

# What Drives Exchange Rates? New Evidence from a Panel of U.S. Dollar Bilateral Exchange Rates\*

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## Abstract

We employ a novel approach to identify the economic forces that have been driving a panel of real U.S. dollar exchange rates. Using a dynamic factor model we identify two common factors in a panel of six of U.S. bilateral real exchange rates: Australia, Canada, the euro, Japan, New Zealand and the United Kingdom. In subsequent analysis, we find that the first common factor has a long-run empirical relationship with U.S. fiscal policy while the second common factor is tightly linked to world commodity prices.

Incorporating these relationships in a state-space model, we then decompose the historical variation of each exchange rate. We find a strong role for economic fundamentals in explaining currency movements, as U.S. fiscal policy and movements in U.S. interest rates play an important element in explaining the 2002 to 2007 period. A smaller, although still significant, role is found for commodity prices.

## 1 Introduction

International economists have struggled to explain the connection between macroeconomic fundamentals and exchange rates. Recognizing the impact that exchange rate

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movements can have on an economy, policymakers have also sought a better understanding of exchange rate determination, particularly as it relates to the impact of their choices. In this paper we use a novel approach to identify some of the key macroeconomic factors behind exchange rate movements. We conclude that a significant portion of the variability in a panel of real U.S. dollar exchange rates over the 1981 to 2007 period can be attributed to a combination of U.S. fiscal policy and commodity price developments.

Our analysis proceeds in three steps. First, we estimate a dynamic factor model that identifies two common factors in a panel of U.S. dollar bilateral exchange rates. The first factor is positively correlated with movements in all six of the bilateral U.S. dollar exchange rates in our panel, while the second latent factor is positively related to the exchange rates of Australia, Canada, New Zealand and negatively related for Europe, Japan and the United Kingdom. We establish a long-run empirical relationship between the first common factor and U.S. fiscal policy. We also show that the second common factor is very tightly linked to world commodity prices. Interestingly, we do not find an important role for international productivity differentials.

Lastly, we develop a state-space model of real exchange rates based on these long-run determinants. U.S. fiscal policy explains a great deal of the low frequency movements in our panel of U.S. dollar exchange rates. Commodity prices also matter, especially for Australia and Canada. Domestic factors remain accountable for a relatively high portion of the variability in the Japanese yen and Canadian dollar exchange rates.

## 2 Literature Review

There have been numerous attempts to build empirical models of exchange rates based on macroeconomic fundamentals. Unfortunately, these models have had rather limited success (Meese and Rogoff (1983), Obstfeld and Rogoff (2000), and Cheung *et al.* (2005)). The track record is only somewhat better for empirical models that link commodity prices to exchange rates for major commodity exporters (Amano and van Norden 1995, Gruen and Kortian 1996, Djoudad *et al.* 2001, Chen and Rogoff 2003 and Issa *et al.* 2006).

An alternative approach to empirical exchange rate modelling, beginning with Diebold and Nerlove (1989) and Mahieu and Schotman (1994), adopts latent factor models from the empirical finance literature. Dungey (1999), for example, uses this approach to decompose high frequency movements in a panel of exchange rates for six Pacific Rim countries into three components - a domestic component, a foreign currency compon-

ent and a world component.

In this paper we bring these different strands of the literature together by incorporating information from observable macroeconomic variables into the common factor framework. The advantage of our approach is that it allows an important role for individual country differences which appear to be very important in understanding bilateral exchange rate volatility<sup>1</sup>, while introducing information from observable macroeconomic data in a way that allows for a more meaningful economic interpretation of the results.

### 3 Extracting Common Movements

Our approach to identifying the key driving forces behind exchange rate movements starts with the use of a dynamic factor model to extract common trends from a panel of real U.S. dollar bilateral exchange rates. Factor analysis is purely statistical and relies on a minimum set of restrictions and assumptions (e.g. Forni and Lippi (2001)). Underlying this technique is the premise that unobservable internal characteristics exist, in which the sample elements differ. These characteristics are commonly referred to as ‘latent factors’, and are assumed to account for the variation and co-variation across a range of observed phenomena.

Formally, factor analysis stipulates that  $p$  random variables  $X$  ( $X = (x_1, \dots, x_p)'$ ) can be expressed as linear functions of  $m$  ( $m < p$ ) hypothetical common factors  $F$  ( $F = (f_1, \dots, f_m)'$ ), plus an error term. In this study we use a panel of  $p$  real U.S. dollar exchange rates  $X$  with mean  $\mu$ . We normalize each exchange rate by its standard deviation. Following this approach ensures that each bilateral exchange rate contributes equally to the total variance of the model. We also allow for the possibility of comovements across time. The resulting dynamic factor model is given by

$$X_t - \mu = LF_t + \varepsilon_t \quad (1)$$

$$f_t = l_1 f_{t-1} + l_2 f_{t-2} + \dots + l_p f_{t-p} + v_t \quad (2)$$

$$\varepsilon_t = \alpha_1 \varepsilon_{t-1} + \alpha_2 \varepsilon_{t-2} + \dots + \alpha_q \varepsilon_{t-q} + \xi_t \quad (3)$$

where  $L = [l_{ij}]_{p \times m}$  is the matrix of factor loadings,  $l_{ij}$  is the loading of the  $i$ th variable on the  $j$ th factor, and  $\varepsilon_t$  is the specific error of  $X_i$ ,  $v_t$  and  $\xi_t$  are white noise processes.

The panel of exchange rates consists of real U.S. bilaterals with Australia, Canada,

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<sup>1</sup>For example, Fratzscher (2007) argues that the degree of financial integration between countries is an important determinant of the sensitivity of bilateral exchange rates to external shocks.

the euro area, Japan, the United Kingdom, and New Zealand between 1981Q1 to 2007Q4.<sup>2</sup> We include countries that have either important trade or financial links with the United States as well as those that are important commodity exporters. During this period, all currencies under consideration floated freely against the U.S. dollar.<sup>3</sup> Figure 1 graphs the real exchange rates of all countries in our sample.<sup>4</sup>

A preliminary analysis of the data suggests that most real exchange rates in our panel are integrated of order one (see Table 1). As regards serial correlation, we find statistically significant, but very small first-order autoregressive term of about 0.3 for all of the differenced real exchange rate series. Consequently, we proceed with a dynamic factor model specified in first differences.<sup>5</sup>

The results from the dynamic factor model suggest retaining two dynamic factors which are plotted in Figure 2. The decision on the number of dynamic factors to retain is based on the fact that the eigenvalue for the first and second factor are 3.6 and 1 respectively which are above the Gutman criterion which suggest keeping factors with eigenvalues greater than one. The eigenvalue for the third identified factor is 0.3 which is clearly below the criteria.

