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The Monetary Model of the US Dollar–Japanese Yen Exchange Rate: An Empirical Investigation

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Abstract

This article considers the long-run performance of the monetary approach to explain the dollar–yen exchange rates during a period of high international capital mobility. We apply the Johansen methodology to quarterly data over the period 1980:01–2009:04 and show that the historical inadequacy of the monetary approach is due to the breakdown of its underlying building-blocks, money demand stability and purchasing power parity. Our findings on long-run weak exogeneity tests emphasize the importance of the extended model employed here. This shows that cumulative shocks to nominal exchange rates can be explained by variables outside the usual price and interest rates.

JEL Classification: F31, F36, C22

Keywords: Cointegration, Exchange Rates, Monetary Approach, Weak Exogeneity

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1. Introduction

Since the collapse of the Bretton Woods fixed exchange rate system in 1971, much attention has been paid towards finding a meaningful explanation of exchange rates. A wide range of models have been proposed to understand movements in the exchange rate, one of which is the monetary model (see Bilson, 1978; Frankel, 1979), which, despite having rigorous theoretical underpinnings, has empirically had limited success until now.

As observed by MacDonald and Taylor (1994), there is little evidence of a long-run relationship between monetary fundamentals and exchange rates, typically with the signs and magnitudes of estimated coefficients not in support of monetary theories. Mark and Sul (2001) find some evidence in a panel context, but this was under the assumption of a high order of heterogeneity across all country models. Similarly, Rapach and Wohar (2002), using a long time series, find some support for the theory, but this related to different exchange rates and macro regimes, with some evolution in the composition of products in price indices. Taylor and Peel (2000) apply non-linear methods to model a nominal exchange rate and monetary fundamentals, but such results are often sensitive to a small number of observations and become less robust as the samples evolve. Frömmel et al. (2005) estimate a model with Markov switching; however, the monetary model related to only one regime.

The aim of this study is to devise a monetary model using a money demand equation based on broader asset classes and to account for the factors that cause the purchasing power parity (PPP) to fail. While Hendry and Ericsson (1990) show the instability of conventional money demand equations, Friedman (1988) and McCornac (1991), using data from the United States and Japan, respectively, confirm the need for real stock prices to stabilize money demand equations. More recently, Gregoriou et al. (2009), using a Vector Autoregressive (VAR) model on the US economy, find liquidity to be a key factor in explaining asset prices, and excess returns on the S&P500 to have a role in explaining real money growth.

Sarno and Taylor (2002) investigate a range of empirical evidence on PPP and find little support for the conventional form. This corresponds well with the classic findings of Balassa (1964) and Samuelson (1964), which indicate that persistent deviations from PPP arise from technology differentials. While Lastrapes (1992) shows fluctuations in the nominal and real exchange rates due to the impact of differentials in productivity and government expenditure along with real oil prices, Caporale and Pittis (2001), analysing the yen–dollar exchange rate, are unable to find a stable relation based on the monetary model. More recently, Chinn and Moore (2011), in comparison of the dollar–euro exchange rate, failed to find a long-run dollar–yen relation even when they included a cumulative order flow.

In this study, we incorporate the real stock prices in the money demand equation, while we use productivity differentials, relative government spending, and real oil prices to explain the persistence in the real exchange rate. Our estimations are based on the quarterly US dollar–Japanese yen exchange rate data for the period characterized by high international capital mobility and volatility, 1980:01 to 2009:04.

We employ the Johansen (1995) methodology to detect long-run relations and observe that, for the conventional monetary model, the exchange rate is weakly exogenous and therefore acts as the driver of the system. However, the extended model has a long-run normalization on the exchange rate. Our findings on long-run weak exogeneity and exclusion have important policy implications, because for the extended model, the cumulative shocks to the nominal exchange rate derive from the factors affecting the relative real stock prices and productivity differentials.

This study is organized as follows: Section 2 provides the analytical framework for the exchange rate monetary model; Section 3 outlines the econometric technique used and describes the data; Section 4 explains the empirical results and the analysis; and Section 5 concludes the study.

2. Analytical Framework

The exchange rate monetary model is based on the assumptions that money demand is stable and that PPP holds. To investigate this, we consider two forms of the exchange rate monetary model and put them under econometric scrutiny. We first examine the 'real interest rate differential' (RID) model, and then a modified RID (MRID) model.

In the following model, derived in detail in Frankel (1979), the features of the fixed- and flexible-price monetary models are amalgamated by incorporating short-term interest rates to capture liquidity:

$$e_t = \beta_1(m_t - m_t^{*}) + \beta_2(y_t - y_t^{*}) + \beta_3(i_t^{s} - i_t^{s*}) + \beta_4(i_t^{l} - i_t^{l*}) + \varepsilon_t, \tag{1}$$

where e_t = log(E_t) denotes the natural logarithm of the spot exchange rate (domestic currency per unit of foreign currency, $/yen), $m_t = \log(M_t)$ the money supply, $y_t = \log(Y_t)$ the real income, i_t^s the short-term interest rate, and i_t^l the long-term interest rate used to capture the expected inflation; the asterisk denotes the foreign country (Japan), and the domestic country is the United States. The following coefficient restrictions apply to both the RID and MRID models:

$$\beta_1 = 1, \beta_2 < 0, \beta_3 < 0, \beta_4 > 0.$$

Friedman (1988) shows that the stability of the money demand function used to specify the monetary model depends on the inclusion of the real stock prices. Furthermore, according to Chortareas and Kapetanios (2004), there is limited support for the conventional PPP for Japan. Indeed, from a visual inspection of Figure 1, we find that the real dollar–yen exchange rate does not appear to revert to the mean. Balassa (1964) and Samuelson (1964) attribute the inadequacy of PPP to real economic shocks—in particular, to the unanticipated movement found in the productivity differentials between the traded and non-traded goods sectors across the economies. Financial variables also appear sensitive to the demand shocks associated with government expenditure and the supply shocks related to the real oil prices.[1] Using these factors, we modify Equation (1) and term it MRID, which is derived as follows in Appendix A:

