COINTEGRATION IN A MONETARY MODEL OF EXCHANGE RATE DETERMINATION

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ABSTRACT:
The monetary model of exchange rate determination is a useful theoretical tool for understanding fluctuations in exchange rates over time. The model postulates the existence of a strong link between nominal exchange rates and a set of macroeconomic fundamentals. In the short-run, the relatively stable fundamentals are inconsistent with the extreme volatility of exchange rates observed in earlier studies, which leads us to postulate that the relationship only exist in the long run. Past empirical studies have not generated sufficient and consistent evidence so as to verify the long run relationship between the exchange rates and macroeconomic fundamentals. In this paper, we investigate the validity of the monetary model of exchange rate determination by applying multivariate time series methodology to test the long run relationship implied by the monetary model.

In this study, we use quarterly data for Germany, Japan, the United States, and the United Kingdom, for the 1973 to 1999 period. We apply the Johansen's cointegretion methodology to test whether there exists a long run relationship between the exchange rate and certain macro economic variables. When the U.S. is excluded, the test results lend strong support for the monetary model of exchange rate determination. If the U.S. is included in the econometric tests, the support for the monetary model tends to be more tenuous. One possible explanation is that since the dollar is the premier world currency, the global demand for it exceeds its domestic demand, compared to other currencies. Hence, the empirical tests of the monetary model may tend to overestimate the demand for U.S. dollars, which may have been responsible for the failure of certain previous tests of the model.

INTRODUCTION

The monetary model of exchange rate determination is a useful theoretical tool for understanding fluctuations in exchange rates over time. This model suggests the existence of a strong link between nominal exchange rates and a set of macroeconomic fundamentals; namely, the real income, the money supply, the interest rate, and the inflation rate. The monetary model implies that the price level of a country is determined by its money supply and money demand. The price level in different countries should be the same when expressed in the same currency, which makes the model theoretically attractive for understanding exchange rate fluctuations over time and which provides a long run benchmark for the nominal exchange rate between two currencies.

After the collapse of the Bretton Woods monetary system in 1973, the exchange rates of industrialized nations were allowed to float freely. In response to this new institutional environment, the monetary approach to exchange rate determination was developed, refined, and empirically tested in the early and mid-1970s. The volatility of foreign exchange markets in the 1980s focused greater interest on exchange rate theory in general, and on the monetary approach in particular. However, attempts to replicate previous empirical results with the new, more volatile data were unsuccessful. Moreover, the forecasting performance of the monetary model was shown to be no better, and sometimes even worse, than the predictions obtained by assuming that the spot exchange rate follows a random walk.

THE MONETARY MODEL OF EXCHANGE RATE DETERMINATION

The monetary model asserts that exchange rates are merely the relative prices of assets, determined in organized markets where prices can adjust instantaneously. Four assumptions are the cornerstone of the monetary models of exchange rate determination: perfect capital mobility, perfect substitution among bonds, purchasing power parity (PPP) and the uncovered interest parity (UIP), which can be used to define the equilibrium conditions.

Two versions of the monetary model are investigated in this section, namely the "flexible price" monetary model and the "sticky price" monetary model.

One important assumption of the monetary model is that purchasing power parity holds continuously over time

$$s_t = p_t - p^*_t + c \qquad (1)$$

where c is a constant, s_t is the logarithm of the exchange rate expressed in units of home currency per foreign currency unit, and p_t and p^*_t are the domestic and foreign price levels, respectively. If $c = 0$, Equation (1) implies an absolute PPP, and if $c \neq 0$, Equation (1) implies that relative PPP holds.

Secondly, a basic tenet of the monetary model of exchange rates is that higher domestic interest rates relative to a foreign country are associated with the appreciation of the domestic currency, a phenomenon known as the uncovered interest parity (UIP). The uncovered interest parity can be expressed as:

$$E(\dot{s}_t) = E(s_{t+1}) - s_t = i_t - i^*_t \qquad (2)$$

The third cornerstone of the monetary model assumes a stable monetary demand function in the domestic and foreign countries. The money market equilibrium condition in both domestic and foreign countries is assumed to depend on the logarithm of real income (y), the logarithm of the price level (p), and the nominal interest rate (i). An identical relationship can be assumed for the foreign country, where foreign variables are denoted by asterisk. The monetary equilibriums in both domestic and foreign countries can be expressed as:

$$m_t = p_t + \beta_2 y_t - \beta_3 i_t \qquad (3)$$

$$m^*_t = p^*_t + \beta^*_2 y^*_t - \beta^*_3 i^*_t \qquad (4)$$

where m_t and m^*_t denote the domestic and foreign money demand, and are assumed to be equal to the money supply; β_2 and β^*_2 are the income elasticity of demand for money, and β_3 and β^*_3 are the interest rate semi-elasticity for the domestic and foreign countries, respectively. Rearranging equation (3) and (4) to solve for the domestic and foreign price levels and substituting into equation (1) yields the flexible price monetary model of the exchange rate:

$$s_t = \beta_1 m_t - \beta^*_1 m^*_t - \beta_2 y_t + \beta^*_2 y^*_t + \beta_3 i_t - \beta^*_3 i^*_t + c + \varepsilon_t \qquad (5)$$

where βs are parameters and c is an arbitrary constant and ε_t is a disturbance term.

In equation (5) the nominal interest rate consists of two components; namely, the real interest rate and the expected inflation rate, that is:

$$i_t = r_t + \pi^e_t \quad (6)$$
$$i^*_t = r^*_t + \pi^{e*}_t \quad (7)$$

where r_t and r^*_t are the domestic and foreign real interest rate and π^e_t and π^{e*}_t are the expected rates of domestic and foreign inflation, respectively. Assuming that real interest rates are equalized in the two countries (it is a common assumption, although real interest rates may in fact differ between the countries). We can write:

$$i_t - i^*_t = \pi^e_t - \pi^{e*}_t \quad (8)$$

Thus, equation (5) can be rewritten as:

$$s_t = (\beta_1 m_t - \beta^*_1 m^*_t) - (\beta_2 y_t - \beta^*_2 y^*_t) + (\beta_3 \pi^e_t - \beta^*_3 \pi^{e*}_t) + c + \varepsilon_t \quad (9)$$

Equation (9) represents the flexible price monetary model. From equation (9), we can see that if one holds the fundamental variables constant, an increase in the domestic money supply will increase the domestic price level. It also calls for an increase of s_t to achieve equilibrium, the domestic currency must depreciate if purchasing power parity is to hold continuously. The same analysis also applies to the foreign country, so that an increase in foreign money supply can lead to the appreciation of the domestic currency.

In the flexible price monetary model, a rise in domestic real income can create an excess demand for the domestic currency. Agents will then decrease their expenditures on goods or services in order to increase their real money balances, thus resulting in a fall in the price level. Then through the purchasing power parity, an appreciation of the domestic currency will restore equilibrium. On the other hand, a decline of domestic real income will trigger the opposite equilibrium process.

Moreover, an increase in the expected long run domestic inflation will cause agents to switch from domestic currency to both domestic and foreign bonds. As a result the demand for domestic currency decreases, causing a depreciation of the domestic currency, which means an increase in s_t. The same is true for the foreign country.

The sticky price monetary model (overshooting model) of exchange rate determination incorporates a short run interest rate to capture the liquidity effect. It assumes that the expected rate of the exchange rate depreciation is a positive function of the gap between the current exchange rate and the long run equilibrium rate, and the expected long run inflation differential between the domestic and foreign countries. This can be expressed in the following equation:

$$E(\dot{s}_t) = -\lambda(s_t - \bar{s}_t) + \pi^e_t - \pi^{e*}_t \quad (10)$$

where λ is the speed of adjustment of the exchange rate towards its equilibrium. This equation states that the current exchange rate is expected to return to its long run equilibrium at the rate of λ. In the long run, $s_t = \bar{s}_t$, and the expected rate of depreciation of the currency will be equal to the difference between the domestic and foreign inflation rates. Combining the uncovered interest parity (equation 2) with equation (10) above results in

$$s_t - \bar{s}_t = -\frac{1}{l}[(i_t - \pi^e_t) - (i^*_t - \pi^{e*}_t)] \quad (11)$$

Equation (11) denotes that the gap between the current exchange rate and its long run equilibrium exchange rate is proportional to the real interest differential between the two countries. If the foreign real interest rate is higher than the domestic real interest rate, there will be capital reallocation from domestic bonds to foreign bonds, until the real interest rates are equalized.