Table 2 shows that all of the loading factors on the first common factor are positive implying that all currencies move in the same direction in response to movements in the first common factor. The sign of the loading factor for the second common component is positive for the Aussie, Canadian and Kiwi dollars but negative for the euro, the yen and the U.K pound.<sup>6</sup>

## 4 What's driving our common factors?

While latent factor models are useful to detect patterns in the data, additional evidence is required to provide an economic interpretation of the factors identified. Using the theoretical literature as a guide to motivate candidate explanations, we provide evidence that suggests a long-run empirical relationship between real exchange rates, commodity prices and U.S. fiscal policy. We establish this link using two different but related empirical approaches: i) cointegration analysis of the latent factors identified

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<sup>2</sup>This sample is chosen because of data limitations associated with the quarterly IMF non-energy commodity prices index and because of the convergence of the behavior of inflation rates across the countries in our sample.

<sup>3</sup>The U.K. pound was briefly pegged within the European Monetary System (EMS) between 1990 and 1992.

<sup>4</sup>See Appendix 1 for data descriptions.

<sup>5</sup>Our results are robust to both using a level specification as well as using a static factor model.

<sup>6</sup>We also estimated a simple state-space model to check the robustness of the principal factor analysis. The approaches yield virtually identical results.

by the dynamic factor model, and ii) an estimated state-space model.

#### **4.1 What does theory have to say?**

Our empirical work focuses on three well-known candidate explanations for long-run real exchange rate determination: productivity, fiscal policy and world commodity prices. Considerable emphasis has been placed on the role of productivity shocks going back to the early work of Balassa (1964) and Samuleson (1964). Their work emphasizes a positive correlation between the productivity in the traded goods sector and a country's real exchange rate due to the rise in the relative price of nontradables. A notable and more recent empirical study of the impact of productivity shocks on the U.S. dollar is Corsetti *et al.* (2007).

Another body of the literature suggests that a rise in government debt, over the medium to long-run, should lead to a worsening of the current account and an depreciation of the real exchange rate (Ganelli (2005), and Kumhoff and Laxton (2007)). In overlapping generations models following Blanchard (1985) and Weil (1989) agents with finite economic lifetimes discount future tax liabilities at a higher rate than the market real interest rate. As a result, consumers do not increase their saving to sufficiently account for the additional future tax burden. Instead their investment in government debt crowds out their investment in physical capital and foreign assets. The reduction in savings leads to a fall in the long-run net foreign asset-to-GDP ratio. To finance the increased level of foreign indebtedness a larger current account surplus is required. This is facilitated through a depreciation of the currency.

The third potential determinant that we explore is commodity prices. Chen and Rogoff (2003) argue that commodity price changes are good proxies for exogenous terms-of-trade shocks and thus can play an important role in the determination of real exchange rates particularly for small economies who are major commodity exporters. Furthermore, Amano and van Norden (1995) argue that major movements in the price oil have been dominated by supply-side developments and are thus reasonable proxies for the exogenous changes in the terms of trade even for large economies like the United States, Germany and Japan.

#### **4.2 A preliminary empirical investigation**

Armed with these candidate explanations from the theoretical literature we conduct an empirical investigation of the forces that are driving the common factors over the sample period. As discussed earlier, the first factor identified common movements in

the direction of *all* bilateral U.S. dollar exchange rates, i.e. the U.S. dollar appreciates or depreciates against all currencies simultaneously. This distinctive pattern rules out the possibility that the first factor is driven by idiosyncratic shocks in any of the countries in our panel – except for the United States. As a result, we label the symmetric exchange rate factor as the U.S. dollar common factor.

Our candidate determinants of the U.S. dollar common factor are U.S. shocks that lead to international differences in either debt-to-GDP ratios or productivity. We proceed by first compiling measures of the ratio of government debt-to-GDP and the ratio of productivity in the manufacturing sector-to-economy-wide productivity, for each country (or currency bloc) relative to the United States.<sup>7</sup> A preliminary statistical analysis of the data suggests that the government debt and productivity variables are I(1). As regards serial correlation, we find statistically significant AR(1) terms for the government debt and productivity variables. As a result, we estimate a dynamic factor model specified in first differences for both the debt and productivity differentials. We then estimate two dynamic factor models (one for productivity and one for government debt) and are able to identify one factor for each variable which moves in the same direction for all country pairs. We label these the U.S.- debt / productivity common factors.

Various cointegration tests, reported in Table 3 suggests that the U.S. dollar common factor has a long-run empirical relationship with the U.S. debt common factor. The negative sign of the coefficient suggests that a deterioration in the U.S. fiscal position relative to all of the other countries in our sample leads to a long-run multilateral U.S. dollar depreciation confirming the theoretical link suggested by overlapping generations models (see Ganelli (2005), and Kumhoff and Laxton (2007)). Figure 3 plots the U.S. dollar common factor, and the cointegration relationship based on the U.S. debt common factor while 4 graphs the gap between the observed and the cointegration relationship. Although the results are not reported here, alternative specifications of the model do not suggest a role for the productivity variable.

The loading factors for the second common exchange rate factor shows a positive relationship with real exchange rates of commodity-exporting countries, and a negative relationship with real exchange rates of commodity-importing countries. Figure 5 visualizes this relationship: it shows a scatter plot of each country's net commodity imports, relative to the United States, and the loading factors estimated in section 4.2.<sup>8</sup> The scatter plot suggests a clear relationship between the commodity net export

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<sup>7</sup>For details on the data see Appendix I.

<sup>8</sup>Net commodity imports, relative to the United States, are defined as the nominal commodity net export position of each country, expressed as a share of nominal GDP, divided by U.S. net exports of commodities,

position of each economy, relative to the United States, and the sign of the loading factors.

