A3.2).[14] To check if the relative price term (*p*) has a unit coefficient, we test the assumption that the coefficients of *e* and *p* are equal with opposite signs in the cointegration space. The likelihood-ratio test statistic of 1.25 follows a $\chi^2(1)$ distribution with a *p*-value of 0.26, indicating that this restriction is not rejected.

For NEMO to be estimated as a single error-correction equation, we need to verify the condition of weak exogeneity for our cointegrating variables (Johansen 1992).[15] Under the assumption of one cointegrating vector and imposing the linear restriction that the coefficients for *p* and *e* are equal with opposite sign in the cointegration space, the likelihood-ratio test statistic of 4.67 has a $\chi^2(4)$ distribution with a *p*-value of 0.32. This suggests that weak exogeneity is satisfied and our single-equation specification for NEMO is valid.

1.3 Estimation results

Our various equations are estimated by the non-linear least-squares approach of Phillips and Loretan (1991). This approach allows us to estimate both the long- and short-run relationship and use standard inference to test hypotheses about the parameters in Π and Γ—though not ϕ—in equation (1).

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13. The variables are weakly exogenous in the sense of Engle, Hendry, and Richard (1983). This is verified below.

14. To check if the exchange rate (*e*) is part of the cointegrating relationship, we excluded it from the cointegration space and repeated the test. In this case, we could not find a cointegrating relationship at any conventional level of significance.

15. A cointegrating variable τ fails to be weakly exogenous if the error-correction mechanism appears in some other equation determining τ. As formulated by Johansen and Juselius (1990), the test of weak exogeneity is a test on whether components of the adjustment matrix Ψ, ψ_i, associated with *p*, *pmg*, and *com*, are equal to zero.

From Table A3.3, EQ1 includes two long-run determinants for the real exchange rate $(e-p)$: relative labour productivities (*pmg*) and real non-energy commodity prices (*com*). For the short-run dynamics, two variables were retained: the lagged nominal interest rate differential (*i*), and the US dollar effective exchange rate excluding Canada (*usd*). In the latter case, our assumption is that part of the overall US dollar adjustment to its fundamentals is reflected in the bilateral Canadian dollar exchange rate (i.e., the coefficient on Δusd should be positive).[16] EQ1 says that higher productivity growth in manufacturing than in the aggregate economy in Canada, relative to the United States, leads to a depreciation of the real exchange rate. To the extent that we associate manufacturing more with traded goods, the sign of the coefficient of *pmg* is opposite of what BSH would predict. It is not inconsistent, however, with new open economy macroeconomic models (see section 2 for a discussion). Positive productivity shocks will tend to induce a real exchange rate depreciation to raise aggregate demand to the higher output potential. In a flexible exchange rate regime, most of the adjustment will come from changes in the nominal exchange rate.

The finding that relatively higher productivity growth in the Canadian (US) manufacturing sector tends to depreciate the Canadian (US) dollar is quite robust.[17] In EQ3, only productivity differentials in manufacturing are considered (rather than as a ratio of aggregate productivity) and we still find a negative relationship between productivity and the external value of the currency.[18] The effect is also present for broader measures of productivity, though neither GDP per employee (EQ4) nor GDP per capita (EQ5) was found to be significant at the conventional levels. If we split the two relative productivity measures into manufacturing and aggregate productivity, their coefficients are of opposite signs, though the aggregate productivity measure is not significantly different from zero at conventional levels (EQ6).

Estimation results with additional financial variables are reported in Table A3.4. Most of the financial variables that are considered add little to the fit of the equation. US current account deficits are not significantly related to the Canadian dollar (EQ8).[19] The coefficient on Δsm is

16. While it is possible to improve on EQ1 by including changes in the Canada-US GDP ratio (EQ2), concerns about endogeneity led us to drop this variable.
17. Some have suggested, and this does not contradict our results, that the main “driver” of *pmg*, at least since the mid-1990s, has been the surge in US manufacturing productivity growth.
18. Note that other definitions of *pmg* would entail different rationales to motivate the inclusion of the relative productivity term in the exchange rate equation.
19. Bailliu, Dib, and Schembri (2005) are more successful with a non-linear relationship that includes threshold effects.

significant and of the expected sign (EQ9). Faster rising stock market prices in Canada lead to an appreciation of the Canadian dollar, but the effect is quite small. Relative federal government budget balances are not significant (EQ10), nor is there an obvious relationship in the data apart from the 1990s (Figure A3.10). In contrast, the emerging-market risk-premium variable (*yus*) that we introduce is highly significant and of the expected sign (EQ11). Our assumption, based on anecdotal evidence, is that Canada gets sideswiped in periods when investors in international markets are more risk-averse or seek safer havens. Higher risk premiums on emerging-market bonds are assumed (and found) to be a negative for the Canadian dollar, though it is not immediately apparent from the data (Figure A3.11). EQ12 indicates that the risk-premium indicator is preferred to the stock market variable.

Among the equations that we considered, EQ11 is the best candidate for NEMO. All its coefficients are significant at the 1 per cent level and of the correct sign. (The sign on the productivity variable is consistent with models that take into account price rigidities, imperfect competition, and preferences favouring local goods.) The Lagrange Multiplier test does not indicate any serial correlation of the residuals, and the White (1980) test suggests no heteroscedasticity problem (Appendix 3). Moreover, the fit is quite good.

Ceteris paribus, the coefficients of NEMO indicate that:

- it takes about four and a half years for the real exchange rate to adjust to its fundamentals;[20]
- higher real commodity prices strengthen the Canadian dollar;[21]
- faster labour productivity growth in manufacturing in Canada than in the United States tends to depreciate the currency—and vice versa for aggregate productivity growth;
- a 100 bp increase in interest rate differentials in Canada's favour will lead to a 2 per cent appreciation of the Canadian dollar in the short run; and

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20. In effect, 90 per cent. This is based on the following formula: $\phi t = \ln(1 - P)$, where ϕ is the adjustment coefficient, t is the number of quarters, and P is the proportion of the gap between the actual and equilibrium real exchange rate according to its long-run fundamentals that is closed. In this case, $P = 0.90$ and $t = 17.7$. After two years, about two thirds of the gap is closed.

21. As major movements in the US dollar will tend to affect commodity prices (since commodity price fluctuations are magnified for the other major economies), we checked whether *usd* and *com* were strongly correlated. We found no significant correlation between these two variables up to four leads or lags. See Appendix 3 for details.

- on average, about 10 per cent of US-dollar movements relative to other currencies will be reflected in the bilateral exchange rate, in the short run.

NEMO can account for the appreciation of the Canadian dollar from the beginning of 2003 to the third quarter of 2004 (Figure A3.12). The contribution of each explanatory variable in NEMO is plotted in Figure A3.13 (for the long-run cointegrating terms) and Figure A3.14 (for the short-run dynamics). According to NEMO, over the past two years, the main factors underlying the appreciation of the Canadian dollar were rising commodity prices (*com*), the depreciation of the US dollar against other major currencies (*usd*), and a lower international risk premium (*yus*). Other factors had only a marginal impact. Over the 1975–2004Q3 period, a decomposition shows that the main factor that contributed to the depreciation of the Canadian dollar was the decline in real commodity prices (Figure A3.15), while interest rate differentials played a major, though temporary, role in supporting the currency around 1990 (Figure A3.16).

1.4 Robustness and predictability

To gauge the robustness of NEMO, we did rolling regressions with a fixed window of 50 observations (Figures A3.17 to A3.22; the date in the charts refers to the last data point in the sample). Two things stand out in these charts. First, the coefficients appear to be stable, as there is no indication of coefficients changing signs, and the range of variation of the estimated coefficients seems to be within the conventional standard errors. Second, the Russian/LTCM episode has a large, temporary impact on the value of the coefficients, suggesting that this period was an "outlier" in the data. We also report estimates of NEMO's coefficients for various sample lengths (including post-1999 data) in Table A3.5, running from 60 to 116 observations. As can be seen, NEMO does well in all sample periods.

Based on a dynamic simulation that starts in 1975 (Figure A3.23), we can conclude that NEMO tracks the historical data well. NEMO is unable to explain the weakness of the Canadian dollar in late 1998 and 2001, however. In both cases, special factors that are not captured in the model were at play. In the summer of 1998, the Canadian dollar came under pressure in the wake of the Russian currency crisis and the collapse of LTCM. This led to abandoning the official policy of intervening on the exchange market to temper daily variability. In September 2001, terrorist attacks in New York and Washington affected the US and Canadian financial systems for a short while, and the Canadian dollar depreciated as capital flowed into the United States.

Before evaluating NEMO's forecasting ability, we need to establish the condition of strong exogeneity by testing the null hypothesis that variables *p*, *pmg*, and *com* in our VAR system do not Granger-cause *e*. Toda and Yamamoto (1995) have established that we can formulate this test in a VAR level representation even with integrated or cointegrated processes, as long as the order of integration does not exceed the true lag length. Since our maximal order of integration is one, we can proceed to test for Granger causality in the usual manner by estimating our VAR with two lags and testing whether the coefficient matrices associated with *p*, *pmg*, and *com* of the first lag are equal to zero. The likelihood-ratio test statistic of 1.25 follows a $\chi^2(3)$ distribution with a *p*-value of 0.74 and allows us to conclude that strong exogeneity is satisfied.

Following the methodology of Meese and Rogoff (1983), we compare NEMO's out-of-sample forecasting performance to a random walk with drift (RWD). We estimate NEMO on data up to the fourth quarter of 1994 and then generate forecasts at one-, four-, eight-, and sixteen-quarter horizons, using the realized values for the explanatory variables. We repeat this process moving one period forward, while maintaining the number of observations fixed, until 2003Q4. The calculated forecast errors are reported as mean absolute error (MAE), root-mean-square error (RMSE), and Theil's U-statistic (THEIL) in Table A3.5. Based on all three criteria, NEMO outperforms the RWD at the one-, four-, eight-, and sixteen-quarter horizons.

2 Discussion: Productivity and the Exchange Rate

Benigno and Thoenissen (2002) provide some insight into our result that higher relative productivity growth in Canada in the manufacturing sector relative to the aggregate economy incurs a real depreciation. They propose a two-country, sticky-price model of real exchange rate determination, which allows for deviation from PPP, both in the short run and in the long-run steady state. The model is calibrated to the United Kingdom and euro-area economies. The authors test if supply-side improvements since 1996 in the United Kingdom can account for the pound's appreciation. In their model simulations, however, improvements in productivity and increases in competitiveness are associated with a depreciation in both the spot and the equilibrium real exchange rates. The only case where a real appreciation occurs is when an increase in productivity is anticipated but has not yet occurred. The increase in perceived permanent income results in greater demand today (relative to supply) and a real appreciation. In the case of the productivity shock in the traded goods sector, a preference for local goods dominates the Balassa-Samuelson effect. In the case of an improvement in competitiveness in the domestic market, the market segmentation channel (as PPP does not hold) dominates.

