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

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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

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

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

$$e_t \quad {}_1(m_t \quad m_t^*) \quad {}_2(y_t \quad y_t^*) \quad {}_3(i_t^s \quad i_t^{s*}) \quad {}_4(i_t^l \quad i_t^{l*}) \quad {}_5(s_t \quad s_t^*) \quad {}_6(prod^T{}_t \quad prod_t^{T*})$$
$$\quad {}_7(gs_t \quad gs_t^*) \quad {}_8 roil_t \quad v_t, \qquad (2)$$

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 ${}_5$ 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 (${}_8 \quad 0$ 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 (${}_7 \quad 0$.

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 1) endogenous variables, all integrated of order one (I(1)), forced by a vector of (n 1) independent Gaussian errors, with the following error-correction representation:

$$= \quad + \quad +\ldots\ldots+ \quad + \quad + \quad , \tag{3}$$

where X_t is an (n 1) variables vector; D_t is a vector containing constants, centred seasonal dummies, and impulse dummies; $_i$ (i =1,.....,p-1) are (n n) parameter matrices capturing the short-run dynamics among the variables; and is an n n matrix decomposed as , with matrices and β dimensioned (n 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 1 (at least one cointegrating vector) and subsequent further orders of cointegration r = i against the alternative r 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 ($_i$) and sample size (T) with

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

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]

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]

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).

Table 3. Johansen Cointegration Test Results for MRID Model

System comprises: [$e, m - m^{*}, y - y\ , i^{s} - i^{s*}, i^{l} - i^{l*}, s - s^{*}, gs - gs\ , Prod^{T} - Prod^{T*}, roil$]

($p -$

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

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

$$e \quad m \quad y \quad i^s \quad i^l \quad s \quad gs \quad prod^T roil$$
$$_1 \quad _2 \quad _3 \quad _4 \quad _5 \quad _6 \quad _7 \quad _8 \quad 0 \quad ,$$

where represents the differential between the home and overseas variables. The cointegrating vector is normalized on the exchange rate by imposing the restriction ($_1$ = -1) and from the long-run exclusion test ($_9$ 0):

$$e \quad m \quad y \quad i^s \quad i^l \quad s \quad gs \quad prod^T roil.$$
$$1 \quad _2 \quad _3 \quad _4 \quad _5 \quad _6 \quad _7 \quad _8 \quad 0 \quad .$$

Next, we sequentially impose zero restrictions on the loading factors, of the standard monetary fundamentals related to

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 r121JETBT1 0 0 1 347.11 2239JETr121n, 1 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 hocksandit229.97 374(Dona277 517.-1

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Appendix A: Derivation of MRID model

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

(1a)

(2a)

where $\bar{m}$ is the money supply, $\bar{p}$ the price level, $\bar{i}$ the nominal interest rate, $\bar{y}$ 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:

(3a)

(4a)

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

(5a)

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

(6a)

If PPP applies primarily to the traded goods, then the $(e_t \quad p_t^T \quad p_t^{*T})$ 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

(71 396.43

(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,

(9a)

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

(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:

(11a)

where $gs_t (gs_t^{*})$ denotes the domestic (foreign) government consumption as a percentage of GDP and *roil*

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 and these along with restrictions on 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