In the long run, the interest rate differential must equal to the long run expected inflation differential,

$$\bar{i}_t - \bar{i}^*_t = \pi^e_t - \pi^{e*}_t \quad (12)$$

Hence equation (11) can be rewritten as:

$$s_t - \bar{s}_t = -\frac{1}{l}[(i_t - \bar{i}_t) - (i^*_t - \bar{i}^*_t)] \quad (13)$$

In the long run, purchasing power parity can be written as follows:

$$\bar{s}_t = \bar{p}_t - \bar{p}^*_t + c \quad (14)$$

Following the previous steps, yields the following expression:

$$\bar{s}_t = (b_1\bar{m}_t - b^*_1\bar{m}^*_t) - (b_2\bar{y}_t - b^*_t\bar{y}^*_t) + (b_3 p^e_t - b^*_t p^{e*}_t) + c + \varepsilon_t \quad (15)$$

Combining equation (13) and (15), the short run sticky price model of Dornbusch (1976) yields the following expression:

$$s_t = (b_1\bar{m}_t - b^*_1\bar{m}^*_t) - (b_2\bar{y}_t - b^*_t\bar{y}^*_t) + (b_3 p^e_t - b^*_t p^{e*}_t) - \frac{1}{l}[(i_t - \bar{i}_t) - (i^*_t - \bar{i}^*_t)] + c + \varepsilon_t \quad (16)$$

Which can be rearranged as follows:

$$s_t = (b_1\bar{m}_t - b^*_1\bar{m}^*_t) - (b_2\bar{y}_t - b^*_t\bar{y}^*_t) + (b'_3 p^e_t - b'^*_3 p^{e*}_t) - (b_4 i_t - b^*_4 i^*_t) + c + \varepsilon_t \quad (17)$$

where $\beta'_3 = \beta_3 - \frac{1}{l}$, $\beta^{*\prime}_3 = \beta^*_3 - \frac{1}{l}$, $\beta_4 = \frac{1}{l}$, $\beta^*_4 = \frac{1}{l}$.

Obviously, the flexible price model is nested within the sticky price model. β_1, β_2 and β_3 are the same as in the flexible price model. β_4 is negative, which implies that an increase in the domestic interest rate leads to a capital inflow, which increases the demand for the domestic currency, and in turn leads to its appreciation.

The sticky price model is appealing not only because it relaxes the flexible price model's uncomfortable assumptions, but also because it can amplify the effect of changes in fundamentals, referred to as exchange rate overshooting. The appeal of the overshooting model is that it squares with empirical findings that exchange rates are excessively volatile when compared with the volatility of fundamentals as specified in the flexible price model.

REVIEW OF THE LITERATURES

Frenkel (1976), Bilson (1978) presented empirical evidence that reflects favorably on the monetary model. Their assessment was based on the multiple correlation coefficients and the comparison of estimated coefficients with the expected signs as predicted from their theoretical models.

In one of the most influential papers, Meese and Rogoff (1983a,b), compared the out of sample forecasting accuracy of various structural and time series exchange rate models. They found that a random walk model performs as well as any estimated model for one to twelve month horizons of the dollar/pound, dollar/mark, dollar/yen and the trade-weighted dollar exchange rate. The candidate structural models included the flexible price model, the sticky price monetary model, and the sticky price model that incorporates the current account. A possible reason for the poor performance of these monetary models may be a partial deviation from uncovered interest parity condition, which means that a risk premium may be an important determinant of the exchange rate. Another reason could be an incorrect specification of the demand for money in either of the two countries, their dynamics, and the restrictions imposed by assuming identical parameters in both money demand functions. On the other hand, Meese and Rogoff concluded that when one looks at forecast horizons longer than one year, the performance of monetary exchange rate model does appear to improve. They found that the root mean squared forecast errors for the random walk model were no longer consistently the lowest, when one considers two- to three-year forecast horizons.

Certain other studies found little evidence of cointegratiom among nominal exchange rates and monetary fundamentals during the post-Bretton Woods float. For example, consider the papers by Meese (1986), Baillie and Selover (1987), McNown and Wallace (1989), Baillie and Pecchenino (1991). The lack of empirical evidence for a stable long run relationship between exchange rates and monetary fundamentals renders the monetary model, arguably as a plausible theoretical model but one with little practical relevance.

The monetary model did not escape the Meese and Rogoff trap that seemingly ensnared all models of exchange rate determination. While considerable work was done on both the theoretical models and on empirical testing of certain propositions about exchange rate determination, little success was attained until Mark (1995) restored the hope for the monetary model.