Ambler, Dib, and Rebei (2003), or ADR, show that the direction of the effect depends on the persistence of the productivity shock. They present an estimated structural model of a small open economy with optimizing agents and nominal rigidities. The model is an extension of the calibrated model in Dib (2003). The ADR model is estimated using quarterly data for Canada and the United States. These models show that a temporary (permanent) positive technology shock induces a real exchange rate depreciation (appreciation) in the long run. Simulations with the International Monetary Fund's new Global Economic Model (GEM) indicate that positive productivity shocks in traded goods in the home country result a real appreciation of the currency (Hunt and Rebucci 2003).[22,23] The emergence and magnitude of the Balassa-Samuelson effect in GEM depend on the specific parameterization of the model.[24] The appreciation of the exchange rate owing to the Balassa-Samuelson effect stems from the presence of the non-tradable sector, combined with perfect labour mobility between the two sectors, which equalizes their nominal wages.[25] In a version of the model without non-tradable goods, however, the real exchange rate must depreciate to create the demand needed to absorb the additional supply of home tradable goods.

As noted above, our results are not consistent with the BSH interpretation. We are skeptical, however, of the BSH for two main empirical reasons. First, the international correlation between the real exchange rate and real GDP per capita, which has been strong among OECD and Asian countries

22. GEM is a new open economy macroeconomics (NOEM) model with specific micro foundations. Short-run demand determination of output originates from costly price and wage adjustment and monopolistic competition. It is a multi-good model with a distribution sector, in the mould of Corsetti and Dedola (2002), inducing market segmentation and endogenous, incomplete pass-through.

23. In Corsetti and Dedola (2002), productivity improvements in tradable goods at home generate a real depreciation. The effect works through the terms-of-trade effect, subject to the pricing decisions of firms.

24. To explain the appreciation of the US dollar and the magnitude of the deterioration of the trade balance, Hunt and Rebucci have to introduce uncertainty in their rational-expectations mechanism and assume that the risk premium on US assets has fallen substantially.

25. To further confuse the issue, Lee and Tang (2003), based on panel estimates of ten Organisation for Economic Co-operation and Development (OECD) countries, find a positive relationship between the exchange rate and productivity when productivity is measured by labour productivity. However, with total factor productivity, they find that an improvement in productivity, while not statistically significantly related to the real exchange rate, sometimes points to a real depreciation.

(Helliwell 1994, 22), but not within other groups of developing countries, is based on differences in productivity levels that are found almost equally among tradables and non-tradables. Second, if and when countries get on a convergence path of income growth that is higher than in the richer countries, productivity growth is higher in both tradables and non-tradables. Although the evidence supports the broad notion that countries often achieve higher real exchange rates as their average productivity levels converge to those of the richer countries, this high productivity growth is found throughout the economy. Thus, it seems to us unpromising to attempt to explain this convergence in terms of relative productivity growth that is higher in manufacturing.

For example, comparing two developed countries, while Canada's labour productivity growth has not kept pace with the United States, the widening gap over the 1990s was much smaller for the economy as a whole than in the manufacturing sector. Tang and Wang (2004) show that the differences are attributable to the fact that the importance of the manufacturing sector declined over the past twenty-five years or so. They estimate the contribution of various sectors to aggregate productivity growth and show that the service sector in the United States experienced higher labour productivity growth and a larger increase in its relative size than in Canada. In the manufacturing sector, the United States had much higher productivity growth than in Canada, but this was offset by a larger decline in relative size.[26]

The key error of assumption in BSH, which tends to drive the results, is that PPP always holds in tradable goods.[27] If goods and tastes differ by country, and if local producers are systematically better at recognizing and providing for local tastes, then it is possible to turn BSH on its head, as shown by Benigno and Thoenissen (2002). In this model, higher general increases in

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26. Data constraints limit their analysis to the 1987–98 period. Over this time, Canada's labour productivity for the total economy increased by 12.0 per cent. Services contributed 12.4 percentage points (pp), manufacturing 2.1 pp, while the primary sector (–1.2 pp) and construction (–1.2 pp) made negative contributions. In the United States, aggregate labour productivity increased by 15.1 per cent, all attributable to productivity increases in services (15.64 pp), as the contribution of other industrial sectors was marginal: primary (-0.84 pp), construction (0.34 pp), and manufacturing (–0.07 pp).

27. Canzoneri, Cumby, and Diba (1999), using a panel of OECD countries, find that PPP between traded goods does not hold when the US dollar is the reference currency. (It does better with the D-mark.) A number of studies have shown that PPP does not hold for traded goods. For a survey of these issues, see Rogoff (1996). This has led to new models that highlight the importance of local currency pricing or pricing-to-market behaviour to explain, among other things, low degrees of estimated exchange rate pass-through to domestic prices.

productivity could lead to a higher real exchange rate (as shown by much of the international data), but an increase in relative productivity growth in manufacturing might be expected to lead to a real depreciation.

In summary, our results suggest that relative productivity in the manufacturing sector is capturing a supply effect in markets where Canadian firms are not price-takers. At the same time, when Canada's overall productivity grows faster than across the border, its real exchange rate appreciates, because this is a sign that its economy has relatively better prospects. While our results invalidate BSH, they are not inconsistent with models that take into account price rigidities, imperfect competition, intermediate goods, and preferences favouring local goods.

Conclusion

While NEMO tracks the historical data quite well, this does not mean that the path of the fitted values, either of the static or dynamic simulations, or of the path described by the cointegration term, represents the equilibrium value of the exchange rate. The real exchange rate is at its equilibrium value when the economy has reached both internal and external balance or equilibrium. Since NEMO does not depend on measures of internal and external disequilibrium, there is no reason why its fitted values should correspond to some notional equilibrium for the economy. What NEMO represents is a strong link between key variables, such that systematic deviations of the Can$/US$ exchange rate from the predicted path of the equation would tend to correct themselves over time.

NEMO is best viewed as an evolutionary step in what has been a series of Bank of Canada exchange rate equations that have used the same basic framework. Like its predecessors, NEMO does not yet adequately reflect either the causes or the consequences of large and sustained moves of the US dollar against all currencies. The inclusion in NEMO of the exchange rate between the US dollar and all other currencies is intended as a move in the right direction, but those changes are not explained, and do not attract a large enough coefficient to permit our equation for the bilateral rate to account fully for any global change in the US dollar that derives from influences other than those in our equation.

The biggest improvements in the fit and forecasting properties of NEMO, relative to its predecessors, flow from the new modelling of the effects of productivity changes, and from re-specifying the dynamics to involve changes in the nominal exchange rate as the dependent variable. We continue to use bilateral interest rate differentials as an important determinant of the dynamic adjustment of the exchange rate towards an equilibrium real exchange rate defined in terms of relative commodity prices and productivity levels.

Our results for the effects of productivity differentials support the recent modelling and UK results of Benigno and Thoenissen (2002), among others, based on differentiated products and preferences favouring local goods, both of which are consistent with work by ourselves and others on the importance of national differences in networks and tastes. NEMO may embody the positive correlation between real per capita incomes and real exchange rates that is so evident across countries at very different levels of per capita income, but only to the extent that the productivity increase is relatively greater in the aggregate economy than in the manufacturing sector (as compared to partner countries). We are not surprised that our data do not support the Balassa-Samuelson hypothesis, since the global facts are more naturally explained by productivity levels that are lower in all industries in poorer countries.

Appendix 1
Definitions of Variables

Note: All variables are expressed as quarterly averages and in natural logarithms.

e: Can$/US$ exchange rate. Noon rate, Canadian interbank money market.

p: ratio of Can/US GDP deflators (1997 = 1).

For Canada, the ratio of GDP at market prices to GDP in chained 1997 dollars. Statistics Canada series *v98086* and *v1992067*, respectively. For the United States, 2000 chained GDP deflator, series *jpgdp*[1] from the US Department of Commerce, Bureau of Economic Analysis, rebased to 1997 = 1.0.

pmg: Can/US labour productivity indexes (1997 = 1).

(a) Manufacturing labour productivity (output per hour), seasonally adjusted (SA).

For Canada, the series are constructed with Bank for International Settlements series *m.uqnaca92*—a Bank of Canada calculation of output in constant 1992 dollars per employed person in manufacturing using the Standard Industrial Classification (SIC), which was then converted to chained 1997 dollars and seasonally adjusted using the Seasonal Adjustment, Bell Labs (SABL) decomposition method—for all periods prior to 1991. For all subsequent periods, a series was constructed with Statistics Canada series *v2036171*—manufacturing output in chained 1997 dollars using the North American Industry Classification System (NAICS)—divided by *v1596771*—all employees in manufacturing using the NAICS. Manufacturing output per hour is then computed by splicing the two manufacturing output per employee series and dividing by the Bank of Canada's calculation for the seasonally adjusted average actual hours worked per week in manufacturing. Note that for all periods after 1997, Statistics Canada series *v21573740* closely approximates and is computationally equivalent to the constructed series and therefore is used to facilitate adding future observations. For the United States, we use the series *jq%mhm* from the US Department of Labor, Bureau of Labor Statistics, consistent with NAICS.

(b) Real GDP per employee (SA).

1. All series code for the United States as found in Global Insight databases.

For Canada, total employment constructed with Statistics Canada series *v3437441*—estimates of total employment in all industries using the NAICS and seasonally adjusted using SABL—for all periods after 1976 and a Bank of Canada calculation for all prior periods. For the United States, real GDP constructed with nominal GDP series *gdp* from the US Department of Commerce, Bureau of Economic Analysis and US GDP chained price index total civilians employed given by series *ehhc* from US Department of Labor, Bureau of Labor Statistics.

(c) Real GDP per capita (SA).

Total population estimates from Statistics Canada series *v1* and US Department of Commerce, Bureau of Economic Analysis series *npbea*, respectively.

com: Real non-energy commodity price (US dollar terms) index (1997 = 1).

Bank of Canada's nominal non-energy commodity price index (US dollar terms), Statistics Canada series *v36383* divided by US GDP chained price index.

i: Can/US nominal interest rate ratio; $(1 + i_{Can})/(1 + i_{US})$. For Canada, we use the three-month prime corporate rate, Statistics Canada series *v122491*. And 90-day commercial paper rate (AA rated non-financial closing rate) from the US Federal Reserve website. Both series expressed as quarterly rates.

usd: US nominal effective exchange rate excluding Canada (1997 = 1).