To further reinforce the notion that this factor reflects the effects of commodity price movements on exchange rates, we show that the second factor is closely associated with fluctuations in commodity prices. Figures 6 and 7 plot the second common factor from the dynamic factor model and the real price of oil and the IMF's real non-energy, respectively.<sup>9</sup> As can be seen, the second principal factor shares a common trend with world commodity prices, and the cointegration tests confirm the tight relationship between the second component and commodity prices. As can be seen in table 3 and figure 8, the second principal component is cointegrated with the real price of oil and the real non-energy commodity price index.

### 4.3 An state-space model with commodity prices, relative debt/GDP and interest rates

Based on the insights from the cointegration analysis of the dynamic factors, we estimate the following state-space model:

$$X_t^i = \gamma_1 C_t^1 + (\gamma_2 + D^{93} \gamma^{CAN}) C_t^2 + v_t^i \quad (4)$$

$$\Delta C_t^1 = \phi_1 \Delta C_{t-1}^1 + \beta_1 rdiff_{t-1} - \lambda_1 (C_{t-1}^1 - \beta_2 Debt_{t-1}) + \eta_t^1 \quad (5)$$

$$\Delta C_t^2 = \phi_2 \Delta C_{t-1}^2 - \lambda_2 (C_{t-1}^2 - \beta_3 p_{t-1}^{NE} - \beta_4 p_{t-1}^{oil}) + \eta_t^2 \quad (6)$$

$$D(L)v_t^i = \varepsilon_t^i \text{ for all } i \quad (7)$$

where  $X_t$  is a 6 x 1 vector representing our panel of real U.S. dollar bilateral exchange rates,  $C_t$  is a set of  $m = 2$  latent common factors,  $Debt$  and  $rdiff$  denote the U.S. debt and interest rate common factors;  $p^{oil}$  and  $p^{NE}$  denote the real prices of energy- and non-energy commodities.<sup>10</sup>  $v_t$  is a  $n$ -dimensional component that represents idiosyncratic movements in the series. The common components  $C_t$  enter each of the country equations, but with different weights ( $\gamma$ ). We allow for the possibility that the  $v_t$  and the  $C_t$  contain (some) unit roots. Consistent with previous empirical work

expressed as a share of U.S. GDP.

<sup>9</sup>See Appendix 1 for descriptions of the data.

<sup>10</sup>The inclusion of real interest rate differential term is motivated through an inflation-adjusted version of Mundell's well known uncovered interest parity condition (UIP). The U.S. interest rate common factor is identified by estimating a static common factor model (specified in levels) on a panel of international short-term real interest rate differentials and taking the factor that triggers symmetric responses in each of the bilateral exchange rates.

done for the Canada-U.S. exchange rate (Issa et al. 2006) we include a dummy variable for energy liberalization in Canada  $D^{93}$  and  $(\gamma^{CAN} + \gamma_2)$  denotes the commodity factor for Canada after the 1993 structural break.<sup>11</sup>

To make the vector of  $C_t$  components the unique source of comovements across the exchange rate series, we assume that the  $v_t$  and the  $C_t$  are mutually uncorrelated. for all leads and lags. This is possible if we assume that the matrix  $D(L)$  is diagonal and that the errors terms  $\eta_t$  and  $\varepsilon_t$  are mutually uncorrelated. In addition, to identify  $C_t$ , restrictions on the variance-covariance matrix of  $\eta_t$  ( $\Sigma_\eta$ ) and on  $\gamma$  are required. Fernandez-Macho, Harvey and Stock (1987) impose three restrictions: they set  $\Sigma_\eta$  equal to a diagonal matrix, restrict  $\gamma_{ij} = 0$  for  $j > i$ , and set  $\gamma_{ii} = 1$  for  $i = 1, \dots, m$ . We set  $\Sigma_\eta$  as a diagonal matrix, but rather than restricting  $\gamma_{ii}$  to be equal to 1 for  $i = 1, 2$ , we set the two diagonal elements of  $\Sigma_\eta$  equal to 1 ( $\sigma_{\eta_1} = \sigma_{\eta_2} = 1$ ). Since our specification is richer than that of Fernandez-Macho *et al.* (1987) we don't need to impose any additional restrictions on  $\gamma_{ij}$ . We estimate the state-space model by a combination of a Kalman filter and maximum likelihood.

Tables 4, 5, and 6 present the estimated coefficients of the state-space model. As can be seen, the loading factors are statistically significant and have the same signs as those from the dynamic factor model. The speed of adjustment parameter of the cointegration relationships between the first factor and the fiscal position variable is very high ( $\lambda_1 = 0.16$ ) with  $t_{\lambda_1} = 3.93$ .<sup>12</sup> The coefficient on the U.S.- debt common factor is ( $\beta_2 = -0.65$ ) and is highly significant. We also find that the U.S.- interest rate term plays a role in the short-run dynamics of the model ( $\beta_1 = 0.25, t_{\beta_1} = 2.51$ ). Similarly, the speed of adjustment parameter between the second common factor and commodity prices is also high ( $\lambda_2 = 0.23$ ) with  $t_{\lambda_2} = 4.48$ . Note lastly, that the second common component is linked to both energy- and non-energy commodities, as both variables are highly significant with very similar coefficient estimates ( $\beta_3 = 0.65; \beta_4 = 0.51$ ).

Figures 10 and 11 show the estimates of the two common factors that come from the state-space model and the dynamic factor model from section 4.2. Note that the behavior of the two common factors is not significantly different. We interpret this

<sup>11</sup>The free trade agreement between Canada and the United States, as well as the liberalization of Canadian energy policy in the 1990s – including deregulation of the North American natural gas market – affected the relationship between the Canadian dollar and energy commodity prices.

While rising energy commodity prices used to cause a depreciation of the Canadian dollar, the effect has changed in 1993. Since 1993, rising energy commodity price result in an appreciating Canadian currency. See Issa et al. (2006) for details.

<sup>12</sup>We are not aware of a test for cointegration using a state-space model. However, the Boswijk (1994) test for the presence of cointegration in an error-correction model confirms cointegration between the three series.

evidence as confirming the robustness of our results.