Mark (1995) found that the superiority of the monetary models for long horizons might actually be statistically significant. Mark showed that deviations from a simple set of monetary fundamentals—relative money supplies and relative output levels, can be useful in predicting U.S. dollar exchange rates for longer horizons, over the 1981-1991 period. On the other hand, Killian (1997) has argued that Mark's asymptotic tests were biased in favor of predictability. Using a boot-strap method on Mark's data set, Killian found little statistically significant evidence that monetary fundamentals help improve long-horizon predictability. Berkowitz and Giorganni (1997) subsequently argued that by imposing the a priori assumption that nominal exchange rates and monetary variables are cointegrated, Mark's approach may be overstating the statistical significance of his results.

Further research on the monetary model of exchange rate determination was done in the late 1990s and found some evidences in support of the monetary model. Diamandis, et al, (1996) examined the exchange-rate determination of the Canadian-U.S. dollar exchange rate over the floating exchange rate period and he demonstrated through the use of multivariate cointegration methodology that an unrestricted monetary model provides a valid explanation of the long run nominal Canadian-U.S. dollar exchange rate. This suggests that the monetary model, interpreted carefully, might still be usefully applied. In his review paper, MacDonald (1999) concluded that there exist sufficient evidence to support the view that exchange rates are predictable at horizons as short as one month forward, and he concluded that both short and long run exchange rate modeling is alive and well.

Diamandis, Georgoutsos, Kouretas (2000) examined the long run properties of the monetary exchange rate model by using data on the drachma/dollar and drachma/mark exchange rates based on the hypothesis that the system contains variables that are integrated of order 2 (I(2)). Their analysis resulted in the rejection of the forward-looking version of the monetary model for the drachma/dollar case but not for the drachma/mark case. Finally, they showed that the monetary model outperforms the random walk model in an out-of-sample forecasting contest. Francis, Hasan, and Lothian (2001) used Canadian-US dollar data to find out whether recent positive findings with regard to purchasing power parity carry over to the monetary approach to exchange rate determination. By using Johansen's cointegration technique, their research provided support for the long run monetary model of the exchange rate. They noted that previous studies that use the cointegration approach with single equation methodology as proposed by Engle and Granger (1987) are inefficient because this method fails to fully capture the dynamics of the data and that the substantial depreciation in real U.S. dollar exchange rates in the mid 1980s offset an earlier appreciation, which is fully reflected in their variable set. On the other hand, Groen (2000) did not find evidence of cointegration in the monetary exchange rate model for a large number of OECD countries. In addition, Groen (2000) found that the use of cross-section regressions for a large number of countries, or tests of cointegration within a fixed individual effect multi-country panel data model, offers empirical evidence in favor of the monetary exchange rate model. Mark and Sul (2001) tested for cointegration based on the monetary model and for exchange rate predictability in a panel of bilateral exchange rates for 17 OECD countries over the 1973-1997 period. Their results indicated that there exist cointegration based on the monetary model and that monetary fundamentals significantly predict future exchange rates when using panel regression estimates with fixed time effects. Rapach and Wohar (2001) tested the long run monetary model of exchange rate determination for 14 industrialized countries using data spanning from the late nineteenth and early twentieth century to the late twentieth century. They found support for a simple form of the long run monetary model in over half of the countries analyzed. They speculated that the failure of the long run monetary model for some countries using long span data must be due to instability of the long run relationship between relative price levels and monetary fundamentals for those countries.

Overall, the cointegration methods have been widely used in testing the monetary model of exchange rate determination. However, the model still contains certain uncomfortable assumptions of the monetary model and a poor use of cointegration in some of the more recent studies.

First, the general form of the sticky price model can be expressed in Equation (17), and rewritten as follows:

$$s_t = (b_1\overline{m}_t - b_1^*\overline{m}_t^*) - (b_2\overline{y}_t - b_t^*\overline{y}_t^*) + (b'_3 p_t^e - b'^*_3 p_t^{e*}) - (b_4 i_t - b_4^* i_t^*) + c + \varepsilon_t$$

Equation (17) is referred to as the unrestricted monetary model and is directly derived from the model. However, most studies have tested the restricted version of the model as follows;

$$s_t = \beta 1(mt - m^*_t) - \beta_2 (y_t - y^*_t) + \beta_3(\pi^e_t - \pi^{e*}_t) + \beta_4(i_t - i^*_t) + \varepsilon_t \qquad (18)$$