Constructed as $(jrxwmcns/(e)^{0.20})^{1.25}$, where series $jrxwmcns$ is the weighted average of the foreign exchange value of the US dollar against an index of major currencies from the US Federal Reserve System.

uca: US current account balance as a percentage of US nominal GDP.

Current account balance series *bopcrnt* from US Department of Commerce—Bureau of Economic Analysis.

sm: Can/US stock market prices (1997 = 1).

TSX composite (300) index of monthly closing prices from Statistics Canada series *v122620*. Standard and Poor's Corporate 500 index of monthly average prices from the *Federal Reserve Bulletin*.

yus: International high-yield bond spreads.

Data available from 1994. Weighted average of Mexico and Brazil high-yield bond spreads given by the J.P. Morgan Emerging Markets Bond Index.

Weights computed as the sample period average of nominal GDP (US dollar terms). For Mexico, nominal GDP and Mexico/US exchange rate given by International Monetary Fund series *q.27399b.czf...h* and *q.273.wf.zf...h*. For Brazil, nominal GDP and Brazil/US exchange rate given by IMF series *q.22399b.zf...h* and *q.223.rf.zf...h*.

df: Can/US federal government deficits as a percentage of nominal GDP.

Canadian and US federal government deficits from Statistics Canada series *v498381* and US Department of Commerce, Bureau of Economic Analysis series *defgf@gi*.

db: ratio of Canadian to US government debt as a percentage of nominal GDP.

Canadian total government debt calculated as sum of Statistics Canada series *v34422, v34460,* and *v34584.* US federal government debt from US Congressional Budget Office.

Appendix 2

CPE has the following specification: $\Delta(e-p)_t = \phi((e-p)_{t-1} - \Pi X_{t-1}) + \Gamma\Delta Z_{t-1} + \varepsilon$,

where $X = [k, com, ene]$ and $Z = [i, db]$;

e: logarithm of the nominal Canada-US exchange rate (Can$/US$);
p: logarithm of the ratio of Canada/US GDP deflators;
com: logarithm of the real non-energy commodity prices;
ene: logarithm of real energy commodity prices;
i: $\ln(1+i_c)/(1+i_u)]$;
$i_c(i_u)$: Canadian (US) three-month commercial paper rate expressed at a quarterly rate;
db: logarithm of the ratio of Canadian to US public sector debt/nominal GDP.

The real exchange rate is a function of real commodity prices in the long run. Commodity exports are a major component of Canada's international trade, and their price movements tend to dominate variations in Canada's terms of trade. Short-run dynamics are captured by interest rate differentials and changes in relative government debt positions. The change in relative public sector debt positions (as a proportion of GDP) is also included. From a demand perspective, while additional government expenditure might lead to an appreciation in the short run, growing foreign indebtedness of the public sector would require a real depreciation over time to compensate for the growing debt servicing outflow in the current account.

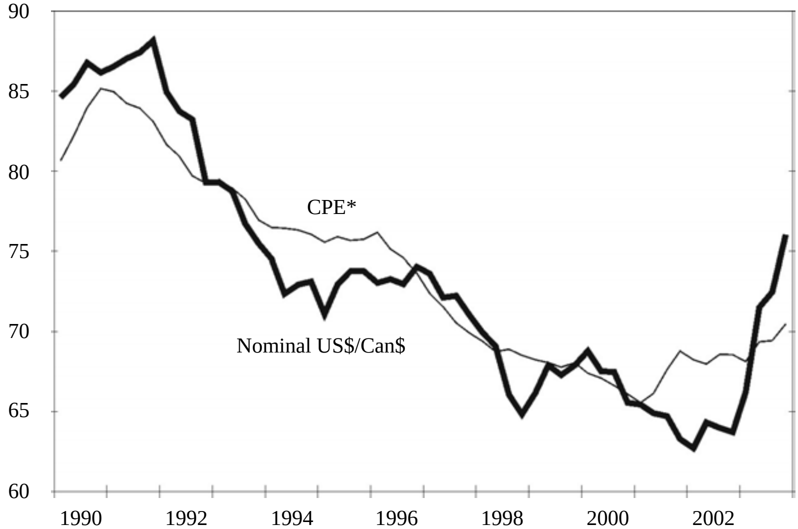
The coefficients of the non-energy commodity prices, interest rate differentials, and changes in relative public debt ratios are all significant and of the correct sign. In addition, corrected for degrees of freedom, CPE explains 25 per cent of the variance of the real exchange rate. However, real energy prices are not significant, and the presence of serial correlation of the residuals (Durbin-Watson statistic of 1.45) suggests that the specification could be improved. Moreover, the equation cannot account for the appreciation of the Canadian dollar in 2003. According to the equation, the appreciation was unwarranted (by its fundamentals) and could be reversed in the near term (Figure A2.1).

Table A2.1
CPE—coefficient estimates, 1975–99[a]

Variables	$(e-p)_{t-1}$	k_{t-1}	com_{t-1}	ene_{t-1}	i_{t-1}	Δdb_{t-1}
Coefficients	–0.15	0.33	–0.42	0.03 [0.36]	–2.80	0.34

a. *P*-values greater than 0.01 are reported in square brackets.

Figure A2.1
Actual vs. dynamic simulation (US cents)



* Estimated over 1975–99 period. Simulation begins in 1975.

Appendix 3

Tables and Figures

Table A3.1
Testing for unit roots and stationarity[a] (1975Q1 to 2003Q4)

	With trend		No trend	
Variables	**DF-GLS**	**MZ_t**	**DF-GLS**	**MZ_t**
e	–1.43	–1.68	–1.26	–1.33
com	–1.93	–2.01	–0.35	0.33
pmg	–2.81	–2.48	–0.31	–0.54
i	–2.32	–2.18	**–2.23**	**–2.01**
usd	–1.36	–1.29	–1.31	–1.28
p	–0.99	–0.75	–0.27	–0.01
yus	–2.77	–2.60	–1.70	–1.66

a. We report only test results for the variables that were retained in NEMO (results for all other variables are available upon request). Numbers in bold represent significance at the 5 per cent critical level. Refer to original papers for information on critical values. DF-GLS and MZ_t refer to the modified ADF and PP tests, respectively. Lag length was chosen using the modified Schwarz information criteria from Ng and Perron (2001).

Table A3.2
Tests for cointegration (1975Q1 to 2003Q4)

Engle-Granger test with null hypothesis of no cointegration[a]

No. of lags	ADF statistic	5% critical value	10% critical value
4	–3.13	–3.74	–3.45

Boswijk test with null hypothesis of no cointegration

No. of lags	Wald statistic	5% critical value	1% critical value
1	18.31	14.38	18.68

Johansen and Juselius test[b]

No. of cointegrating vectors under the null hypothesis	Trace statistic	5% critical value	1% critical value
Less than 1	56.40	47.86	54.68
Less than 2	26.00	29.80	35.46
Less than 3	10.78	15.49	19.94
Less than 4	2.88	3.84	6.63

No. of cointegrating vectors under the null hypothesis	λ^{max} statistic	5% critical value	1% critical value
Less than 1	30.40	27.58	32.72
Less than 2	15.22	21.13	25.86
Less than 3	7.90	14.26	18.52
Less than 4	2.88	3.84	6.63

a. Uses the data-dependent lag-selection procedure advocated by Campbell and Perron (1991). Critical values are from MacKinnon (1991).
b. The information criteria selected one lag as the optimal lag structure. The system is estimated with a constant in the cointegration space and an assumed linear trend only in the data. The results are not sensitive to this specification (details available upon request). Critical values are based on MacKinnon-Haug-Michelis (1999).

Table A3.3
Nominal exchange rate equations for the Canadian dollar[a]

Variables	EQ1	EQ2	EQ3	EQ4	EQ5	EQ6
Long-run						
e_{t-1}	–0.13	–0.13	–0.13	–0.10	–0.10	–0.14
p_{t-1}	1	1	1	1	1	1
k	0.32	0.31	0.30	0.34	0.35	0.31
pmg_{t-1}	1.58[b]	1.75[b]	1.19[c]	1.60 [0.07][d]	0.50 [0.36][e]	1.51[f]; –1.15 [0.13]
com_{t-1}	–0.56	–0.57	–0.63	–0.51	–0.42	–0.59
Short-run						
i_{t-1}	–2.22	–2.26	–2.27	–1.96	–1.97	–2.26
Δusd_t	0.11	0.10 [0.01]	0.11	0.11	0.10 [0.02]	0.11
Δgdp_t	0	–0.38 [0.04]	0	0	0	0
Statistics						
$\bar{R}^2$	0.34	0.36	0.32	0.21	0.18	0.33
DW	1.70	1.74	1.62	1.33	1.28	1.69
RMSE(I)	0.027	0.027	0.036	0.055	0.056	0.029
RMSE(O)	0.060	0.068	0.050	0.054	0.069	0.058

a. Sample is 1975Q1 to 1999Q4. Only *p*-values greater than 0.01 are reported in square brackets. $\bar{R}^2$ is the adjusted $\bar{R}^2$ statistic; DW: Durbin-Watson statistic; root-mean-squared errors in [RMSE(I)] and out-of-sample [RMSE(O)] from dynamic simulations.
b. *pmg* refers to the ratio of manufacturing labour productivity to GDP per employee for Canada/US.
c. *pmg* refers to Canada/US labour productivity in manufacturing only.
d. *pmg* refers to Canada/US GDP per employee.
e. *pmg* refers to Canada/US GDP per capita.
f. *pmg* split into manufacturing and aggregate labour productivity, respectively.

Table A3.4
Nominal exchange rate equations[a]

Variables	EQ7	EQ8	EQ9	EQ10	EQ11	EQ12	EQ13
Long-run					NEMO		
e_{t-1}	–0.14	–0.14	–0.14	–0.14	–0.13	–0.14	–0.16
p_{t-1}	1	1	1	1	1	1	1
k	0.31	0.31	0.31	0.32	0.31	0.31	0.32
pmg^{b}_{t-1}	1.62	1.57	1.67	1.58	1.57	1.63	1.35
com_{t-1}	–0.53	–0.56	–0.54	–0.56	–0.54	–0.54	–0.49
Short-run 1							
i_{t-1}	–2.32	–2.21	–2.42	–2.27	–2.15	–2.27	–2.73
Δusd_t	0.09 [0.01]	0.11	0.09 [0.01]	0.11 [0.01]	0.11	0.10	0
Short-run 2							
Δuca_t	–0.19 [0.58]	–0.12 [0.75]	0	0	0	0	0
Δsm_t	–0.05 [0.07]	0	–0.08 [0.01]	0	0	–0.05 [0.10]	0
Δdf_t	–0.11 [0.37]	0	0	–0.11 [0.41]	0	0	0
Δyus_t	0.42	0	0	0	0.47	0.43	0
Statistics							
$\bar{R}^2$	0.45	0.33	0.37	0.34	0.45	0.46	0.29
DW	1.75	1.70	1.74	1.75	1.69	1.73	1.78
RMSE(I)	0.023	0.027	0.026	0.026	0.025	0.024	0.029
RMSE(O)	0.075	0.061	0.081	0.060	0.055	0.071	0.070

a. Statistics as in Table A3.3.
b. Ratio of manufacturing labour productivity to GDP per employee for Canada/US.