## 5 Historical Decompositions

Recent years have been characterized by considerable swings in the value of key exchange rates (table 9). This period of notable exchange rate volatility coincides with historically unprecedented movements in the price of commodities and a surge in the value of the currencies of large commodity exporters against the U.S. dollar. At the same time, however, we have also seen large swings in the U.S. fiscal position and a more generalized weakness of the U.S. dollar against a broader basket of currencies.<sup>13</sup> In what follows, we attempt to disentangle the impact of these and other forces by decomposing movements in each of the bilateral exchange rates into the three components estimated by state-space model: the U.S. dollar common factor, the commodity component, and country-specific developments. Figures 12-17 show the three stochastic components for all countries. The vertical axis is in percentage points and the different components are centred on zero. Our discussion focuses on the 2002 to 2007 period.<sup>14</sup>

### 5.1 Australia

Figure 12 shows that over the entire sample, movements of the real Australian exchange rate relative to the U.S. dollar are clearly dominated by the two common components. More formally, we can reject the hypothesis of no cointegration between the real Australia-U.S. exchange rate and the two principal factors. Together, the U.S. factor, driven by the U.S. debt common factor, and world commodity prices account for almost all of the swing in the Aussie dollar - U.S. dollar exchange rate over the 2002 to 2007 period with each factor accounting for roughly 50 percent of the appreciation.

### 5.2 Canada

Together the commodity price and U.S. factor explain about 50 percent of the long-run variance in the Canada-U.S. exchange rate leaving the country-specific factor to account for the remaining 50 percent. Preliminary work suggests a possible relationship between the country-specific component of the exchange rate and a Canadian debt factor reflecting the severe deterioration in the Canadian fiscal position over the 1980s and early 1990s, and the sharp turnaround shown since the late 1990s.

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<sup>13</sup>Although the U.K. was an oil net exporter, overall it was a net commodity importer.

<sup>14</sup>Note that the main information is contained in the change in the level over a given period of time, not in the absolute level, nor the sign of the stochastic components.

As regards the most recent period of appreciation of the Canadian dollar between 2002 to 2007, the two common factors together explain about 2/3 of the appreciation in the Canada-U.S. exchange rate. Of this rise, the U.S. factor, driven by the U.S. debt common factor, explains about 50% and commodities explaining about 50% (see Figure 13).

### **5.3 The Euro area**

Like Australia, the two common factors explain almost all of the variation in the real Euro-U.S. dollar exchange rate. In fact, we are able to reject the hypothesis of no cointegration between the real euro-U.S. dollar exchange rate and the two common factors.<sup>15</sup> Unlike Australia, however, U.S. shocks can explain almost all of the appreciation in the euro-U.S. dollar real exchange rate between 2002 and 2007 (see Figure 14). This result is consistent with the results reported in Fratzscher (2007) which argues that the Euro and its predecessor currencies have contributed to the bulk of the adjustment of the U.S. dollar effective exchange rate over the past 25 years. Fratzscher (2007) suggests that the high degree of financial integrations between the Europe and the United States explains this result. World commodity prices contributed to slight downward pressure on the euro.

### **5.4 United Kingdom**

For the United Kingdom, Figure 15 shows that U.S. factors play a large role in explaining the volatility of the pound-U.S. dollar exchange rate. Domestic factors also seeming played an important role. In particular, note the upward pressure on the pound-U.S. dollar exchange rate in the late 1990s. Over the 2002 to 2007 period, our decomposition suggests that the U.S. factor played the predominant role in explaining the appreciation of the pound vis-a-vis the U.S. dollar while commodity prices had only a modest downward impact.<sup>16</sup>

### **5.5 Japan**

The country-specific factor for Japan shows a very distinct pattern (Figure 16). Domestic developments have resulted in upward pressure on the Yen until the mid-1995, and substantial downward pressure since the start of the Japanese deflation and the

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<sup>15</sup>This could reflect that the euro area – a currency area composed of more than 10 individual countries – is less prone to idiosyncratic shocks than other countries in our sample.

<sup>16</sup>Note that the United Kingdom was a net exporter of oil during our sample, but still a net importer of commodities as a whole.

associated economic difficulties. Preliminary work suggests that this downward pressure on the yen-U.S. dollar exchange rate may be attributable to the deterioration in Japanese fiscal position.

Between 2002 and the end of our sample, the main factor influencing the bilateral exchange rate for Yen and the U.S. dollar is country-specific. In addition, commodity prices also exert some downward pressure on the Yen-U.S. dollar exchange rate, reflecting Japan's dependency on imports for both energy- and non-energy commodities. On the other hand, there is significant upward pressure on the yen coming from the U.S. factor over the 2002 to 2007 period, which offsets much of the downward pressure coming from the other two components.

## **5.6 New Zealand**

The case of New Zealand is intriguing. New Zealand is a large commodity exporter, but its exports are largely concentrated in food and agricultural products. As a result, the rise in global commodity prices – which is mostly focused on energy and industrial materials – plays a less important role in explaining the appreciation of the New Zealand - U.S. exchange rate than for other commodity-exporting countries in our sample. Between 2002 and 2007, the U.S. factor accounts for the bulk of the appreciation of the currency.

## **6 Conclusion**

Understanding movements in exchange rates is a notoriously difficult task. Combining the literature on factor models and exchange rates, we propose a novel approach to analyze exchange rates and conclude that U.S. fiscal policy and commodity prices have played very important roles in determining the value of a number of U.S. dollar exchange rates. In future work, we would like to better understand the "domestic" factors that may be driving a number of the exchange rates in our panel. In addition, given recent developments as they pertain to the relative deterioration of the U.S. fiscal position, it would be interesting to project the future evolution of the bilateral exchange rates based on alternative assumptions regarding the future path for the debt and commodity price variables.

## A Data Appendix

### 1. Real exchange rates

The nominal exchange rate data is from IMF's IFS. We construct the euro exchange rate data, over the period 1981 to 1998, by using data on the ECU-U.S. dollar exchange rate, excluding the U.K. pound and Danish krona. The real exchange rates are calculated using GDP price deflators.

### 2. Commodity Prices

Our commodity price measures are the IMF non-energy commodity price index and the West Texas Intermediate (WTI) crude oil price. Both are expressed in U.S. dollar terms and are deflated by the U.S. GDP price deflator.