The restricted version of the model implies that both domestic and foreign countries are subject to the same conventional money demand functions. The income elasticity of demand for money and the interest rate semi-elasticity are the same both for the domestic and foreign countries ($\beta_2 = \beta^*_2$, $\beta_3 = \beta^*_3$), which may be a very strong assumption. Considering the different economic, social, and financial structural arrangements in different countries and also considering the different preferences for holding money by people in different cultures, the assumptions of the restricted model are unlikely to hold. Also, the restricted monetary model implies that $c = 0$, which corresponds to the absolute version of purchasing power parity. Absolute purchasing power parity is a strong form of the PPP. While most of the recent studies suggest a the weak version of the purchasing power parity (relative PPP) holds in the long run, this does not necessarily imply that absolute PPP will also hold. Hence, some of the assumptions of the restricted monetary model are not very sound and they can cause problems in the empirical analysis.

Second, although there exist some promising evidences of applying cointegration techniques to forecast exchange rates, the way cointegration analysis was applied in the past, and given the application of the Johansen approach in particular, may in some cases be poor. The exchange rate and the fundamental variables should be cointegrated if one or some of these variables are stationary. That is, if we find through an empirical test the existence of a cointegraing vector, and one stationary variable in the model, it lends support for the existence of a long run relationship between the variables, even if none exists. Indeed, the rank of cointegration not only depends on whether there exists a long run relationship between the variables, but also on whether the variables included are stationary. Hence, it is essential to check the variables for stationarity when estimating the cointegration relationship.

Another relevant point is that the test results may differ depending on which currency is used as the base currency. Especially, when the US dollar is used as the base currency, empirical tests tend to reject the PPP relationship. Papell and Theodoridis (1998) concluded that the evidence on PPP is uniformly stronger when the mark is used as the base currency rather than the dollar. One wonders whether this base currency bias can also be present when testing the monetary model in this study.

COINTEGRATION METHODOLOGY

The cointegration technique allows for the estimation of a long run equilibrium relationship. Simply put, one can argue that various non-stationary time series are cointegrated when their linear combinations are stationary. Stationary deviations from the long run relationship are allowed in the short run. The cointegration technique was pioneered by Engle and Granger (1987), and extended by Johansen (1988) and Johansen and Juselius (1990).

For Johansen's procedure, the process X_t, a vector of order p can be defined as

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + e_t, \quad t=1,2,\ldots \qquad (19)$$

where X_t is integrated of order 1, such that $?X_t$ is stationary; e_t is an i.i.d. p-dimensional Gaussian random variables with mean zero and variance ?. We can then define:

$$\Pi = I - \Pi_1 - \ldots - \Pi_k \qquad (20)$$

which has rank r < p. We express it as

$$\Pi = a b' \qquad (21)$$

for suitable $p \times r$ matrices a and ß . We assume that, although $?X_t$ is stationary and X_t is non-stationary as a vector process, the linear combinations given by ß 'X_t are stationary. This means that the vector process X_t is cointegrated with cointegration vector ß . The space spanned by ß is the space spanned by the rows of the matrix Π, which is known as the cointegration space.

We next want to estimate the space spanned by ß, from observations X_t. For any $r \leq p$ we formulate the model as the hypothesis;

$$H_0: \text{rank}(\Pi) \leq r \text{ or } \quad \Pi = a b' \qquad (22)$$

where a and ß are $p \times r$ matrices. The parameters a and ß cannot be uniquely identified since they amount to an over-parameterization of the model, however we can estimate the space spanned by ß .

We rewrite equation (19) as

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Gamma_k X_{t-k} + e_t, \qquad (23)$$

where

$$\Gamma_1 = -I + \Pi_1 + \ldots + \Pi_i, \qquad i = 1,..,k \qquad (24)$$

then $\Pi = -\Gamma$.

We first regress $?X_t$ on the lagged differences given the residual R_{0t} and then regress X_{t-k} on the lagged differences given by the residuals R_{kt}. The likelihood function then becomes proportional to

$$L(a, b, \Lambda)$$

$$= |\Lambda|^{-T/2} \exp\left\{-\frac{1}{2}\sum_{t=1}^{T}\left(R_{0t} + a b' R_{kt}\right)' \Lambda^{-1}\left(R_{0t} + a b' R_{kt}\right)\right\} \qquad (25)$$

For fixed ß we can maximize over a and ? by the regression of R_{0t} on – ß'R_{kt}. The result are:

$$\hat{a}(b) = -\, S_{0k} b\, (b' S_{kk} b)^{-1} \qquad (26)$$

and

$$\hat{\Lambda}(b) = S_{00} - S_{0k} b\, (b' S_{kk} b)^{-1}\, b' S_{k0} \qquad (27)$$

where $$S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R_{jt}^{'}, \quad i, j = 0, k. \qquad (28)$$