Table A3.5
NEMO parameter estimates for various samples[a]

Variables	75Q1–89Q4	75Q1–92Q3	75Q1–95Q1	75Q1–97Q3	75Q1–00Q1	75Q1–03Q4
Long-run						
e_{t-1}	–0.19	–0.14	–0.15	–0.15	–0.14	–0.11
p_{t-1}	1	1	1	1	1	1
k	0.30	0.28	0.29	0.29	0.31	0.32
pmg_{t-1}	1.44	1.79	1.70	1.69	1.54	1.89
com_{t-1}	–0.52	–0.52	–0.52	–0.52	–0.53	–0.62
Short-run						
i_{t-1}	–2.50	–1.97	–2.03	–1.96	–2.13	–1.83
Δusd_t	0.10 [0.01]	0.10 [0.01]	0.11	0.12	0.11	0.16
Δyus_t	n/a[b]	n/a	0.35	0.33	0.48	0.53
Statistics						
$\bar{R}^2$	0.44	0.40	0.47	0.47	0.45	0.52
DW	1.59	1.65	1.77	1.79	1.68	1.69
NOBS[c]	60	70	80	90	100	116

a. Statistics as in Table A3.3.
b. Data start in 1994.
c. Number of observations in the estimation.

Table A3.6
Forecast comparison: NEMO vs. random walk with drift[a]

Horizon (quarters)	NEMO MAE	RWD MAE	NEMO RMSE	RWD RMSE	THEIL[b]
1	1.80	2.43	2.33	3.40	0.69
4	3.81	5.86	4.92	8.35	0.59
8	4.70	6.93	6.00	9.72	0.62
16	5.29	7.32	7.17	9.18	0.78

a. Except for THEIL, all numbers shown are multiplied by 100.
b. THEIL is the ratio of NEMO's RMSE to the RMSE of a RWD. A value less (greater) than one implies that NEMO performs better (worse) than a random walk with drift.

Table A3.7
Lagrange multiplier test for Kth order serial correlation[a]

Order	Test statistic[b]	
1	2.65	[0.10]
2	3.67	[0.16]
3	4.01	[0.26]
4	8.85	[0.07]
5	8.29	[0.14]
6	11.29	[0.08]
7	10.99	[0.14]
8	11.14	[0.19]

a. Breusch (1978)-Godfrey (1978) test with null hypothesis of no serial correlation.
b. Test statistic asymptotically follows the χ^2 distribution. *P*-values are reported in square brackets.

Table A3.8
Test for heteroscedasticity[a]

Test statistics[b]	5% critical value
21.47	23.69

a. White (1980) test with the null hypothesis of homoscedasticity.
b. Test statistic asymptotically follows the χ^2 distribution.

Table A3.9
Correlation coefficient test: Real non-energy commodity prices vs. US nominal effective exchange rate (excluding Canada)[a]

Lags/leads	Test statistic[b]
–4	–0.277
–3	0.063
–2	0.479
–1	0.832
0	–0.316
1	0.062
2	0.410
3	0.775
4	1.047

a. Testing the null hypothesis that the correlation coefficient is zero.
b. Test statistic asymptotically follows the *t* distribution. The 95 per cent critical value with 100 degrees of freedom is 1.98.

Figure A3.1

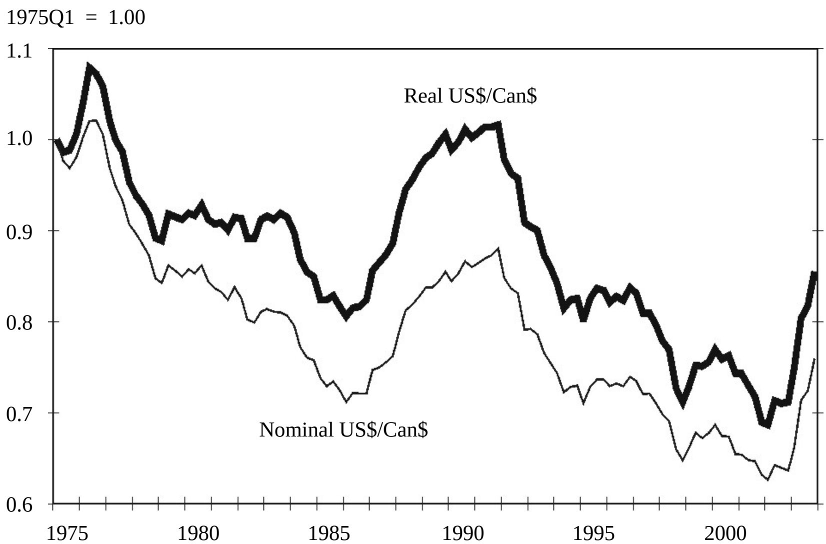


Figure A3.2

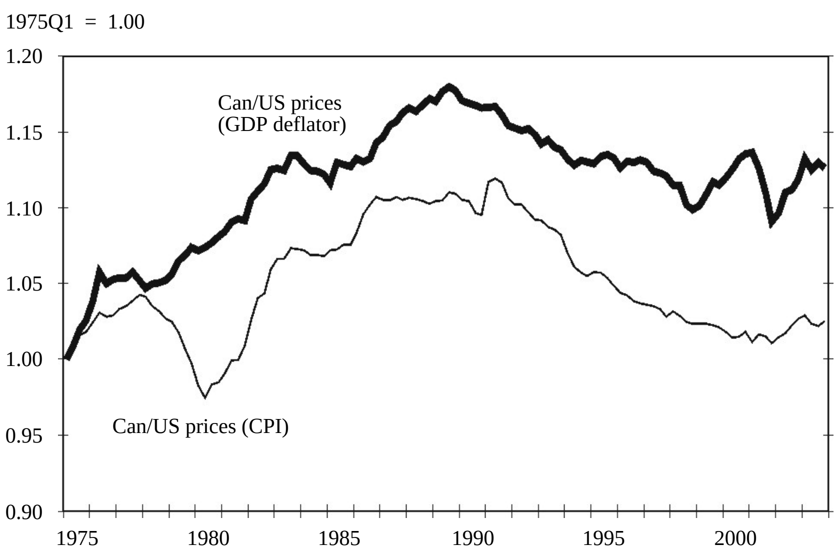


Figure A3.3

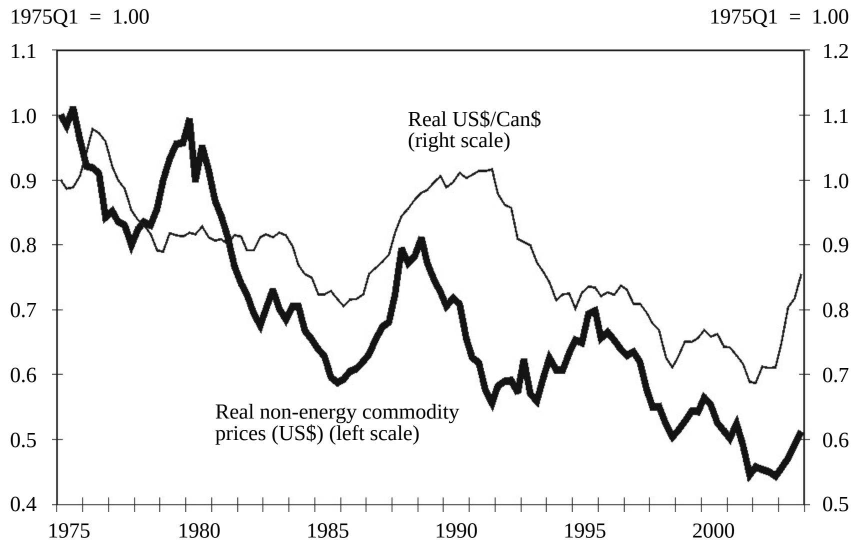
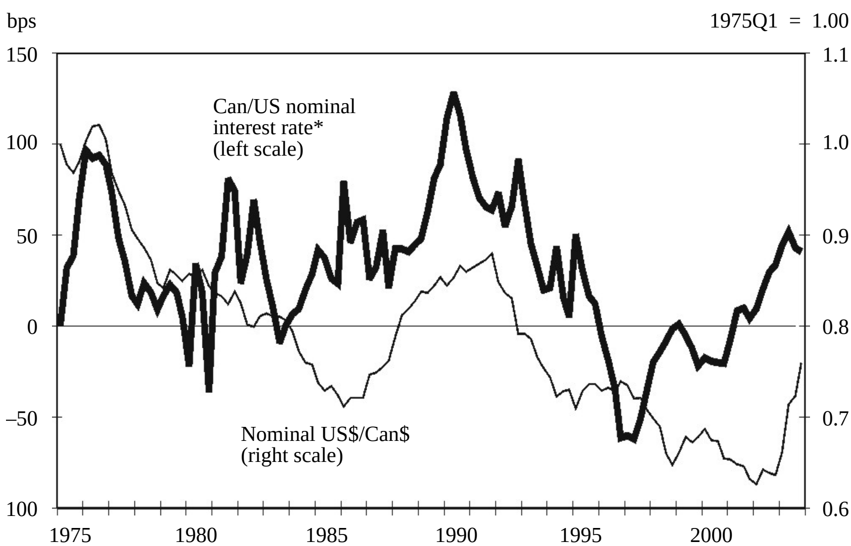


Figure A3.4



*ln[(1 + *i_can*)/(1 + *i_us*)]