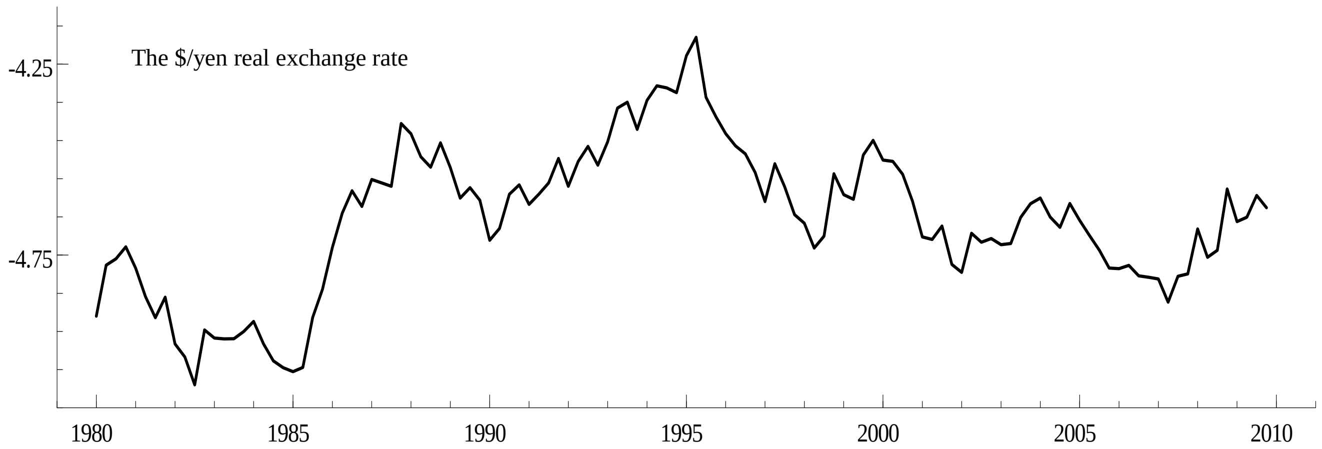

Figure 1. Behaviour of the real dollar–yen exchange rate for the period 1980:Q1–2009:Q4

$$e_t = \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_3(i_t^s - i_t^{s*}) + \beta_4(i_t^l - i_t^{l*}) + \beta_5(s_t - s_t^*) + \beta_6(prod^T{}_t - prod_t^{T*})$$
$$+ \beta_7(gs_t - gs_t^*) + \beta_8 roil_t + v_t, \tag{2}$$

where s_t stands for the log of real stock prices, gs_t government consumption as a percentage of GDP, $prod_t$ productivity in the traded sector, and $roil_t$ the real oil price. The sign of the real stock prices β_5 depends on the extent to which the substitution effect (positive) dominates the wealth effect (negative) in the money demand equation. The sign of the oil price is expected to be negative ($\beta_8 < 0$) because higher real oil prices would lead to an appreciation of the US dollar (see Amano and van Norden, 1998) and oil prices are given in dollars. The input costs in Japan are highly sensitive to oil prices because Japan is a net importer country and the third largest oil consumer and importer country after the United States and China.[2] The sign of the productivity differential depends on the relative competitiveness of the traded goods sector. The differential in government expenditure captures demand side shocks and is likely to appreciate the exchange rate ($\beta_7 < 0$).

3. The Econometric Approach and Data

The Econometric Approach

We employ the Johansen methodology to investigate the long-run equilibrium relationship between the variables of the two models. Johansen (1995) formulates an unrestricted VAR model of order p with ($n \times 1$) endogenous variables, all integrated of order one (I(1)), forced by a vector of ($n \times 1$) independent Gaussian errors, with the following error-correction representation:

$$\Delta X_t = \Pi X_{t-1} + \Gamma_1 \Delta X_{t-1} + \ldots\ldots + \Gamma_p \Delta X_{t-p+1} + \gamma D_t + \varepsilon_t, \qquad (3)$$

where X_t is an ($n \times 1$) variables vector; D_t is a vector containing constants, centred seasonal dummies, and impulse dummies; Γ_i (i =1,.....,p-1) are ($n \times n$) parameter matrices capturing the short-run dynamics among the variables; and Π is an $n \times n$ matrix decomposed as $\alpha\beta'$, with matrices α and β dimensioned ($n \times r$), relating to the speed of adjustment and long-run relations, respectively.

We use the trace test to determine the rank r of Π. Johansen (1995) explains that the test has an optimal sequence starting with the null hypothesis $r = 0$ (no cointegration) against the alternative $r \leq 1$ (at least one cointegrating vector) and subsequent further orders of cointegration $r = i$ against the alternative $r \leq i+1$; the sequence stops at $r = i$ when the null cannot be rejected. The test is a likelihood ratio test that can be written in terms of eigenvalues (λ_i) and sample size (T) with

$$\lambda_{trace} = -T\sum_{i=1}^{n}(1-\lambda_i). \tag{4}$$

The results associated with the Johansen test are well defined when the VAR model is well specified (Johansen, 1995). The most appropriate lag length for the model is often based on model selection criteria such as the Akaike Information Criterion (AIC). However, Burke and Hunter (2007) suggest that there can be a substantial size distortion of the trace test relative to the null distribution when the selected lag order is sub–optimal;[3] therefore, we extend the model to remove serial correlation.