The likelihood profile now becomes proportional to

$$|\hat{\Lambda}(b)|^{-T/2},$$

it now remains to solve the minimization problem

$$\min| S_{00} - S_{0k} b\,(b' S_{kk} b)^{-1}\, b' S_{k0} |, \tag{29}$$

where the minimization is over all p×r matrices ß . Equation (29) is equivalent to

$$\min| b' S_{kk} b - b' S_{k0}\, S_{00}^{-1}\, S_{0k} b\, |/|\, b' S_{kk}\, b\, | \tag{30}$$

with respect to the matrix b .

Let D denote the diagonal matrix of ordered eigenvalues $\hat{l}_1 > \ldots > \hat{l}_p$ and of $S_{k0}\, S_{00}^{-1}\, S_{0k}$ with respect to S_{kk} as the solution to

$$| l S_{kk} - S_{k0}\, S_{00}^{-1}\, S_{0k} | = 0, \tag{31}$$

where E is the matrix of the corresponding eigenvectors so that,

$$S_{kk} ED = S_{k0}\, S_{00}^{-1}\, S_{0k}\, \mathrm{E} \tag{32}$$

where E is normalized so that $E' S_{kk} E = I$. Choosing $b = Ex$ where x is p×r, we can minimize

$$| x'x - x' Dx | / | x'x | \tag{33}$$

This can be accomplished by choosing x to be the first r unit vectors or by choosing $\hat{b}$ to be the first r eigenvectors of $S_{k0}\, S_{00}^{-1}\, S_{0k}$ with respect to S_{kk} , the first r columns of E. These are called the canonical variates and the eigenvalues are the squared canonical correlations of R_k with respect to R_0. All possible choices of an optimal b can be found from $\hat{b}$ by $b = \hat{b}\,\rho$, where ρ is an r×r full rank matrix. The eigenvectors are normalized by the condition $\hat{b}' S_{kk} \hat{b} = I$ so that the estimates of the other parameters are given by

$$\hat{a} = -S_{0k} \hat{b} (\hat{b}' S_{kk} \hat{b})^{-1} = -S_{0k} \hat{b}\ , \tag{34}$$

which clearly depends on the choice of an optimizing b , whereas

$$\hat{\Pi} = -S_{0k} \hat{b} \hat{b}' \tag{35}$$

and

$$\hat{\Lambda} = S_{00} - S_{0k} \hat{b} \hat{b}' S_{k0} = S_{00} - \hat{a}\, \hat{a}' \tag{36}$$

and the maximized likelihood is given by

$$L_{\max}^{-2/T} = | S_{00} | \prod_{i=1}^{r} (1 - \hat{l}_i) \tag{37}$$

which does not depend on the choice of an optimizing b .

It is possible to find estimates of Π and Λ without the constraint (22), which follow equations (26) and (27) for r = p and b = I. The following represents the maximized likelihood function without the constraint (22);

$$L_{\max}^{-2/T} = | S_{00} | \prod_{i=1}^{p} (1 - \hat{l}_i) \tag{38}$$

Finally, a likelihood ratio test that there are at most r cointegrating vectors is given as;

$$\mathrm{LR}_{tr}(r|p) = -T \sum_{i=r+1}^{p} \ln(1 - l_i) \tag{39}$$

where $\hat{l}_{r+1},..., \hat{l}_p$ are the p-r smallest squared canonical correlations. The test statistic in equation (39) is call a trace statistic, and the r in the trace statistic is the number of roots above which the remaining roots are significant.

Another statistic is the maximal eigenvalue statistic which tests the null hypothesis of r cointegrating relations against the alternative of r + 1 cointegrating relations, which is

$$LR_{max}(r|r+1) = -T\ln(1-l_{r+1}) = LR_{tr}(r|p) - LR_{tr}(r+1|p) \quad (40)$$

For r = 0, 1, .., k-1. The r and r + 1, in the maximal eigenvalue statistic refer to alternative number of roots being tested for. Thus, we test whether r + 1 cointegrating relations can be rejected in favor of roots.

Both the trace test statistic and the maximal eigenvalue test statistic follow an abnormal distribution (Johansen, 1988, 1991).