### 3. Manufacturing Labour Productivity

The relative manufacturing labour productivity of each country is calculated by:

$$\frac{((\text{Real Manufacturing Gross Output}) / (\text{Manufacturing Number of Workers}))}{((\text{Real Total Gross Output}) / (\text{Total Number of Workers}))}$$

The relative manufacturing labour productivity is then indexed (2000=100) and interpolated to a quarterly frequency. Annual productivity for Australia, Euro Area, Japan, U.K. and the U.S. were collected from EU KLEMS. Quarterly productivity data for Canada was collected from Statistics Canada.

### 4. Debt-to-GDP Ratio

The debt-to-GDP ratios for Canada, U.K., Japan, U.S. and Australia were collected from the OECD Economic Outlook while the debt-to-GDP ratio for New Zealand was collected from the New Zealand Treasury.

### 5. Real Interest Rates

The real interest rate is calculated by  $(1 + i)/(1 + \pi) = (1 + r)$  where  $i$  denotes the nominal interest rate;  $r$  denotes the real interest rate;  $\pi$  is the year-over-year inflation rate. The nominal interest rate is the 3 month treasury bill rate which was collected from various sources including Bloomberg, DataStream and the IMF's IFS. The inflation rate is calculated using the national CPIs and was collected from Global Insight and the BLS.

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Table 1: Augmented Dickey-Fuller Unit-Root Tests, sample period 1981q1 to 2007q4

Log level of the U.S. real bilateral exchange rate	No Trend	Trend
Australia (AU)	-2.22	-1.97
Canada (CA)	-0.99	-0.42
Euro (EU)	-1.62	-2.31
Japan (JA)	-2.03	-1.75
United-Kingdom (UK)	-1.74	-2.04
New Zealand (NZ)	-1.28	-3.12
Critical Value (5 percent)	-2.89	-3.44

Table 2: Principal Factor Analysis: Loading Factors

Country	Factor 1	Factor 2
AU	0.63	0.44
CA	0.45	0.36
EU	0.74	-0.34
JA	0.53	-0.26
NZ	0.75	0.18
UK	0.71	-0.26

Table 3: Cointegration Tests

	First Factor (US Factor)	Second factor (Commodity Factor)
Test Statistic (Saikkonen)	-3.56	-4.62
Test Statistic (Engle-Granger)	-3.36	-4.29
Critical Values		
	1 percent	-4.44
	5 percent	-3.83
	10 percent	-3.52

Table 4: Estimation of the Structural State Space Table A

Parameter	Coefficient	T-Stat
$\gamma_1^{AU}$	0.46	9.18
$\gamma_1^{CAN}$	0.33	4.69
$\gamma_1^{EU}$	0.78	13.14
$\gamma_1^A$	0.50	7.04
$\gamma_1^{NZ}$	0.58	9.65
$\gamma_1^{JK}$	0.65	11.37
$\gamma_2^{AU}$	0.57	11.63
$\gamma_2^{CAN}$	0.21	2.66
$\gamma_2^{EU}$	-0.28	-5.78
$\gamma_2^A$	-0.18	-2.24
$\gamma_2^{NZ}$	0.25	3.59
$\gamma_2^{JK}$	-0.16	-2.10
$\gamma^{CAN}$	0.43	2.90

Table 5: Estimation of the Structural State Space Table B

Common Components Parameters	Coefficient	T-Stat
$\lambda_1$	0.16	3.93
$\beta_1$	0.25	2.51
$\beta_2$	-0.65	-5.88
$\lambda_2$	0.23	4.48
$\beta_3$	0.65	5.10
$\beta_4$	0.51	3.30

Table 6: Estimation of the Structural State Space Table C

AR 1 Coefficient	Coefficient	T-Stat
$\phi_1$	0.31	3.44
$\phi_2$	0.31	2.92
$v^{CAN}$	0.27	2.69
$v^{JAP}$	0.28	3.16
$v^{UK}$	0.19	1.78
$v^{AU}$	0.78	6.67
$v^{EU}$	0.63	1.77

Table 7: Loading factor for the commodity common component for Canada

Period	Loading factor
1980-1993	0.21
1993-2007	0.64

Table 8: Estimation of the Structural State Space Table C

Variance of the Country specific shocks	Coefficient	T-Stat
$\sigma^{aus}$	0.21	6.85
$\sigma^{can}$	0.50	11.85
$\sigma^{eur}$	0.08	2.31
$\sigma^{jpn}$	0.57	13.62
$\sigma^{nz}$	0.43	12.33
$\sigma^{uk}$	0.37	11.16

Table 9: Real Bilateral Exchange Rates: Percentage Change 2002Q1 to 2007Q1

	AU	CA	EU	JA	UK	US	NZ
AU	-	13	15	90	22	70	0
CA	-12	-	1	68	7	50	-12
EU	-13	-1	-	66	6	48	-13
JA	-47	-40	-40	-	-36	-11	-48
UK	-18	-7	-6	56	-	39	-18
US	-41	-33	-32	12	-28	-	-41
NZ	0	14	15	91	22	70	-