As a result of sharp changes in monetary policy in the United States and Japan throughout the sample period, we include impulse dummies, which remove the impact of extreme observations relating to 1980:4, 1982:3, 2002:2, and 2008:4. The corresponding known events for these dummies relate to the large short-term interest rate fluctuations in the United States and Japan in the early 1980s, the monetary expansion (now termed Quantitative Easing [QE]) adopted by the Bank of Japan from March 2001 to March 2003, and the QE in the United States as a result of the 2007–2008 banking crisis. The fourth quarter of 1980 corresponds with the end point of the fiscally liberal 60s and 70s that led to the election of Ronald Reagan as the US President and the Volker reforms at the Federal Reserve.

Our modelling approach follows Juselius and MacDonald (2004) who consider joint modelling of the international parity relations between the United States and Japan. We examine the RID and

MRID models econometrically by estimating Equation (3) using the following variable vectors in the respective levels:

$$X'_{(RID)t} = [e_t, m_t - m_t^*, y_t - y_t^*, i_t^s - i_t^{s*}, i_t^l - i_t^{l*}],$$

$$X'_{(MRID)t} = [e_t, m_t - m_t^*, y_t - y_t^*, i_t^s - i_t^{s*}, i_t^l - i_t^{l*}, s_t - s_t^*, prod_t^T - prod_t^{T*}, gs_t - gs_t^*, roil_t].$$

We suggest that by investigating these two variable sets, we might be able to determine the key factors that identify the long-run monetary model of the exchange rate and explain the short-run behaviour of the different systems. The monetary approach depends on a stable money demand relation and the assumption that PPP holds. Using series that are I(1), we can observe an exchange rate equation by finding a cointegrating relation and showing via a likelihood ratio test that this variable is neither long-run excluded (Juselius, 1995) or weakly exogenous (Johansen, 1992). According to Burke and Hunter (2005), such a finding can help in interpreting and identifying a long-run relation.

Data

For this study, we use quarterly seasonally unadjusted data, where available, for the United States *vis-à-vis* Japan over the period 1980:1–2009:4. We choose the start of the sample period in order to control for structural change in the Japanese financial system because by the end of 1979, the interbank rates in Japan were deregulated, capital controls were removed, and the certificate of deposit market developed (McCornac, 1991). We use quarterly data as GDP data are not available on a monthly basis. The short-term interest rates are represented by the official discount rate,[4] and the long-term interest rates are represented by the 10-year government bond yields. We use the Consumer Price Index (CPI) data to deflate the stock price indices represented by the S&P 500 for the United States and the Nikkei 225 for Japan. Government spending is defined as government consumption in proportion to GDP, and productivity differential is defined as industrial production divided by the corresponding employment level. The real oil price is the West Texas Intermediate (WTI) Cushing crude oil spot price in dollars per barrel deflated by the US CPI; the stock prices, exchange rates, oil prices, and short-term interest rates are all end-of-period figures.[5]

4. Empirical Results

The variables in this study are all I(1), as stationarity is confirmed in the multivariate setting by fixing the i^{th} element of a single cointegrating vector to unity and in turn the other elements to zero. Cointegration then is tested using Johansen (1995) procedure. The first subsection presents the analysis of RID model; the second subsection analyses the MRID model; and finally MRID model validation is reported in the third subsection.

Long-Run Analysis of the RID Model

The AIC indicates that the lag length of the VAR is $p = 1$ from the data set X_{RIDt}. However, in order to remove any serial correlation and enhance the specification of the model, we require that $p = 4$.[6] On the basis of this specification, the estimated eigenvalues and trace statistics are reported in Table 1.

The trace test indicates that the null hypothesis of no cointegration is rejected, but since the subsequent test reported in Table 1 for the null (r = 1) does not exceed the critical value, this supports the idea that there is a single cointegrating vector. This vector can be generically identified in the long run via a normalization process (see Boswijk, 1996), and from the literature, this implies the nominal exchange rate:[7]

Table 1. Johansen Cointegration Test Results for RID Model

System comprises $[e, m - m^*, y - y^*, i^s - i^{s*}, i^l - i^{l*}]$					
$(p - r)$	r	Eigenvalue	Trace test	95% critical value	P-value
5	$r = 0$	0.398	100.940	69.611	0.001[a]
4	$r \leq 1$	0.186	42.054	47.707	0.526
3	$r \leq 2$	0.119	18.219	29.804	0.832
2	$r \leq 3$	0.021	3.534	15.408	0.965
1	$r \leq 4$	0.009	1.053	3.841	0.344

Note: The lag length is selected using the Akaike Information Criterion (AIC), subject to correction for serial correlation by the inclusion of further lags. r denotes the number of cointegrating vectors.

[a] and [b] indicates significance at the 1% and 5% levels, respectively.

$$e_t = 2.250(m_t - m_t^*) + 14.988(y_t - y_t^*) + 0.090(i_t^s - i_t^{*s}) - 1.065(i_t^l - i_t^{*l})$$
$$\quad (1.664) \qquad\qquad (3.301) \qquad\qquad (1.014) \qquad\qquad (7.890) \tag{5}$$

$(t-\text{statistics in parentheses})$, LM(8)=1.2042[0.0883], Jarque Bera test =17.259 [0.0688].

An inspection of the results would show that the coefficient on the relative money supply has the sign expected by theory; therefore, based on one-sided inference, we consider it significant at the

5% level. However, the relative income and the short-term and long-term interest rate differentials have signs that are not consistent with theory.

It is often felt that normalization is innocuous, but Boswijk (1996) has suggested that the validity of an identifying restriction requires testing via further rank conditions. However, as shown in Burke and Hunter (2005; chapter 5), a coherent strategy for identification is to preclude normalization on variables that are either long-run excluded or weakly exogenous; cointegrating vectors are defined on non-stationary series, thus invalidating normalization on a stationary variable.