Figure A3.5

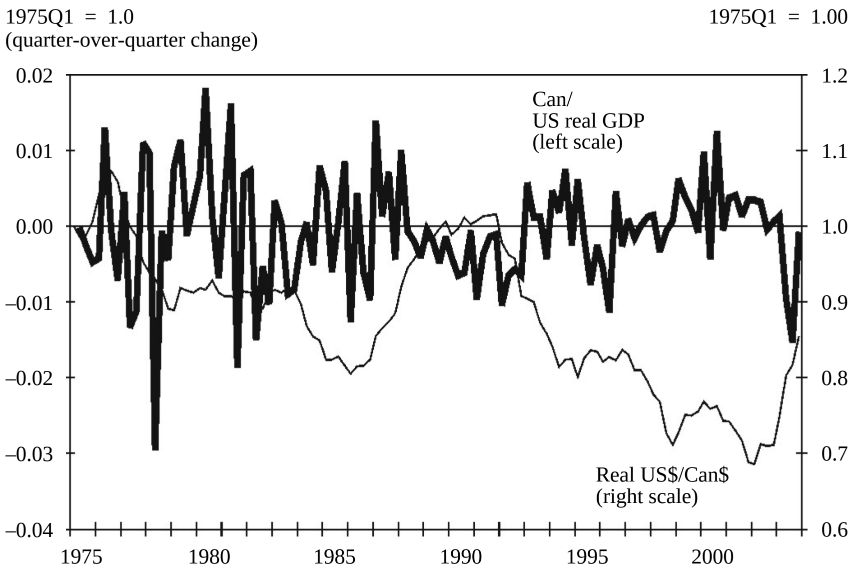


Figure A3.6

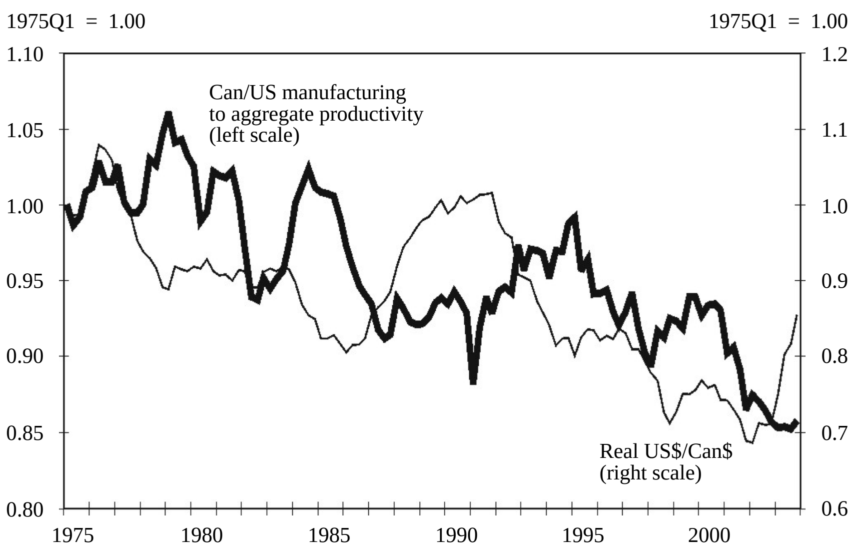


Figure A3.7

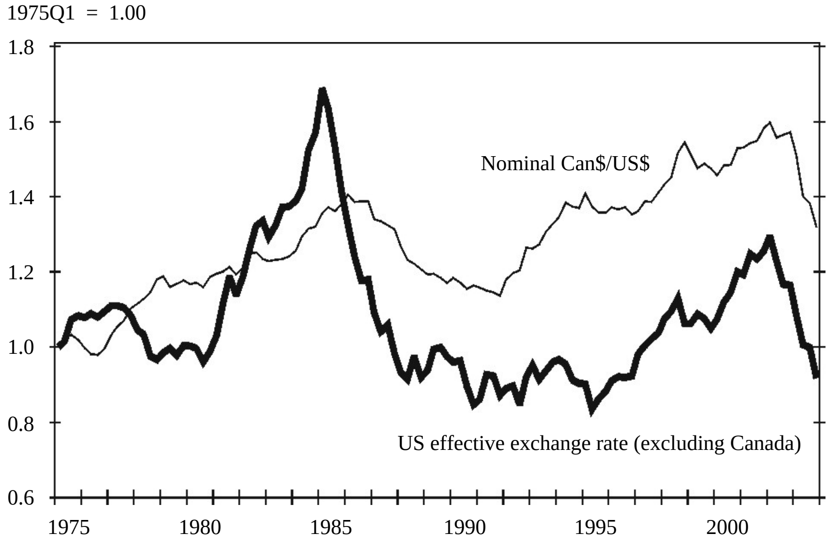


Figure A3.8

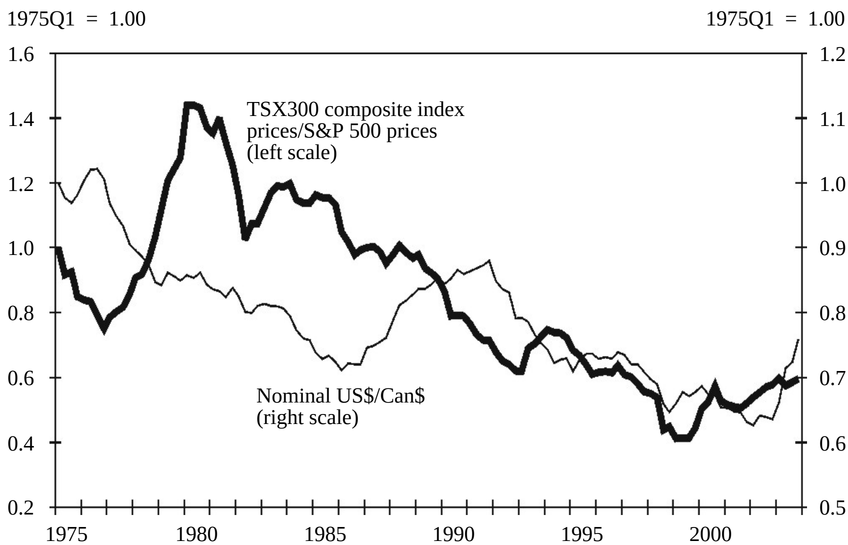


Figure A3.9

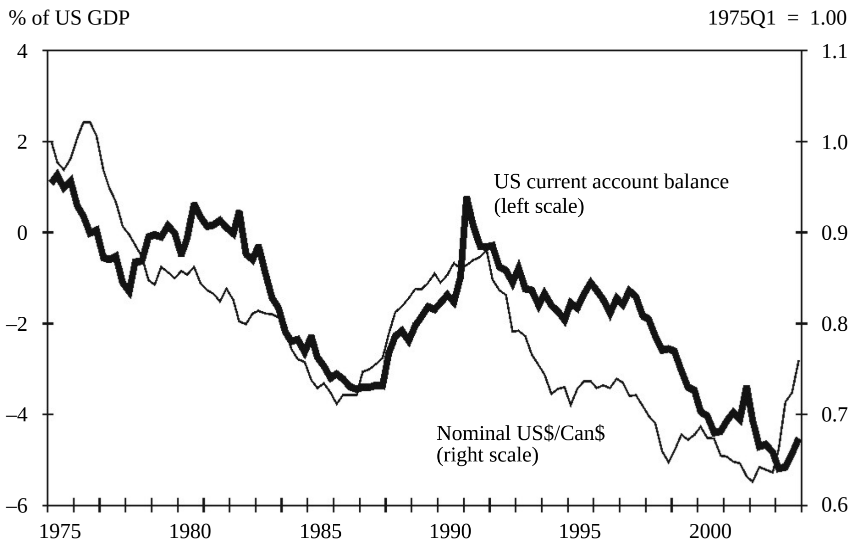


Figure A3.10

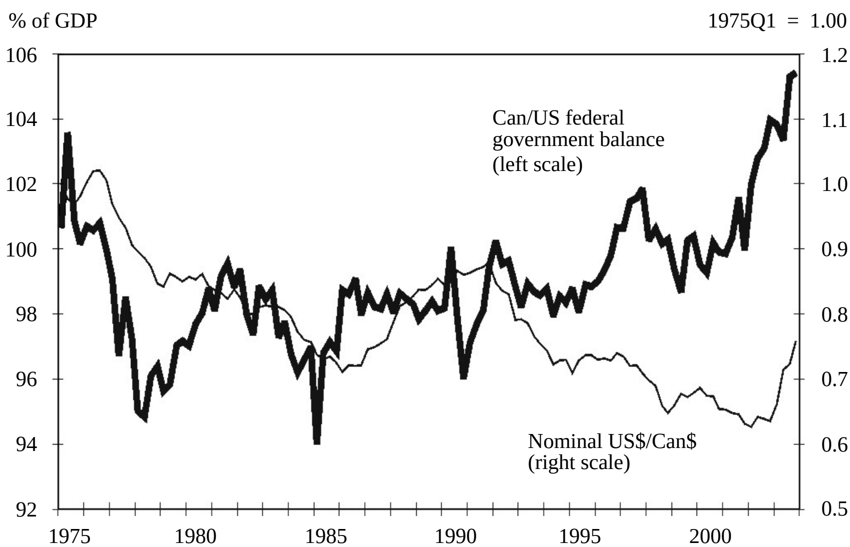
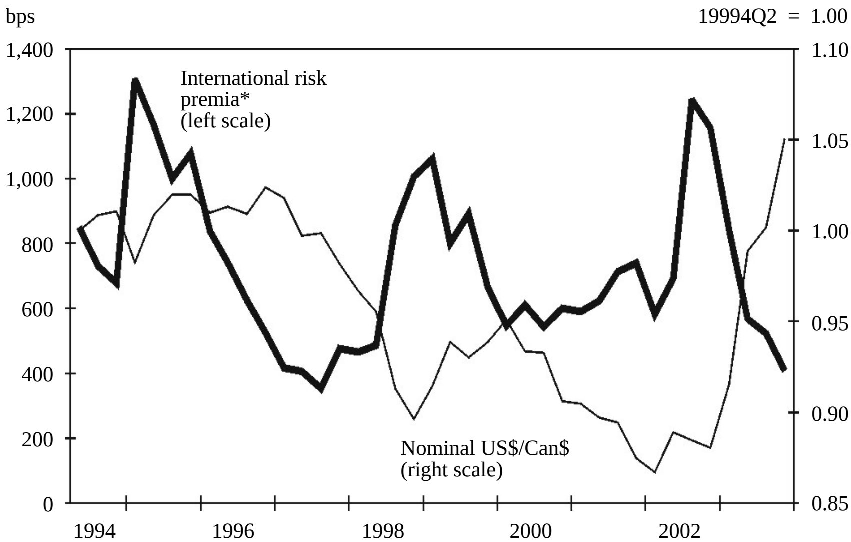


Figure A3.11



* Based only on Mexico and Brazil high-yield spread using average relative GDP weights.