Figure 1: Real U.S. Dollar Bilateral Exchange Rates

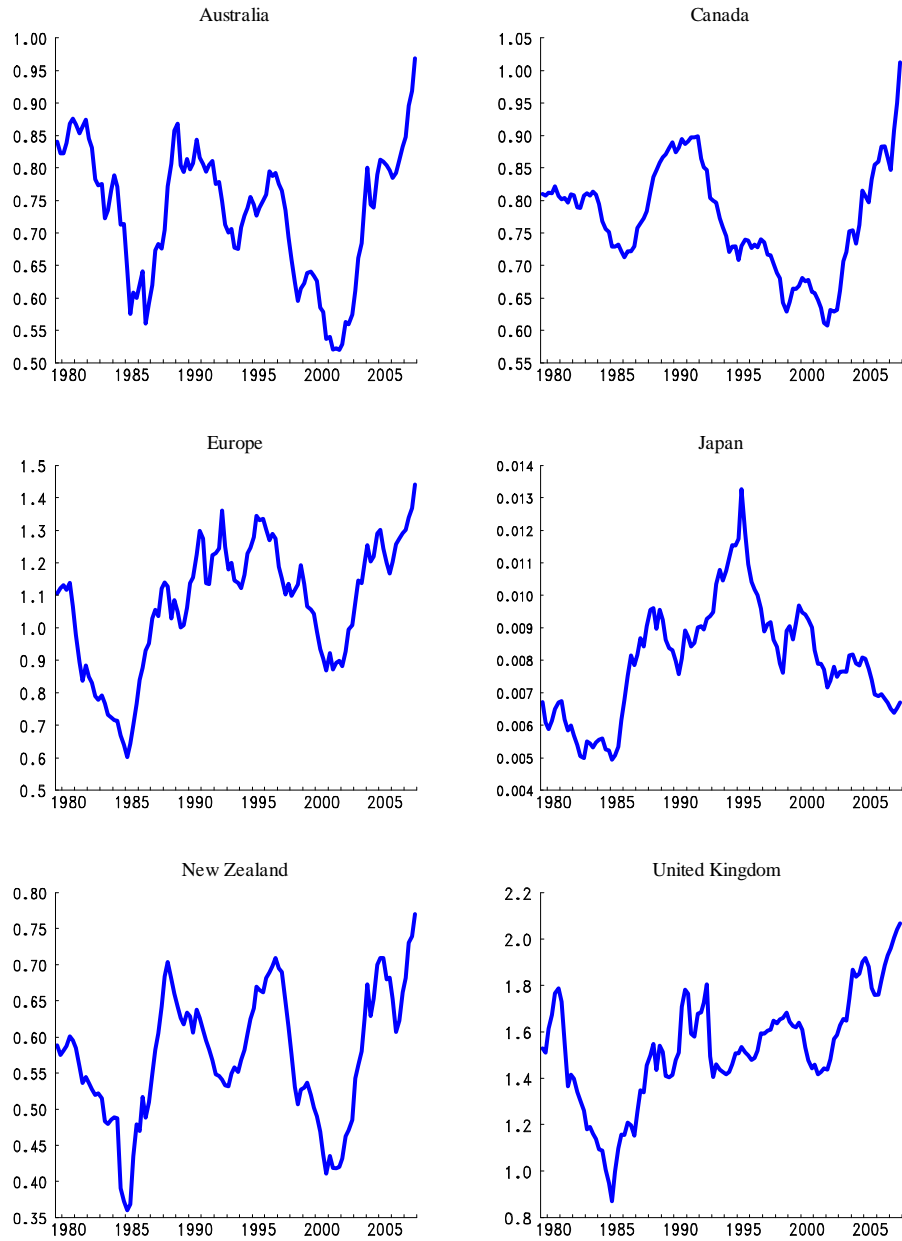


Figure 2: Principal Component Model

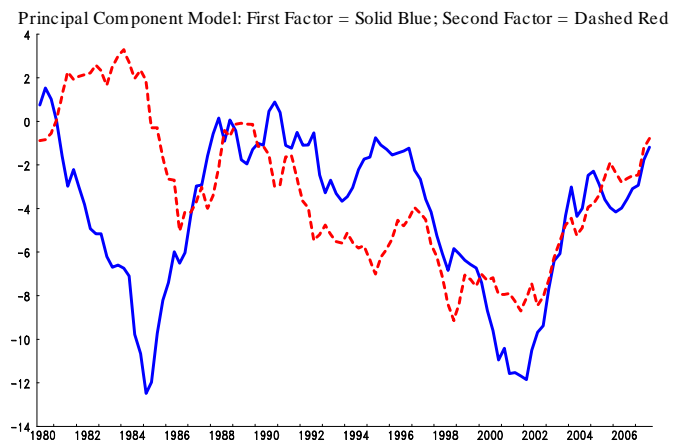


Figure 3: Cointegration Relationship: U.S. Factor

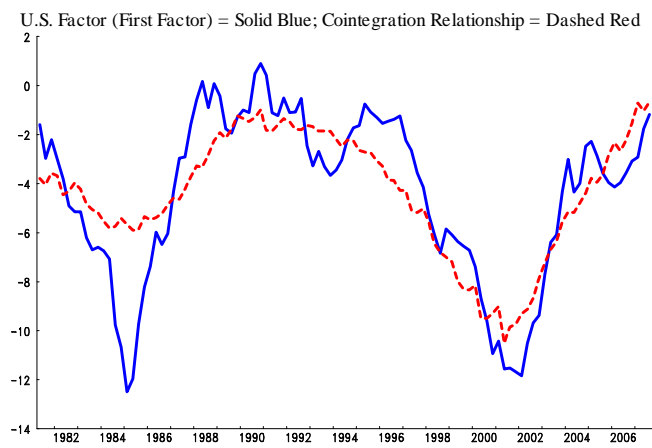


Figure 4: Residual from the Cointegration Relationship: U.S. Factor

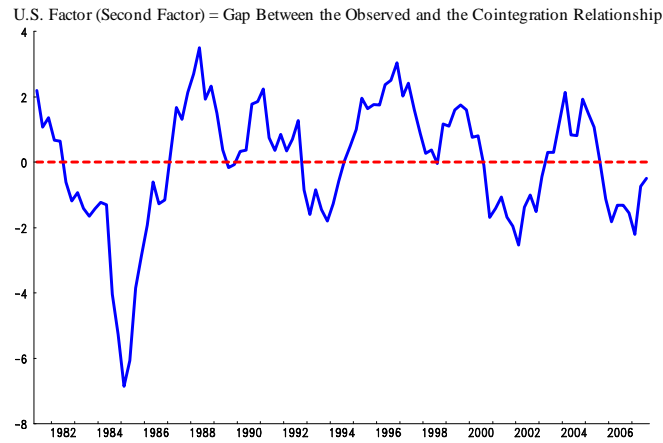


Figure 5: Loading Factor 2 vs. Net Commodity Imports relative to the US

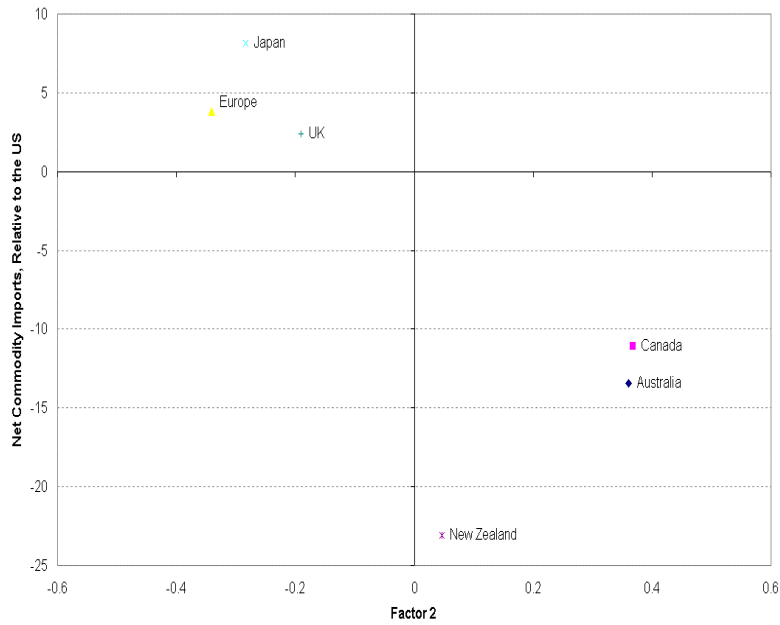


Figure 6: Principal Factor 2 and Oil (Log-level)

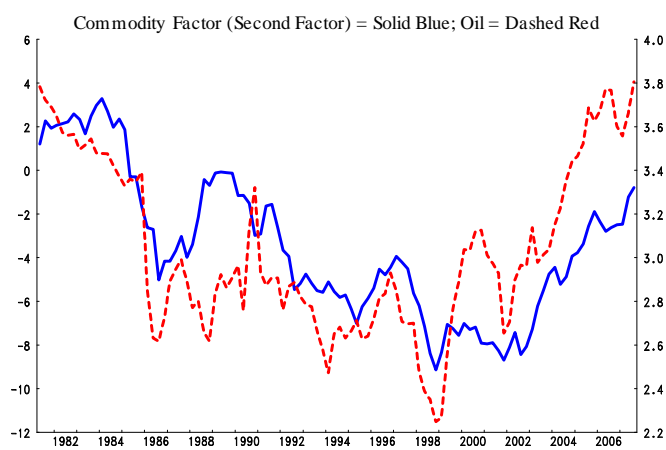


Figure 7: Principal Factor 2 and Non Energy Commodities (Log-level)