The tests of long-run exclusion (LE), weak exogeneity (WE), and stationarity are asymptotically distributed chi-squared (Johansen, 1992), and in Table 2 we report our results on a variable by variable basis. The LE tests indicate that except for the relative income and long-term interest rate differentials, all the other variables can be excluded from the cointegration space. Hence, a long-run model based on the exchange rate may be ill defined, as the related parameter is not different from zero. In the subsequent panel, the proposition that the exchange rate and short-run interest rate are weakly exogenous cannot be rejected. Hence, at best, the long run ought to be conditioned on the exchange rate. Similar results are found in Hunter (1992)[8] among others.

In conclusion, a long-run relation derived from variables drawn from an RID model cannot relate to an exchange rate equation, as this variable can be either excluded or viewed as weakly exogenous. The latter is not very surprising, given the literature suggesting that the exchange rate follows a random walk, although tests of WE are sensitive to changes in the information set (Juselius and MacDonald, 2004). The stationarity tests confirm that the series prior to differencing are all I(1).

Long-Run Analysis of the MRID Model

The findings given above cast serious doubts on the conventional monetary approach regarding the dollar–yen exchange rate model. Therefore, we consider it of paramount interest to investigate the reasons for this failure. To this end, the VAR model is now based on the vector $X_{(MRID)t}$. Since the price of oil is a global factor and all other factors are differentials between the United States and Japanese variables, we treat the real oil price as exogenous to the system, though this was confirmed by conducting a weak exogeneity test.[9] This is also consistent with the intuition of Amano and van Norden (1998) that oil prices in the decades preceding their study were governed by the major supply-side shocks resulting from political instability in the Middle East, and are thus external to developed economies.

With regard to the VAR specification, the AIC indicates a lag length p = 1, while diagnostic tests imply p = 3 to improve the specification. The results for the exchange rate equation shown below are representative of the system. From the p-value for the Lagrange multiplier (LM) test, the results suggest that the model does not suffer from serial correlation up to order 8, and the same applies to ARCH effects up to order 4. However, the multivariate normality test is rejected, but the sources of such failure seem to result from excess kurtosis. Gonzalo (1994) demonstrated the lack of sensitivity of the cointegrating rank to excess kurtosis, suggesting that these findings are robust.

Table 3 reports the trace test related to the MRID model. It is evident that the null hypothesis of no cointegration is rejected, but evidence for more than one cointegrating vector cannot be rejected at

Table 3. Johansen Cointegration Test Results for MRID Model

System comprises: [e, $m - m^*$, $y - y^*$, $i^s - i^{s*}$, $i^l - i^{l*}$, $s - s^*$, $gs - gs^*$, $Prod^T - Prod^{T*}$, $roil$]					
($p - r$)	r	Eigenvalue	Trace test	95% critical value	P-value
8	$r = 0$	0.443	230.054	204.989	0.002[a]
7	$r \leq 1$	0.389	161.594	166.049	0.085
6	$r \leq 2$	0.245	103.946	131.097	0.630
5	$r \leq 3$	0.191	71.056	100.127	0.799
4	$r \leq 4$	0.144	46.276	73.128	0.864
3	$r \leq 5$	0.121	28.068	50.075	0.869
2	$r \leq 6$	0.095	12.942	30.912	0.917
1	$r \leq 7$	0.011	1.259	15.331	0.998

Note: See note of Table 1.

Table 4. Long-run Exclusion (LE), Weak Exogeneity (WE), and Stationarity (S) Tests for MRID Model

Variables	e	(m - m^*)	(y - y^*)	(i^s - i^{s*})	(i^l - i^{l*})	(s - s^*)	($prod^T$- $prod^{T*}$)	(gs - gs^*)
Panel A. LE tests								
$\chi^2(1)$	5.641	2.058	4.556	9.756	7.942	2.561	6.057	9.163
p-value	0.018[b]	0.151	0.033[b]	0.002[a]	0.005[a]	0.11	0.014[b]	0.002[a]
Panel B. WE tests								
χ^2 (1)	3.978	0.192	0.225	0.006	4.220	2.461	1.627	3.261
p-value	0.046[b]	0.662	0.636	0.939	0.040[b]	0.117	0.202	0.071
Panel C. S tests								
χ^2 (1)	38.038	38.254	37.133	39.459	23.569	30.839	29.992	33.191
p-value	0.000[a]	0.000[a]	0.000[a]	0.000[a]	0.000[a]	0.000[a]	0.000[a]	0.000[a]

Note: See note of Table 2.

the 5% level. Although the cointegrating rank does not change, this indicates that the augmented factors follow a stochastic trend common to the nominal exchange rate and monetary fundamentals in the RID model. One explanation for this is that conditioning the system on the real oil price is disentangling a secondary effect that feeds through the exchange rate, and implies this is a forcing variable; this does not seem to be the case when the model is extended. Long-run exclusion tests are likely to give more information regarding the nature of the contribution of the augmented factors and the variables on which the long run may be normalized.

Table 4 reports the LE, WE, and stationarity tests of the variables included in the MRID model. The stationarity tests imply that none of the variables in the cointegration space are stationary. On the other hand, the LE tests indicate that the real oil price is the primary candidate for exclusion in a long-run relation, while the relative money supply and real stock prices could be excluded on a single-variable basis, although this would be rejected at the 15% level. However, at this stage, we do not exclude any variable based on a single-variable test. In the next subsection, we use these results to obtain a more parsimonious long-run relation.

One of our key findings is that the nominal exchange rate is not weakly exogenous for the extended case. The change in WE status is a de facto indication of changes in long-run feedback and is of paramount interest (Juselius and Macdonald, 2004). This is in contrast to the RID model, and indicates that the nominal exchange rate adjusts to the long-run equilibrium and does not force the system when the relative real stock prices, the productivity differentials, the relative government spending, and the real oil prices are included. From the tests reported in Table 4, we cannot reject the finding that the real stock prices, productivity differentials, relative government spending, and real oil prices seem to be weakly exogenous, although the long-term interest rate differential is not. The variables found to be weakly exogenous can be used to condition the long run. The findings shown in Table 4 suggest that the model can be normalized on the nominal exchange rate and primarily driven by the real and financial market shocks, corresponding to the results of Ahn and Kim (2010).