DATA

The countries included in the cointegration tests are Japan, Germany, the United Kingdom, and the United States. The data are quarterly, seasonally unadjusted data from the International Monetary Fund (IMF)'s *International financial statistics*. The test period for Japan and the United Kingdom is from the first quarter of 1973 to the last quarter of 1999, thereby giving 108 observations. While the data for Germany range from the first quarter of 1973 to the last quarter of 1996, giving 98 observations. The variables included in the study are:

s_t: End of period exchange rate in terms of units of foreign currency per US dollar.

y_t: Real gross domestic product (GDP) or real gross national product (GNP) whichever is available.

i_t: Short term interest rate (end of period federal funds rate for the US and end of period discount rates for Japan, Germany and the United Kingdom).

m_t: M1 or M2 for all countries.

p_t^e: Expected inflation rate, calculated from consumer price index (CPI).

First, we test whether the monetary model holds when the US dollar is selected as the base currency. We subsequently test whether we get different results when testing the monetary model for the other three currency pairs, namely mark/pound, yen/mark, and yen/pound.

EMPIRICAL RESULTS

Recall, that the general form of the monetary model of exchange rate determination can be rewritten as follows:

$$s_t = (b_1 m_t - b_1^* m_t^*) - (b_2 y_t - b_t^* y_t^*) + (b'_3 p_t^e - b'^*_3 p_t^{e*}) - (b_4 i_t - b_4^* i_t^*) + c + \varepsilon_t.$$

In testing the monetary model of exchange rates we inquire whether there exists a long run relationship between the nominal exchange rate and the fundamentals, namely, real income, the money supply, the interest rates, and the expected inflation rate in both the domestic and foreign countries, which is equivalent to testing whether there exists cointegration relationship among the variables in the vector (s_t, m_t, m^*_t, y_t, y^*_t, i_t, i^*_t, p_t^e, p_t^{e*}). However, the pre-requirement of the cointegration test is that all the individual variables must be I(1). The unit root test suggests all the variables except the p_t^e, p_t^{e*} follow the I(1) process. Given a stationary process, we cannot include p_t^e, p_t^{e*} in the testing vector. Intuitively it means that the stationary process will always return to a constant mean and can be treated as a constant in the long run. Including a stationary process in the cointegration test can result in a misleading conclusion, which implies a long relationship is invalid. So we deleted both p_t^e, p_t^{e*} from the cointegration test. The monetary model then takes the following form:

$$s_t = (b_1 m_t - b_1^* m_t^*) - (b_2 y_t - b_t^* y_t^*) - (b_3 i_t - b_3^* i_t^*) + c + \varepsilon_t \qquad (41)$$

Therefore, the vector that can be tested for cointegration is (s_t, m_t, m^*_t, y_t, y^*_t, i_t, i^*_t).

Before conducting the cointegration test, we need to determine the lag length, which is the parameter k in equation (23). Certain information criteria were chosen to determine the lag length. When the US dollar is used as the base currency, the lag length in the German and United Kingdom models are chosen as one under the information criteria, while lag length two is chosen in the Japanese case.

In the cointegration test, the following null hypothesis is chosen instead of the null hypothesis in (22)

$$H_0: \ \Pi y_{t-1} = a(b' y_{t-1} + r) + d \qquad (42)$$

Where a and ß are $p \times r$ matrices. r is the number of cointegrating relations which are conditional on the assumptions made about the trend.

The reason for choosing hypothesis (42) is:

1. As explained before, the cointegrating relationships should include a constant term.
2. From the data, we can clearly make out an upward linear trend or a downward trend for almost all the variables.

We can test hypothesis (42) using the same theory and we can also use the same test statistics. The difference is that the test statistics follow different distributions (Johansen, 1991).

When the US dollar is used as base currency, for all the three cases, the trace tests indicate that there exist cointegration relations between the nominal exchange rate and the fundamentals. The rank r in the case of Germany is 2; for Japan, it is 3 and for the United Kingdom, it is 2. All the above results are significant at 0.05. However, the maximal eigenvalue tests do not show any cointegrations for Germany and United Kingdom, and suggest r = 1 for Japan at 0.05 significant level.