Figure A3.12
Proportional change (%): Actual vs. dynamic simulation:
Sample ending 2002Q4

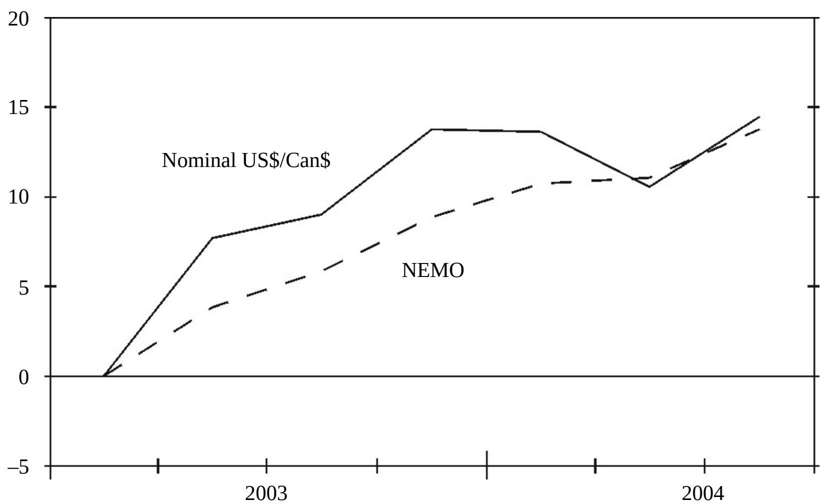


Figure A3.13
Proportional change (%): Long-run variables

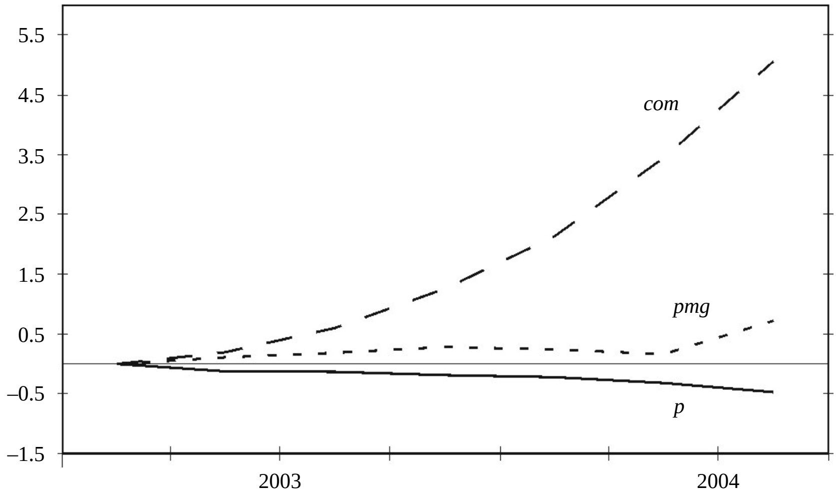


Figure A3.14
Proportional change (%): Short-run variables

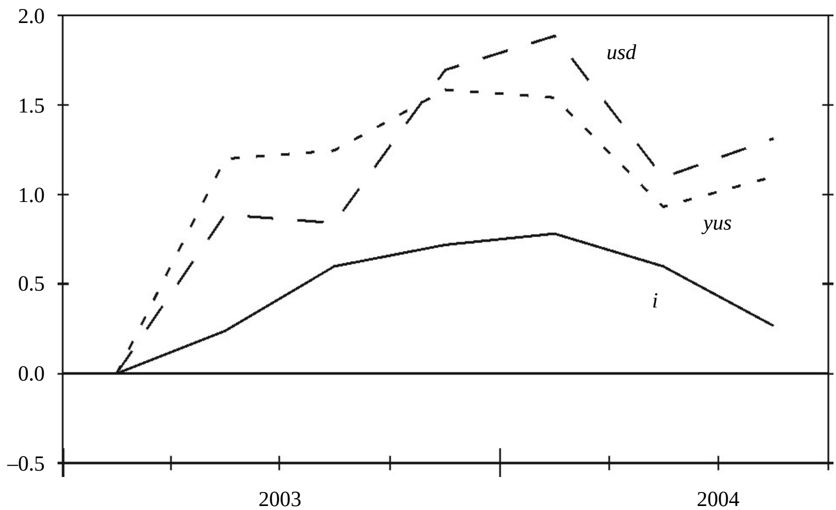


Figure A3.15
Proportional change (%): Long-run variables, 1975Q1 to 2004Q3

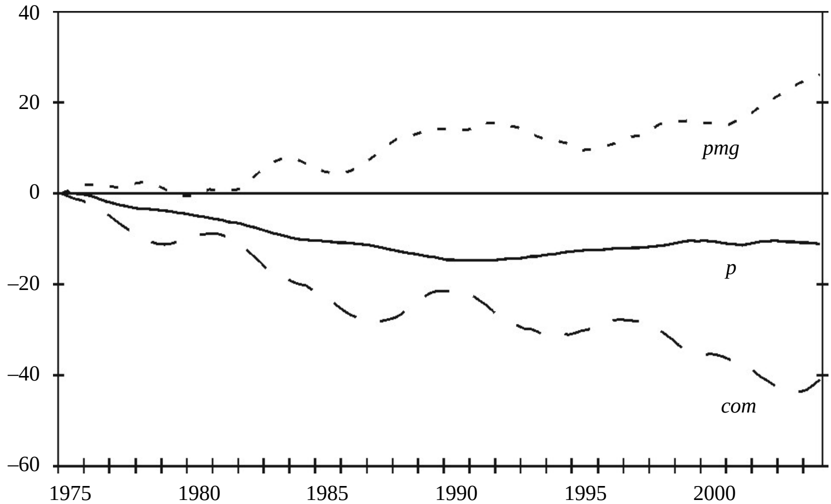


Figure A3.16
Proportional change (%): Short-run variables, 1975Q1 to 2004Q3

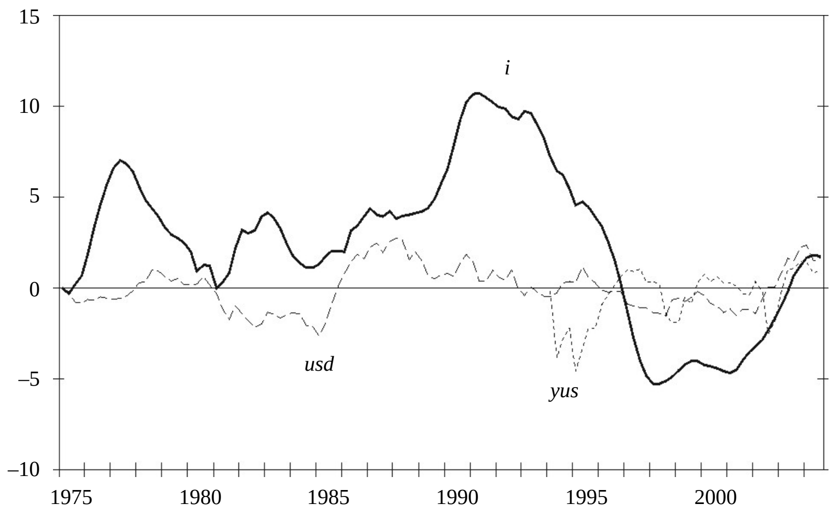


Figure A3.17
Parameter constancy: *e*

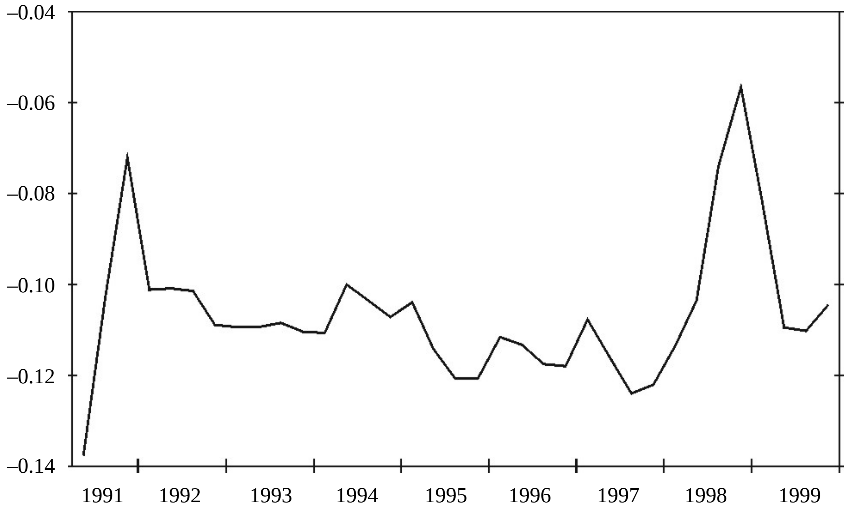


Figure A3.18
Parameter constancy: *k*

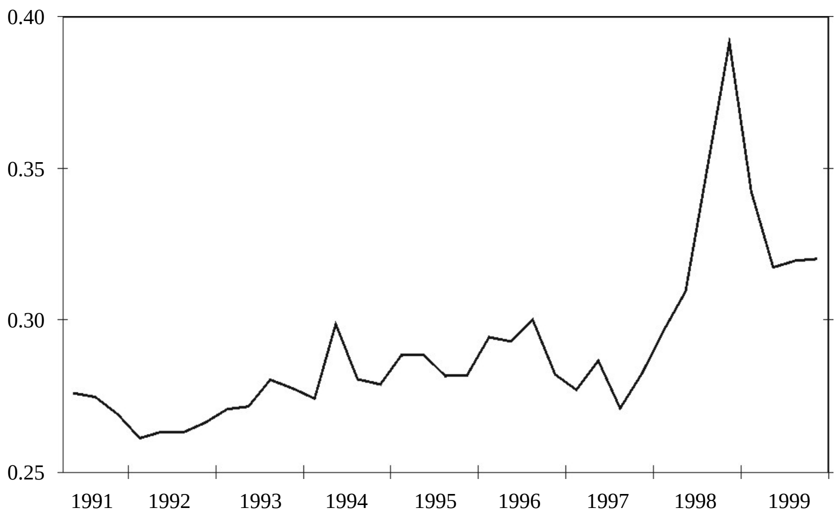


Figure A3.19
Parameter constancy: *pmg*

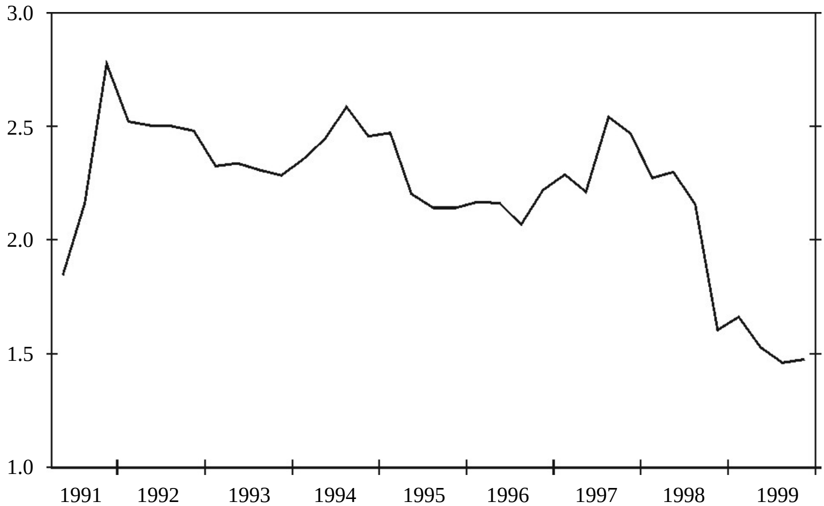


Figure A3.20
Parameter constancy: *com*

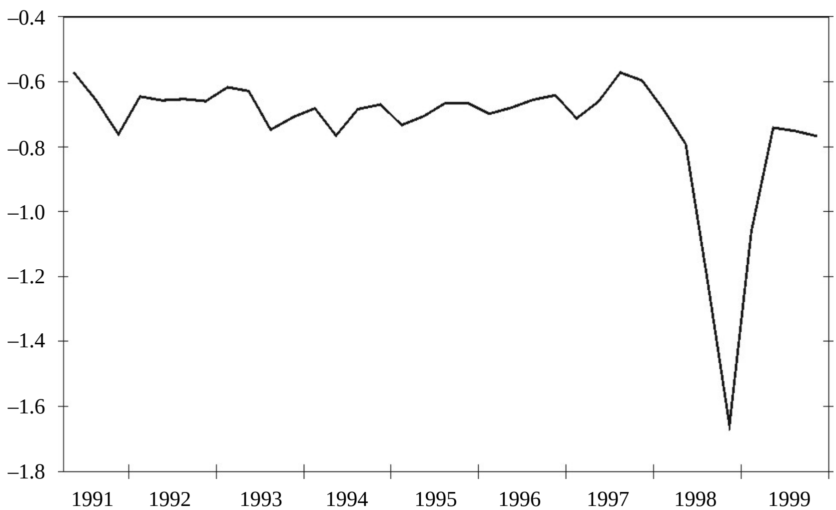


Figure A3.21
Parameter constancy: *i*

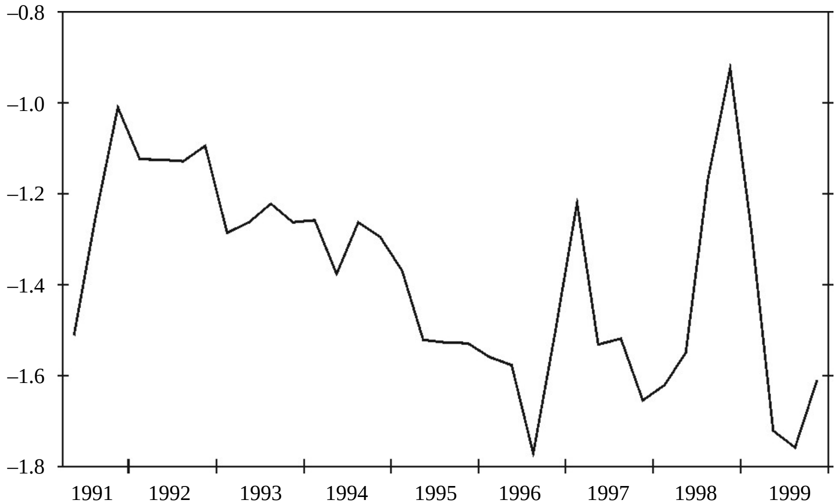


Figure A3.22
Parameter constancy: *usd*

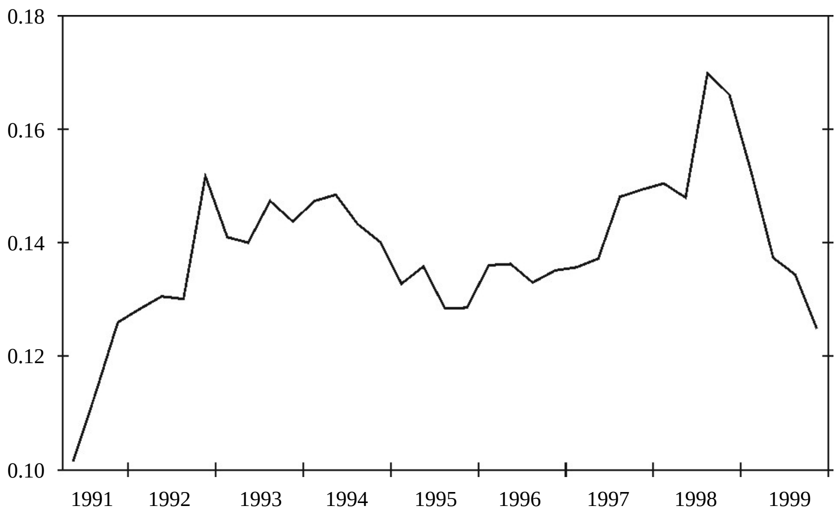
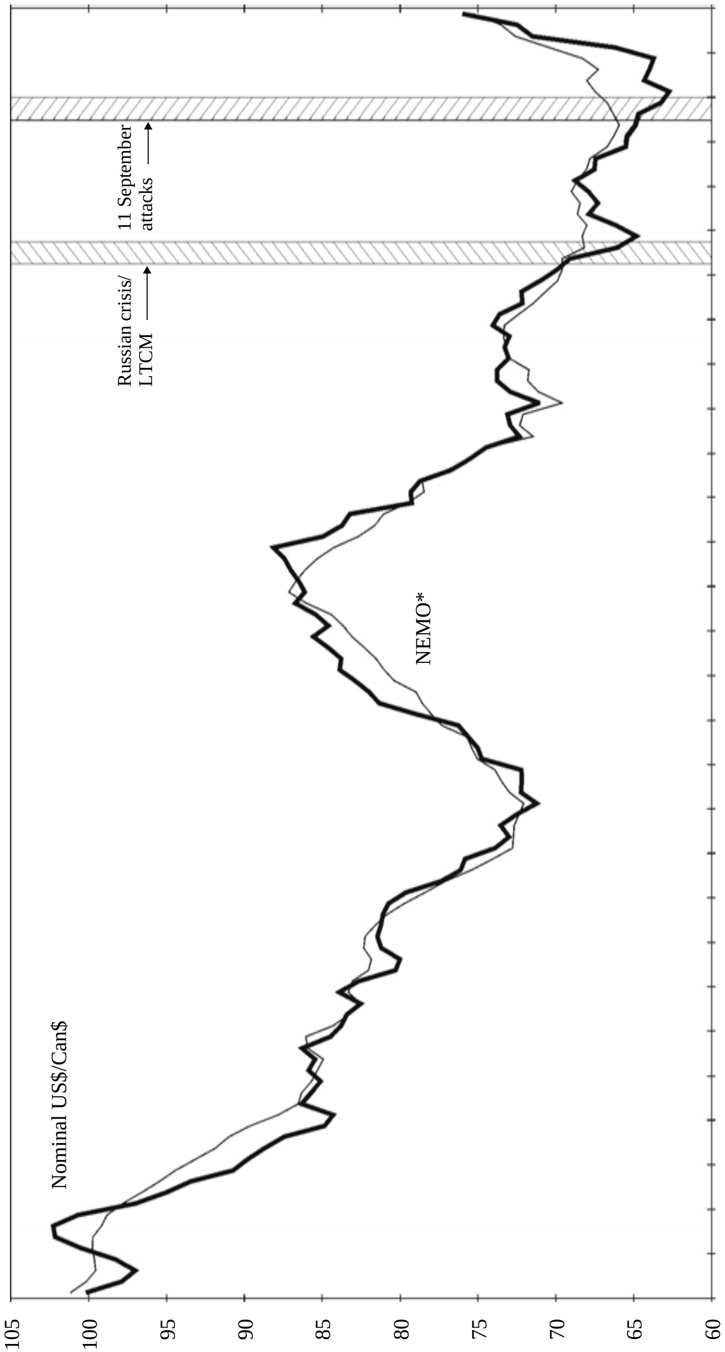


Figure A3.23
Actual vs. dynamic simulation (US cents)



* Estimated over 1975–99 period. Simulation begins in 1975.

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Discussion

Rebecca Driver

Introduction

Ever since Meese and Rogoff (1983), finding a model that can systematically out-predict a random walk (or forecast of no change) has been a major goal in exchange rate economics. NEMO (or nominal exchange rate model) is of that genre. This single-equation model of the nominal exchange rate was constructed to track movements in the Can$/US$ exchange rate. Its intention is empirical rather than theoretical. The authors conduct a careful specification search to identify NEMO and, once they have done so, demonstrate that it can out-forecast a random walk with drift at the 1-, 4-, 8-, and 16-quarter horizons.

In my discussion, I will address four issues. First, I would like to explore why an ability to forecast exchange rates might be useful, particularly in a central bank context. I will touch on how NEMO compares with similar exchange rate models and raise two questions about its forecast abilities. Finally, even if NEMO provides the best empirical explanation for past movements in exchange rates, I ask whether there is anything that NEMO might miss that a central bank needs to worry about.