Note that the findings on long-run weak exogeneity for both the short-term and long-term interest rate differentials do not vary according to model specifications and are consistent with the term structure of interest rates. This is important for the conduct of a monetary policy because findings on the term structure are unsupportive if the interest rate data are analysed alone. Here, the long run is identified as a nominal exchange rate equation:

$$
\begin{aligned}
e_t = {} & \underset{(1.77)}{0.935}(m_t - m_t^*) - \underset{(3.61)}{5.524}(y_t - y_t^*) - \underset{(5.46)}{0.214}(i_t^s - i_t^{*s}) + \underset{(4.83)}{0.262}(i_t^l - i_t^{*l}) - \underset{(2.52)}{0.477}(s_t - s_t^*) - \underset{(5.52)}{7.822}(prod^T{}_t - \\
& prod_t^{T*}) - \underset{(8.34)}{12.420}(gs_t - gs_t^*) + \underset{(1.25)}{0.205}(roil_t) \qquad (6)
\end{aligned}
$$

(t - statistics in parentheses), LM(8) = 1.2723[0.0529], Jarque Bera test = 63.801[0.000].[7]

The coefficients on monetary fundamentals are all significant and consistent with monetary theory. The coefficient on money supply is not materially different from 1, and is significant based on a one-sided test at the 5% level. All the other variables (relative income and short-term and long-term interest rate differentials) have their hypothesized signs and are significant at the 1% level.

Furthermore, as hypothesized by Frankel (1979), the parameter on the long-term interest rate differential is greater than that on the short-term interest rate differential in absolute value. All the factors that have been used to augment the monetary approach are significant, except for the real oil prices that can be excluded from the long run and, as with Johansen and Juselius (1992), treated as exogenous. The coefficient on the relative real stock prices is negative, implying that the wealth effect dominates the substitution effect in the underlying money demand functions in the United States and Japan, which is consistent with Friedman (1988). The productivity differential across the industrial sector and relative government spending are negative and significant. Thus, a higher domestic productivity or government spending differential results in an exchange rate appreciation. The fact that the real oil prices can be excluded from the long-run part of the VAR system implies that it impacts the long run only indirectly by enhancing the econometric performance of the model.

Model Validation

The above results strongly indicate that the MRID model dominates the RID model on theoretical and econometric grounds in explaining the dollar-yen exchange rate in the long run. However, to check the robustness of our results, we conduct three further checks. First, we use the results on LE and WE to obtain a more specific and robust formulation of the long run based on the MRID model. Having determined that r = 1, the structure of α and β, subject to *roil* being weakly exogenous, is as follows:

$$\begin{array}{cccccccccc} & e & \nabla m & \nabla y & \nabla i^{s} & \nabla i^{l} & \nabla s & \nabla gs & \nabla prod^{T} & roil \\ \alpha' = & [\alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & \alpha_6 & \alpha_7 & \alpha_8 & 0\ ] \end{array},$$

where ∇ represents the differential between the home and overseas variables. The cointegrating vector is normalized on the exchange rate by imposing the restriction (β_1 = -1) and from the long-run exclusion test (β_9 = 0):

$$\begin{array}{ccccccccc} e & \nabla m & \nabla y & \nabla i^{s} & \nabla i^{l} & \nabla s & \nabla gs & \nabla prod^{T} & roil. \\ [-1 & \beta_2 & \beta_3 & \beta_4 & \beta_5 & \beta_6 & \beta_7 & \beta_8 & 0] \end{array}.$$

Next, we sequentially impose zero restrictions on the loading factors, α of the standard monetary fundamentals related to money supply, relative income, and short-term interest rate differentials because given the size of the adjustment coefficients, these weak exogeneity restrictions are empirically plausible and consistent with monetary theory. The tests displayed in Table 5 indicate that the imposed restrictions are strongly accepted; the constrained final long-run relation normalized on the exchange rate indicates the significance of these variables with their hypothesized signs. Further, the trace test implies that there is still a single cointegrating vector r = 1. This indicates the robustness of our results in terms of the long-run formulation and direct impact of the augmenting factors on the long-run exchange rate monetary model.

Then, we subject our proposed MRID model to an array of forward and backward recursive stability tests proposed by Hansen and Johansen (1999) to gain further insight into the adequacy of the

Table 5. Joint tests of weak exogeneity and long-run exclusion conditional on r =1

Tests under the null:	Statistics [p-value]
(1) $\beta_9 = 0$	$\chi^2(1) = 0.845$ [0.358]
(2) $\beta_9 = 0, \alpha_4 = 0$	$\chi^2(2) = 0.856$ [0.652]
(3) $\beta_9 = 0, \alpha_4 = 0, \alpha_2 = 0$	$\chi^2(3) = 1.690$ [0.639]
(4) $\beta_9 = 0, \alpha_4 = 0, \alpha_2 = 0, \alpha_3 = 0$	$\chi^2(4) = 2.010$ [0.734]

The implied long-run relation by test (4):

Variables	$(m - m^*)$	$(y - y^*)$	$(i^s - i^{s*})$	$(i^l - i^{l*})$	$(s - s^*)$	$(prod^T - prod^{T*})$	$(gs - gs^*)$
Coefficients	0.740	- 4.028	-0.169	0.172	- 0.557	- 6.748	-11.231
t-statistics	-1.743[b]	3.363[a]	5.758[a]	4.529[a]	3.669[a]	5.743[a]	9.095[a]

Notes: [a] and [b] indicate statistical significance at 1% and 5% levels, respectively.