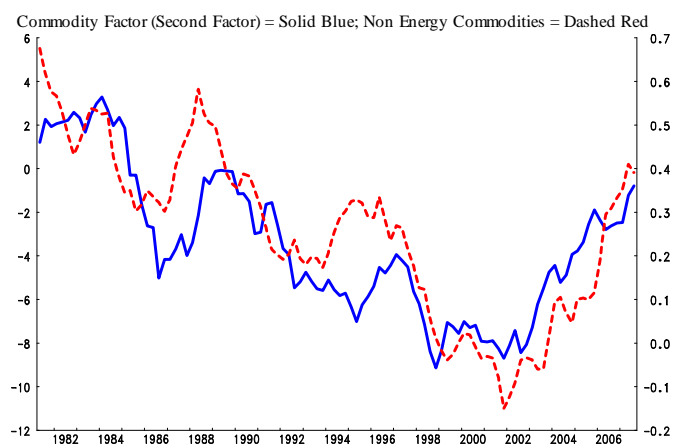


Figure 8: Cointegration relationship: commodity factor

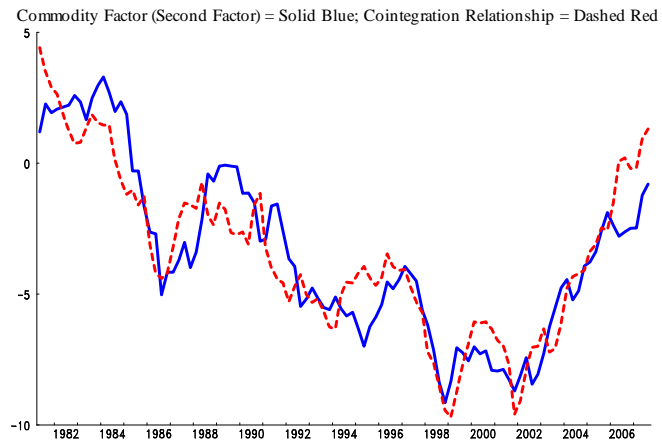


Figure 9: Residual from the Cointegration Relationship: Factor 2

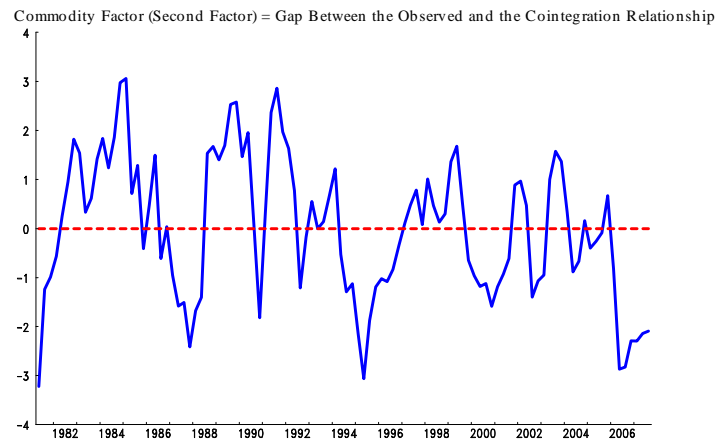


Figure 10: State-Space Model vs. Principal Factor Model: First Factor

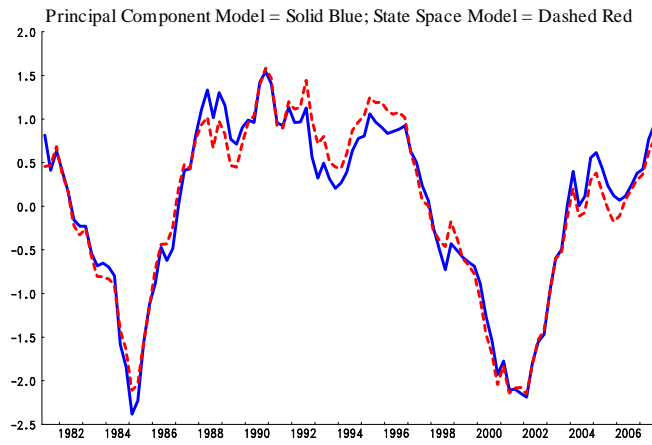


Figure 11: State-Space Model vs. Principal Factor Model: Second Factor

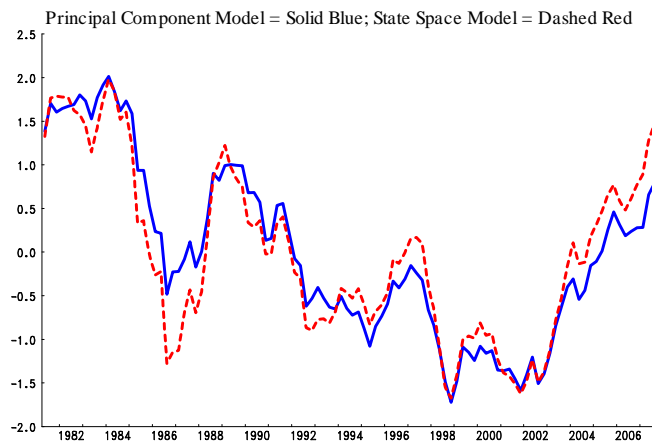


Figure 12: Australia Exchange Rate Stochastic Components