Why Model Short-Run Exchange Rate Movements?

Why would anyone want to forecast the exchange rate? Well, from a central bank perspective, changes to the exchange rate can have a significant impact on the forecast for inflation, and understanding how exchange rates are likely to evolve can be important. Nickell (2002), for example, cites unexpected movements in the exchange rate as significant in explaining the undershoot in UK inflation over the period 1999Q2 to 2001Q1.

Examples of the importance of the assumed exchange rate path for the inflation forecast, at least in the UK context, can be found in the *Inflation Reports*, published by the Bank of England. For example, the May 2000 *Inflation Report* provides an indication of how the forecast for RPIX (the retail price index excluding mortgage interest payments) inflation in the United Kingdom would have changed if the exchange rate profile had been based on either uncovered interest parity (UIP) or a random walk, instead of on the average of the two.[1] The May 2000 forecast for RPIX inflation would have been 0.1 percentage points higher than the central projection at the one-year horizon, and 0.2 percentage points higher at the two-year horizon if pure UIP had been assumed.[2] Clearly, the sensitivity of the inflation profile depends on the expected evolution of interest rates at home and abroad and hence the implied UIP path. However, improving our ability to forecast exchange rates could yield important improvements in our ability to forecast inflation and might help us understand the risks associated with forecasting exchange rates using either UIP or a random walk.

How Does NEMO Compare?

NEMO fits in, albeit not exactly, with a class that aims to model short-run equilibrium movements in exchange rates. Examples of such models include BEERs (behavioural equilibrium exchange rates), CHEERs (capital enhanced equilibrium exchange rates), and ITMEERs (intermediate term model-based equilibrium exchange rates).[3] In other words, NEMO is an exchange rate model informed by theoretical considerations, but whose form largely reflects empirical relationships.