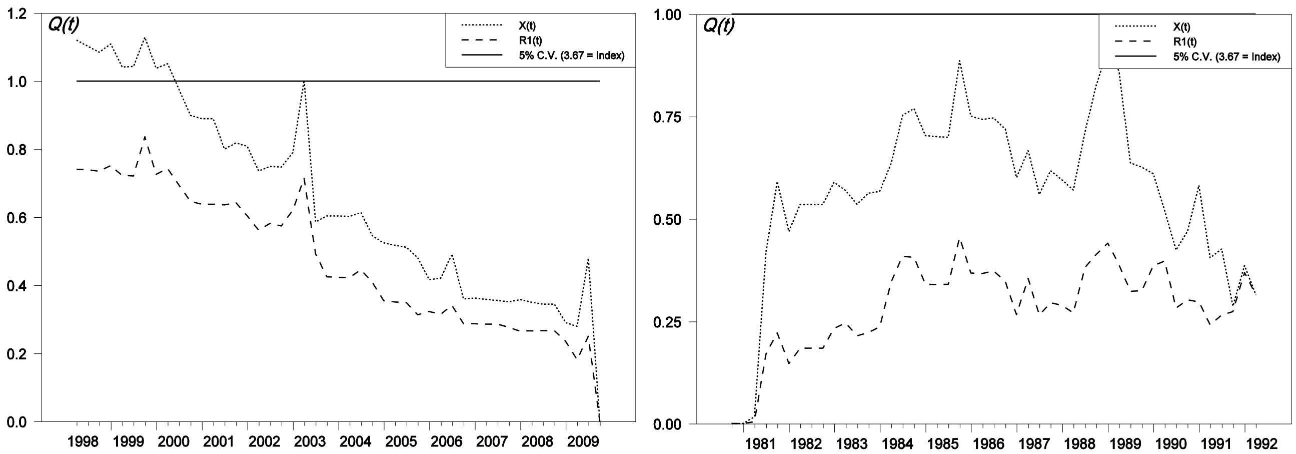

Figure 2. Recursively calculated test for the constancy of β in MRID model (1.0 corresponds to 5% critical value)

estimated model. The test reported here relates to the behaviour of the max tests of β and is displayed in Figure 2. The forward and backward tests appear in the figure's left and right panels, respectively, with the corresponding 5% critical value represented by the solid line. Broadly speaking, the model shows a reasonable degree of stability of the parameters in the cointegrating vector. Hence, the model seems to be adequate and does not exhibit structural breaks in relation to the long run for the period under observation.

Thereafter, to confirm that the failure of the monetary approach is due to the breakdown of its underlying building blocks, we have considered the performance of the standard flexible-price monetary model (Bilson, 1978) against its modified version. The results show that there is no cointegration among the variables of the standard flexible-price monetary model, additionally indicating its contrast to the modified model (MRID) by its inadequacy in explaining exchange rate determination.

5. Conclusion

In this article, we analyse two versions of the monetary model, RID and MRID, to explain the dollar–yen exchange rate using quarterly data from 1980 to 2009. The period is characterized by high international capital mobility as well as periodic volatility in exchange rates. To distinguish between the models, we employ the Johansen methodology to test for cointegration, long-run exclusion, and weak exogeneity. We find a single cointegrating vector for both models, but the method confirms that the RID model does not appear to give an appropriate long-run explanation of the dollar–yen exchange rate.

The failure is attributed to instability in the money demand equation, deriving from the exclusion of key variables that impact transactions (Friedman, 1988). A key feature of globalized financial markets is a highly active market in cross-border investment, merger and acquisitions, and cross-listed stocks; the futures contract on the Nikkei is listed as an asset in the US stock market. The second component relates to the failure of PPP due to the impact of non-traded goods, reflecting the relatively insular nature of Japanese society that may limit the effectiveness of arbitrage.

The MRID model performs significantly better, with the stock prices appearing in the long-run money demand relation and the impact of non-traded goods being captured by incorporating the productivity and government expenditure differentials. Real oil prices have been suggested in literature, but the empirical findings show an indirect impact via the dynamic specifications of the VAR. This compares well with Juselius and MacDonald (2004), who suggest that the dollar–yen exchange rate is driven by speculation in capital markets rather than goods price differentials.

Our empirical findings show that the dollar–yen exchange rate relies on n - 1 common stochastic trends. Shocks to the exchange rate, productivity differentials, relative real stock prices, and government expenditure interact to drive the long run. Thus, the exchange rate interacts with the residual behaviour of the stock market, productivity, and government expenditure. Interactions also occur with regard to long-run interest rates, but a key finding here relates to the term structure of interest rates with the short-rate apparently driven by the long rate. Our conclusion on weak exogeneity suggests that the dollar–yen exchange rate is driven by money, income, and short-rate differentials, but not vice-versa. This implies a substantial role for real economic and financial market variables in a well-formulated monetary model in determining long-run exchange rates.

References

Ahn, Lian and Yoonbai Kim, "Sources of Exchange Rate Movements in Japan: Is the Exchange Rate a Shock-absorber or a Source of Shock?," *Review of International Economics* 18 (2010): 265–276.

Amano, Robert A. and Simon van Norden, "Oil Prices and the Rise and Fall of the US Real Exchange Rate," *Journal of International Money and Finance* 17 (1998):299–316.

Balassa, Bela, "The Purchasing Power Parity Doctrine: A Reappraisal," *Journal of Political Economy* 99 (1964):1252–1271.

Bilson, John F. O., "The Monetary Approach to the Exchange Rate: Some Empirical Evidence," *IMF Staff Papers* 25 (1978):48–75.

Boswijk, H. Peter, "Testing Identifiability of Cointegrating Vectors," *Journal of Business & Economic Statistics* 14 (1996):153–160.

Burke, Simon P. and John Hunter, *Modelling Non-Stationary Economic Time Series: A Multivariate Approach*, Basingstoke: Palgrave Macmillan (2005).