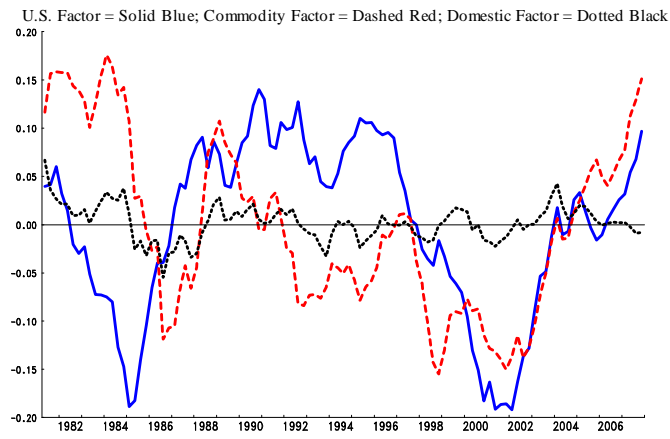


Figure 13: Canada Exchange Rate Stochastic Components

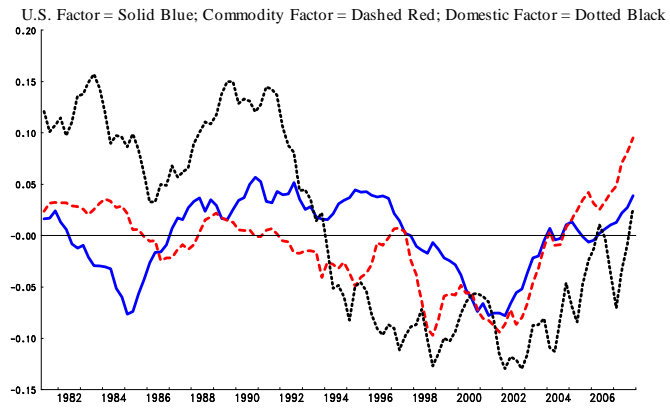


Figure 14: Euro Area Exchange Rate Stochastic Components

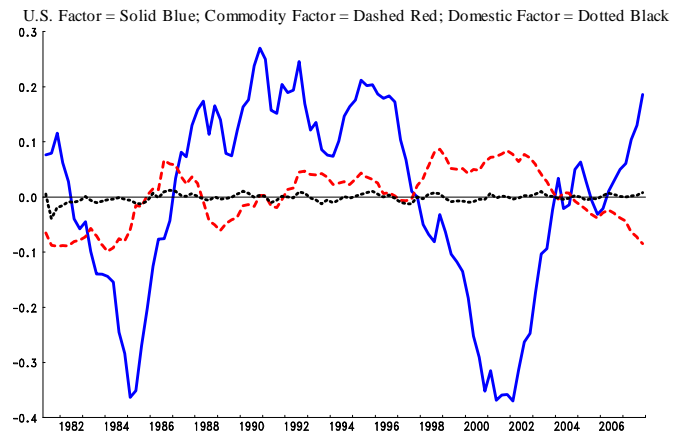


Figure 15: U.K. Exchange Rate Stochastic Components

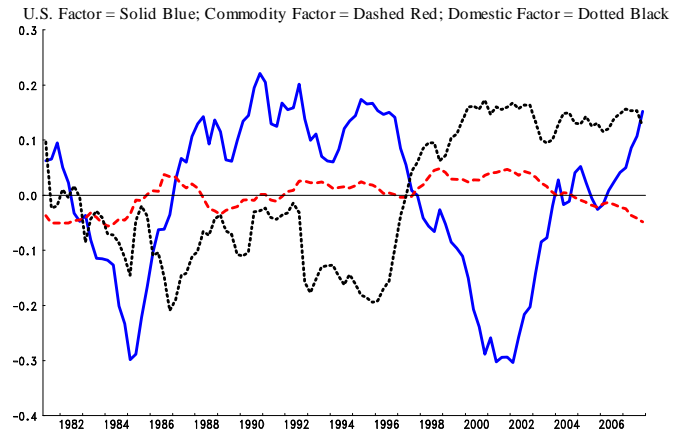


Figure 16: Japanese Exchange Rate Stochastic Components

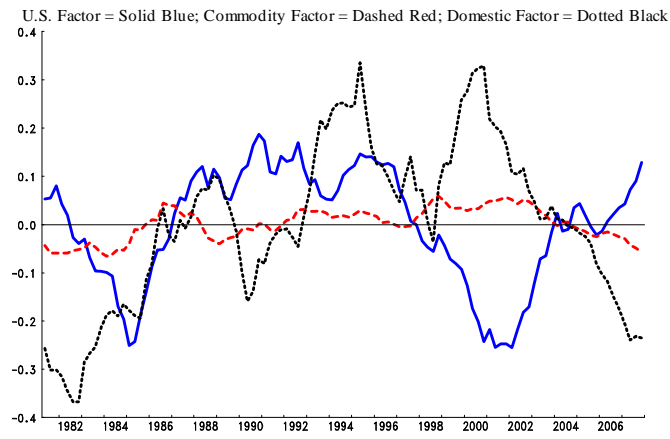


Figure 17: New Zealand Exchange Rate Stochastic Components