Of the three models, the BEER is probably the most general and most popular.[4] How, then, does NEMO compare with the BEER framework? The BEER framework is based around UIP, with the assumption that the

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1. Since November 1999, the Bank of England has used an average of a random walk and UIP as the exchange rate forecast underlying its *Inflation Report* projections. See the box on “The exchange rate in forecasting and policy analysis” from the November 1999 *Inflation Report*, published by the Bank of England.
2. Symmetry implies that the projection for RPIX inflation constructed using a pure random-walk model would have been 0.1 percentage points lower than the central projection at the one-year horizon and 0.2 percentage points lower at the two-year horizon. See Table 6.B on page 62 of the May 2000 *Inflation Report*, published by the Bank of England.
3. See Driver and Westaway (2005) for a review of short-, medium-, and long-run equilibrium exchange rate models.
4. See Alberola et al. (1999); Clark and MacDonald (2004); Maeso-Fernandez, Osbat, and Schnatz (2001); and MacDonald (2002) for examples of BEERs, as well as the discussion in Driver and Westaway (2005).

equilibrium level of the real exchange rate may move and there may also be a risk premium associated with UIP.[5] Therefore, in addition to interest rate differentials, exchange rates are explained using variables that are likely to drive either long-run equilibrium exchange rates or the risk premium. Clearly, given the coefficient on the interest rate differential, NEMO is not predicated on the assumption that UIP holds. However, some of the variables that have been used within the BEER framework might also be relevant for NEMO. Such variables include the relative price of traded versus non-traded goods, relative net foreign assets as a percentage of GDP, and relative government debt. It would be interesting to see if similar variables have something to add to NEMO.

The first of these variables, the relative price of traded versus non-traded goods, might be particularly interesting, since it could potentially capture Balassa-Samuelson effects. This variable is more likely to do so than relative productivity at home and abroad (either whole economy or manufactured sector), since the relative performance of the traded and non-traded sectors is the key to Balassa-Samuelson effects. It is therefore probably not surprising that the relative productivity variable in NEMO has the opposite sign to the one predicted by Balassa-Samuelson. The authors stress alternative justifications in their discussion of this variable, and I found them quite convincing. Indeed, my prior would have been that an increase in productivity at home relative to abroad would have necessitated an exchange rate depreciation (which is what they find) because, as the underlying balance models stress, an increase in supply without any change in demand will require a decrease in the price of domestic goods relative to foreign goods in order to re-equilibriate demand and supply.[6]

Losing NEMO

One of the big worries about attempting to model short-run exchange rate movements is that the relationships that underpin these models, which are often based more on empirical rather than theoretical relationships, might disappear. Therefore, it is important to ask the question, “Should we worry about losing NEMO?” On this front, I would raise two concerns, both of which could affect NEMO’s forecast performance.

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5. The other key difference between the BEER framework and NEMO, therefore, is that the exchange rate variable typically used in the BEER framework is a real, rather than a nominal, exchange rate.
6. See Driver and Westaway (2005) for a discussion of this point and of underlying balance models.

My first concern is the presence of international high-yield bond spreads in the final specification for NEMO. These data are only available from 1994, and their inclusion reflects the fact that NEMO's specification was determined using a sample period ending in 1999Q4. However, the forecast comparisons between NEMO and a random walk, which are contained in the authors' Table 6, are conducted over the period 1994Q4 to 2003Q4. A true out-of-sample forecast test would have decided what form NEMO should take using data only up until 1994Q4, and my guess is that international high-yield bond spreads would not have been included in that specification. It would therefore be interesting to see the same forecast comparison exercise conducted over the period from 1999Q4 to the present.

Table 5 in the paper shows evidence on the variability of the estimated parameters in NEMO over different sample periods. The results indicate that the coefficient on international high-yield bond spreads displays the greatest variation between the largest and smallest estimates.[7] This is not unexpected, given the paucity of observations for the shorter sample periods. For this reason, it will be important to monitor the importance of international high-yield bond spreads in NEMO's performance going forward. It would also be interesting to see whether an equation of the same form as NEMO, but excluding international high-yield bond spreads, could also out-forecast a random walk.

Another potential concern about NEMO's specification is the inclusion of the change in the US nominal effective exchange rate (excluding Canada) in the short-run dynamics of NEMO. Specifically, what happens if the main trends in the Can$/US$ exchange rate simply reflect trends in the US dollar more generally, or in other words, are exchange rate movements purely a US story? This might be important since, over the sample period used to estimate NEMO, the direction of change in the Can$/US$ and US-dollar exchange rate (excluding Canada) has been the same in over 60 per cent of occasions at the 1-quarter horizon. To investigate this, I ran a very simple test that compared the forecast performance over the four horizons (1, 4, 8, and 16 quarters) of two simple models. The first model is simply a pure random walk (RW). The second model (Dollar) forecasts movements in the Can$/US$ exchange rate by adjusting the current period's exchange rate by the actual change in the US effective exchange rate (excluding Canada) over the relevant horizon. The results from this experiment can be seen in Table 1, which compares the results from three sample periods.

7. This is true if the four sample periods that include estimates of the coefficient on international high-yield bond spreads are used, or if all six sample periods are included.

Table 1
Root-mean-squared errors comparison for two simple models

Horizon	Whole sample RW	Whole sample Dollar	Forecasts from 1994Q4 RW	Forecasts from 1994Q4 Dollar	Forecasts from 1999Q4 RW	Forecasts from 1999Q4 Dollar
1	2.51 (119)	4.64 (119)	3.36 (36)	4.35 (36)	4.09 (16)	3.95 (16)
4	6.49 (116)	11.30 (116)	8.15 (33)	9.00 (33)	10.86 (13)	9.89 (13)
8	9.75 (112)	17.28 (112)	10.08 (29)	13.94 (29)	13.47 (9)	13.06 (9)
16	14.56 (104)	23.89 (104)	12.68 (21)	14.92 (21)	15.66 (1)	2.72 (1)

Note: All numbers are multiplied by 100. Number of observations in parentheses.

The results suggest that movements in the Can$/US$ exchange rate have not simply reflected a US-dollar story since, except over the most recent sample period (from 1999Q4), the root-mean-squared errors associated with the random-walk model are smaller than those associated with the dollar model at all horizons.

Regardless of whether or not including the US nominal effective exchange rate (excluding Canada) leads to a biased impression of NEMO's success as a forecasting tool in traditional out-of-sample tests, there is another potential problem with including it; namely, in a real forecast situation, actual observations on movements in the US nominal effective exchange rate (excluding Canada) will not be available. Therefore, unless it is possible to find a model that can outperform a random walk for this exchange rate, this will reduce NEMO's potential success rate. The structure of NEMO reflects differences in the US and Canadian economies. It is not, therefore, clear that it can be generalized to other US exchange rates. The academic criterion for judging exchange rate forecast models has always been: can we beat a random walk given actual outturns for our explanatory variables. This reflects the desire to give the models every possible advantage, so that they are not rejected simply because one cannot forecast the explanatory variables. From a central bank perspective, however, the criterion may need to be adjusted. In particular, we should perhaps think about how our ability to predict the explanatory variables will influence the success of the model. If an important part of our increased explanatory power comes from variables that we cannot predict, we may be no better off.

What Might NEMO Miss?

An empirical equation such as NEMO is one way to assess the risks to an inflation forecast stemming from the exchange rate. However, NEMO may not capture all of the risks associated with specific one-off events, since the coefficients will reflect the average interactions between variables rather than shock-specific outturns. One such example would be the risks stemming from a correction in the US dollar. An alternative approach would be to use the type of model explored in Obstfeld and Rogoff (2004) to supplement NEMO and to ask the question: How does the structure of the Canadian economy differ from the rest of the United States' main trading partners and, therefore, how different will the Canadian experience be? Obstfeld and Rogoff identify relative movements in non-traded goods prices as particularly important for determining the size of the necessary dollar correction in a general-equilibrium setting. NEMO does not include variables that would capture the behaviour of non-traded goods and does not impose an economic structure that would allow Canada's role relative to the rest of the world in a dollar correction to be assessed. For these reasons, while NEMO's forecast performance is impressive, it might usefully be supplemented by an Obstfeld and Rogoff-style approach.

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General Discussion*

In response to Paul Masson's comments on neglecting Canada's fiscal and current account balances, Jeannine Bailliu noted that Canada's current account balance was found not to be significant. One of the models, of course, included the differential in fiscal balances. She also argued that since the United States was assumed to be the driving force in the threshold model, consideration of bilateral factors was secondary. In a rejoinder, Masson said that a multilateral approach did not obviate the need for bilateral comparisons of economic determinants.

Robert Lafrance responded to Rebecca Driver's comments by noting that NEMO was not meant to be a forecasting equation (work was under way to develop a variant of NEMO for this purpose), but rather a means to interpret current developments as one of many inputs to monetary policy decisions. To the extent that NEMO tracks the historical data well, it conveys the message that markets work and that the exchange rate reflects economic fundamentals—most of the time.

In the general discussion that followed, Charles Engel argued that forecastability (as in Meese and Rogoff 1983) should not be considered an important validation criterion for an exchange rate model. Exchange rates are forward looking. They reflect expectations and change in response to news—they can't be forecast. The fact that commodity prices and interest rates reflect expectations about the future might explain why they are useful in explaining movements in the Canadian dollar. Gregor Smith asked if the adjustment parameter in NEMO was stable over time in light of changes that

* Prepared by Robert Lafrance.

occurred in the conduct of monetary policy since 1975. Lafrance answered that it was.

Marcel Fratzscher found the non-linearities in the Bailliu, Dib, and Schembri (BDS) model quite interesting. He sought further detail on their rationale and how they improved the model's fit. Bailliu responded that more work will be done on testing the importance of twin deficits in multilateral adjustment. Steve Kamin wondered why the BDS model indicated a threshold effect for the US fiscal deficit and not for the current account. Presumably, both deficits mattered. He also noted that exchange rate equations are important model components for policy simulation purposes. Lafrance pointed out that neither NEMO nor the threshold models were part of the Bank's macroeconomic model. These single-equation models are devised to test and tell stories. Bailliu remarked that the threshold model tells a twin-deficit story. Hafedh Bouakez wanted to see confidence intervals around the dynamic simulations that were presented. Lafrance responded that confidence intervals would not be very informative for dynamic simulations, since they grow over time by definition. He also noted that the coefficient estimates of NEMO were quite tight. Bill White observed that the twin-deficit story in the threshold model was not sufficient. It assumed that one should worry only if a shortage of national savings (reflected in a large current account deficit) was due to fiscal profligacy. He assumed that the "Lawson doctrine" was passé. Of major concern in the current conjuncture was the lack of household savings in the United States. Bailliu agreed that if the US current account deficit was financing a consumption boom, then it was not sustainable.

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