———, "The Wold Representation, Degree of Non-cointegration, and the Johansen Trace Test," *Quantitative and Qualitative Analysis in Social Sciences* 1 (2007):21–39.

Caporale, Guglielmo Maria and Nikitas Pittis, "Parameter Instability, Superexogeneity, and the Monetary Model of the Exchange Rate," *Review of World Economics* 137 (2001):501–524.

Chinn, Menzie David, "Whither the Yen? Implications of an Intertemporal Model of the Dollar/Yen Rate," *Journal of the Japanese and International Economies* 11 (1997):228–246.

———, “The Usual Suspects? Productivity and Demand Shocks and Asia-Pacific Real Exchange Rates,” *Review of International Economies* 8 (2000):20–43.

Chinn, Menzie David and Michael J. Moore, “Order Flow and the Monetary Model of Exchange Rates: Evidence from a Novel Data Set,” *Journal of Money, Credit and Banking* 43 (2011):1599–1624.

Chortareas, Georgios and George Kapetanios, “The Yen Real Exchange Rate May Be Stationary after All: Evidence from Non-linear Unit-root Tests,” *Oxford Bulletin of Economics and Statistics* 66 (2004):113–131.

Frankel, Jeffrey A., “On the Mark: A Theory of Floating Exchange Rate Based on Real Interest Differentials,” *American Economic Review* 69 (1979):610–622.

Friedman, Milton, “Money and the Stock Market,” *Journal of Political Economy* 96 (1988):221–245.

Frömmel, Michael, Ronald MacDonald, and Lukas Menkhoff, “Markov Switching Regimes in a Monetary Exchange Rate Model,” *Economic Modelling* 22 (2005):485–502.

Gonzalo, Jesus, “Five Alternative Methods of Estimating Long-run Equilibrium Relationships,” *Journal of Econometrics* 60 (1994):203–233.

Gregoriou, Andros, John Hunter, and Feng Wu, “An Empirical Investigation of the Relationship between the Real Economy and Stock Returns for the United States,” *Journal of Policy Modeling* 31 (2009):133–143.

Hansen, Henrik and Soren Johansen, “Some Tests for Parameter Constancy in Cointegrated VAR-Models,” *The Econometrics Journal* 2 (1999):306–333.

Hendry, David F. and Neil R. Ericsson, “An Econometric Analysis of U.K. Money Demand in ‘Monetary Trends in the United States and the United Kingdom’ by Milton Friedman and Anna Schwartz,” *American Economic Review* 81 (1990):8–38.

Hunter, John, “Tests of Cointegrating Exogeneity for PPP and UIP Parity in the United Kingdom,” *Journal of Policy Modeling* 14 (1992):453–63.

Johansen, Soren, “Testing Weak Exogeneity and the Order of Cointegration in UK Money Demand Data,” *Journal of Policy Modeling* 14 (1992):313–334.

———, *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, Oxford: Oxford University Press (1995).

Johansen, Soren and Katarina Juselius, “Testing Structural Hypotheses in a Multivariate Cointegration Analysis of the PPP and UIP for UK,” *Journal of Econometrics* 53 (1992):211–244.

Juselius, Katarina, “Do Purchasing Power Parity and Uncovered Interest Rate Parity Hold in the Long-run? An Example of Likelihood Inference in a Multivariate Time-series Model,” *Journal of Econometrics* 69 (1995):178–210.

Juselius, Katarina and Ronald MacDonald, “International Parity Relationships between the US and Japan,” *Japan and the World Economy* 16 (2004):17–34.

Lastrapes, William D., “Sources of Fluctuations in Real and Nominal Exchange Rates,” *The Review of Economics and Statistics* 74 (1992):530–539.

MacDonald, Ronald and Mark P. Taylor, “The Monetary Model of the Exchange Rate: Long-run Relationships, Short-run Dynamics and How to Beat a Random Walk,” *Journal of International Money and Finance* 13 (1994):276–290.

Mark, Nelson C. and Donggyu Sul, “Nominal Exchange Rates and Monetary Fundamentals: Evidence from a Small Post-Bretton Woods Panel,” *Journal of International Economics* 53 (2001):29–52.

McCornac, Dennis C., ‘‘Money and the Level of Stock Market Prices: Evidence from Japan,’’ *Quarterly Journal of Business & Economics* 30 (1991): 42-51.

Rapach, David E. and Mark E. Wohar, ‘‘Testing the Monetary Model of Exchange Rate Determination: New Evidence from a Century of Data,’’ *Journal of International Economics* 58 (2002): 359–385.

Samuelson, Paul A., ‘‘Theoretical Notes on Trade Problems,’’ *Review of Economics and Statistics* 46(1964):145-154.

Sarno, Lucio and Mark P. Taylor, ‘‘Purchasing Power Parity and the Real Exchange Rate,’’ *IMF Staff Papers* 49 (2002): 65–105.

Schnabl, Gunther, “Purchasing Power Parity and the Yen/Dollar Exchange Rate,’’ *World Economy* 24(2001): 31-50.

Strauss, Jack, “Productivity Differentials, the Relative Price of Non-tradables and Real Exchange Rates,” *Journal of International Money and Finance* 18 (1999): 383-409.

Taylor, Mark P. and David A. Peel, “Nonlinear Adjustment, Long-run Equilibrium and Exchange Rate Fundamentals,’’ *Journal of International Money and Finance* 19 (2000): 33-53.