We therefore cannot determine that a cointegrating relationship exists in both the German and the United Kingdom cases. In Japan's case, suppose that the cointegration is of rank one, this means that the β space is one dimensional, which is the only case in which we can identify such a cointegrating relationship:

$$s_t = -1.6284 m_t - 0.1823 m_t^* + 0.6968 y_t + 1.2553 y_t^* + 0.0659 i_t - 0.009185 i_t^* + c + \varepsilon_t$$

(0.9553) (0.1716) (0.9874) (0.4479) (0.0225) (0.0161)

Given the above results, a simple t-test suggests that β^*_1, β_2 and β^*_3 are insignificant. The significant parameters, β_1 and β_3 have the wrong sign and only the sign of β^*_4 is as expected.

Generally speaking, our results are mixed and do not provide convincing evidence in support of the monetary model of exchange rate determination, when using US dollar as the base currency.

The following tests are designed to determine whether different results can be obtained when we test the monetary model for the mark/pound, yen/mark, and yen/pound cases. Following the above steps, we first determine the lag length based on the information criteria selected for these three pairs. For the case of mark/pound and yen/pound, the lag length is two; for the yen/mark, the lag length is six. For all three cases, both the trace tests and the maximal eigenvalue tests uniformly reject the hypothesis of no cointegration. For the case of mark/pound, both tests suggest that the cointegration ranks are 1 at 0.01 significant level; for the case of yen/mark, trace test report a conintegration rank of 4, and an maximal eigenvalue test rank of 4 at a 0.01 significance level. For the case of yen/pound, trace test suggests a cointegration of rank 1 and maximal eigenvalue test reports a cointegration of rank 2 at the 0.01 significance level. All three cases support the monetary model at a 0.01 significance level, a much stronger results than those reported for the US dollar.

The above cointegration results suggest that when we include the US dollar in the monetary model, we are more likely to conclude that the monetary model does not hold. The reason may be the unique property of the US dollar as a world currency. It is estimated that by the late 1990s, more than 80% of all foreign exchange transactions were in dollars, about 50% world exports were denominated in dollars, and two thirds of official reserves were held in dollars. About 400 billion dollar notes circulate outside the US. The BIS (2000) reported that the share of US dollar denominated in international money market instruments were 79% in 1993, and 43% in 2000. The share of the US dollar denominated international bonds and notes has increased from 38% in 1993 to 47% in 2000. Furthermore the share of euro-dollar in euro-currency market has decreased from 79% in 1984 to 49% in 1995, and has stayed around 50% since then. All of the above confirm the proposition that the dollar is the most important currency in the world. The Federal Reserve's monetary policy not only provides dollars for domestic use, but also for world wide use. The Federal Reserve's distributes US dollars throughout the United States and all regions of the world, through banking channels.

Given equation (3), for the US dollar, the domestic money demand is not equal to the total money supply, and there can be a substantial gap between them. However, in testing the monetary model, we assume that a country's domestic money demand is equal to its total money supply. This assumption is not a big problem for non-dollar currencies, but in the case of dollar, it simply does not hold up. So, in the case of US dollar, equation (3) may be mis-specified and might result in the rejection of monetary model.

In general, the results of this paper tend to support the monetary model of exchange rate determination except in the special case of the US dollar. In the case of the US dollar, there may be other reasons why it tends to reject the monetary model, which will require further research.

CONCLUSION

Since the collapse of the Bretton Woods system, increasing attention has been given to the problem of exchange rate determination under floating exchange rates. Although many studies have been carried out in the past thirty years, it is fair to say that the problem is still far from resolved. One of the most significant approaches to this problem is the use of select macro fundamentals to explain the movement of the exchange rates. However, in the short-run, the relatively stable fundamentals do not explain the extreme volatility of the exchange rate, and some analysts have stated that the monetary model postulates a long run relationship. Unfortunately, the empirical studies have not generated sufficient and consistent evidence to verify this long run relationship, although certain interesting results were reported recently.

The cointegration test is one of the most frequently used methods to test for the long run relationship in the monetary model. The results of these tests have been mixed.

In this paper, we have investigated the following propositions:

1. We have examined whether the long run relationship derived from the monetary model exists by applying the cointegration technique. The model tested is the unrestricted monetary model with relative PPP, which is not as frequently applied as the restricted version of the absolute PPP.
2. We have inquired whether the US dollar, as a world currency, presents a special case that tends to reject the monetary model in the long run and hence merits further investigation.

Generally our results support the proposition that the monetary model for the US dollar is a special case. In the case of US dollar, the evidence does not offer support for the monetary model. It is possible that this is due to the unique property of the US dollar as a world currency. Although for the cases of mark/pound, yen/mark and yen/pound, the results provide strong support for the monetary model of exchange rate determination.

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