Appendix A: Derivation of MRID model

Following Friedman (1988), the money demand equations in Frankel's (1979) RID model are modified as follows:

$$\overline{m} - \overline{p} = \alpha_1 \overline{y} - \alpha_2 \bar{i} + \alpha_3 \bar{s} \tag{1a}$$

$$\overline{m}^* - \overline{p}^* = \alpha_1 \overline{y}^* - \alpha_2 \bar{i}^* + \alpha_3 \bar{s}^* \tag{2a}$$

where $\overline{m}$ is the money supply, $\overline{p}$ the price level, $\bar{i}$ the nominal interest rate, $\overline{y}$ the real income, and $\bar{s}$ the real stock price index (the variables except interest rates are in logs). Now, the aggregate price levels are decomposed into the prices of traded p_t^T and non-traded p_t^{NT} goods:

$$p_t = (1-a) p_t^T + a p_t^{NT} = p_t^T + a\,(p_t^{NT} - p_t^T) \tag{3a}$$

$$p_t^* = (1-a) p_t^{*T} + a p_t^{*NT} = p_t^{*T} + a\,(p_t^{*NT} - p_t^{*T}). \tag{4a}$$

The real exchange rate q_t is the nominal exchange rate adjusted for domestic and foreign price levels:

$$q_t = e_t - p_t + p_t^*. \tag{5a}$$

Substituting the aggregate price levels in (5a) with those in (3a) and (4a), the real exchange rate is

$$q_t = (e_t - p_t^T + p_t^{*T}) - a\,[(p_t^{NT} - p_t^T) - (p_t^{*NT} - p_t^{*T})]. \tag{6a}$$

If PPP applies primarily to the traded goods, then the $(e_t - p_t^T + p_t^{*T})$ in (6a) should be zero (see Schnabl, 2001) and the real exchange rate expressed in terms of both the traded and non-traded goods is

$$q_t = -a\,[(p_t^{NT} - p_t^T) - (p_t^{*NT} - p_t^{*T})]. \tag{7a}$$

In a competitive world, the relative price movements of non-traded goods should reflect the unit labour costs in each sector (Strauss, 1999), so that

$$p^{T} = w - prod^{T}, p^{NT} = w - prod^{NT}, p^{*T} = w^{*} - prod^{*T}, p^{*NT} = w^{*} - prod^{*NT} \quad (8a)$$

where w is the wage rate equated across both the traded and non-traded sectors due to internal labour mobility, while $prod^{T}$ and $prod^{NT}$ indicate the productivity in the traded and non-traded sectors. Thus,

$$p_t^{NT} - p_t^{T} = prod^{T} - prod^{NT}, p_t^{*NT} - p_t^{*T} = prod^{*T} - prod^{*NT}. \quad (9a)$$

Substituting (9a) into (7a) results in the following real exchange rate relation:

$$q_t = -\alpha[(prod^{T} - prod^{*T}) - (prod^{NT} - prod^{*NT})]. \quad (10a)$$

To further capture the demand side shocks (see Chinn, 2000) and the terms of trade shocks represented by real oil prices (see Amano and van Norden, 1998), we extend (10a) as follows:

$$q_t = -\alpha[(prod^{T} - prod^{NT}) - (prod^{*T} - prod^{*NT})] + \alpha_2(gs_t - gs_t^{*}) + \alpha_3 roil_t. \quad (11a)$$

where $gs_t(gs_t^{*})$ denotes the domestic (foreign) government consumption as a percentage of GDP and *roil* is the real oil price, deflated by consumer prices. Chinn (1997) explains that the quarterly data of the non-traded sector is limited, and this leads to the assumption that $prod^{NT} = prod^{*NT}$, and so (11a) becomes

$$q_t = -\alpha(prod^{T}{}_t - prod_t^{*T}) + \alpha_2(gs_t - gs_t^{*}) + \alpha_3 roil_t. \quad (12a)$$

We obtain the MRID model by using (12a) along with (1a) and (2a), and this results in the following form:

$$e_t = \beta_1(m_t - m_t^{*}) + \beta_2(y_t - y_t^{*}) + \beta_3(i_t^{s} - i_t^{s*}) + \beta_4(i_t^{l} - i_t^{l*}) + \beta_5(s_t - s_t^{*}) + \beta_6(prod^{T}{}_t - prod_t^{T*})$$
$$+ \beta_7(gs_t - gs_t^{*}) + \beta_8 roil_t + v_t$$

Notes

1. Chinn (1997, 2000) among others suggest that real economic factors affect the persistence of the real yen-dollar exchange rate.

2. Japanese oil consumption and imports in 2010 were respectively 23% and 42.7% of the consumption and imports of the United States (figures obtained online from the Central Intelligence Agency World Factbook, 2011). However, the US is rich in natural resources.

3. As can be seen from their simulations, in the near cointegration case the true DGP is a first order Vector Moving Average model that exhibits considerable size distortion with samples as large as T = 400 observations. It does not go away as the sample evolves.

4. The official discount rate has been for a long time a major policy instrument for the Bank of Japan and other short-term interest rates such as call rate and bills discount rates have moved in line with the official rate.

5. The $/yen exchange rate, interest rates, national income, industrial production and price levels (CPI) are from IMF' *International Financial Statistics (IFS).* Money (M1), oil price, and stock prices are from Thomson DataStream; the oil price prior to 1982 is from the Federal Reserve Bank of St. Louis. To be consistent with the end of period DataStream data, the last month snapshot in each quarter is considered. Government spending and employment figures are obtained from the OECD main economic indicators (MEI) database.

6. Specification tests for the system appear below the results and those for the single equations are available on request from the authors.

7. LM(8) is a Language Multiplier test of serial correlation up to order 8, [p values] in square brackets.

8. Hunter (1992) finds that a number of variables are weakly exogenous, for the two cointegrating vectors, but in any system there are a maximum of n-r variables that satisfy WE. In the final model different restrictions are imposed that suggest a quasi diagonal structure on α and these along with restrictions on β in terms of the exchange rate give rise to cointegrating exogeneity instead.

9. Johansen and Juselius (1992) assume that the real oil price is strictly exogenous. Hunter (1992) shows that this corresponds in the long-run to the oil price being weakly exogenous and long-run excluded, but these restrictions were found to be rejected. Here the p-value of this test is .741.