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STRUCTURAL BREAK AND COINTEGRATION TESTS OF THE MONETARY EXCHANGE RATE MODEL

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Abstract: Using various cointegration tests, the paper examines the validity of the monetary model as a theory of long-run equilibrium condition for the exchange rate of a developing economy experiencing chronic and at times accelerating inflation. Contrary to the findings of some earlier research, this study offers no evidence of long-run equilibrium relationship among the variables of the monetary model. It does not also provide any evidence of structural shift in the relationship. These results suggest that the monetary model is not a valid framework for analyzing the long-run movements of the rupee-dollar exchange rate. The failure of the model, despite some evidence of long-run relative PPP, may be attributed to the absence of monetary equilibrium condition.

JEL classification: C22, C32, F31.
Key-words: structural break, unit-root, cointegration, exchange rate, purchasing power parity.

1. INTRODUCTION

Monetary models of exchange rate determination have been subjected to extensive empirical testing since the late-1970s. The flexible-price monetary model received empirical support from Frenkel (1976), Bilson (1978a) and Hodrick (1978). On the other hand, Frankel (1979) provided evidence consistent with the sticky-price version of the model. Despite empirical support at the early stage, the models, however, have not been very successful in explaining exchange rate movements. See, for example, Backus (1984), Boothe and Poloz (1988), Boughton (1987), Finn (1986), Frankel (1984), Lafrance and Racette (1985), McNown and Wallace (1989), Meese (1986), Meese and Rogoff (1983a, 1983b, 1988), Meese and Rose (1989) and Smith and Wickens (1986). It has also been demonstrated

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that the structural models do not perform better than the random walk model in out-of-sample forecasts (Boughton, 1987; Meese and Rogoff, 1983a, 1983b). Somanath (1986), however, found that while some structural models dominate the random walk model, a lagged adjustment contributes towards better performance. West (1987) also demonstrated that two basically standard monetary models are consistent with the variability of the dollar-deutschemark exchange rate during 1974–84. More recently, using a multivariate cointegration technique, Macdonald and Taylor (1994) argued that an unrestricted monetary model is a valid framework for analysing the long-run exchange rate movements. Moreover, after taking account of the short-run data dynamics, they observed that an unrestricted monetary model outperforms the random walk and other models in out-of-sample forecast competition.

The results of the studies cited above are specific only to the major industrialized countries. It may, however, be expected that the monetary models would perform better if tested for high inflation countries where monetary factors rather than real nonstationary factors are expected to be dominant in exchange rate changes. Using maximum likelihood cointegration test, McNown and Wallace (1994) found some evidence in favour of the monetary approach to exchange rate determination for three high inflation countries—Argentina, Chile and Israel. Even though the estimated parameter values and signs are sensitive to model specifications, "cointegration among the variables of the monetary model is strongly supported across all specifications of the model for all three countries" (McNown and Wallace, 1994: 409).

This paper re-examines the validity of the monetary approach as a theory of long-run equilibrium condition for exchange rate determination for a developing country like India. The country has been experiencing chronic and at times accelerating inflation. It has been argued that inflationary process in India is fundamentally a monetary phenomenon. It has also been argued that the causation between money and prices is not unidirectional as postulated by the monetarist model; Inflationary process in India is characterized by a self-perpetuating cycle of fiscal deficit-induced inflation followed by inflation-induced deficit (Jadav and Singh, 1990; and Rangarajan and Arif, 1990). In such condition, it may be expected that the monetary factors rather than real factors would be more important in the long-run movements of the exchange rate of this country. Moreover, using Engle-Granger cointegration test, we have found some evidence in favour of the long-run relative purchasing power parity (PPP) for India. The ADF statistic for a unit root in the cointegrating residuals from a regression involving p, s, p^* and a constant turned out to be -3.948 which is significant (see section 2 for definition of the variables). This motivates us to re-evaluate the performance of the monetary approach as a theory of long-run equilibrium condition for the rupee-dollar exchange rate in the post-Bretton Woods period. A number of cointegration tests have been used to examine whether long-run equilibrium exists between the exchange rate and the variables that determine it. The cointegration tests are carried out on the flexible-price monetary model only, as the sticky-price version (proposed by Dornbusch,1976 and extended by Frankel, 1979, 1984) which allows for temporary overshooting of exchange rate is not inconsistent with the existence of long-run equilibrium condition implied by the former. We also extend the earlier efforts to test the monetary model of exchange rate by implementing cointegration tests in the presence of structural break. This enables us to see if there had been any structural shift in the underlying equilibrium relationship at any point during the sample period.

The sample covers Indian (domestic) and the U.S. (foreign) quarterly data for the period 1973 : 1 to 1995:1. These are collected from various issues of *International Financial Statistics*(IMF). The exchange rate of Indian rupee is measured against the U.S. dollar. Money supply is represented by M1. Real income is measured by industrial production. Nominal short-term interest rate is represented by bank rate.[1]

The rest of the paper is organized as follows. While section 2 outlines the monetary model, section 3 examines the univariate time series properties and the order of integration of the variables included in the model. Using Engle-Granger and maximum likelihood tests of cointegration, section 3 also evaluates empirically the performance of the model as a theory of long-run equilibrium condition for the rupee-dollar exchange rate. Section 4 uses cointegration tests in the presence of structural break proposed by Gregory and Hansen (1996) and searches for structural shift in the underlying long-run equilibrium relationship at any endogenously determined breakpoint. Section 5 concludes.

2. THE MONETARY MODEL

The monetary model of exchange rate attributed to Frenkel (1976), Mussa (1976) and Bilson (1978a, 1978b) assumes that PPP holds continuously so that

$$s=p-p^* \tag{1}$$

where s is the natural logarithm of spot rate defined as the price of domestic currency per unit of foreign currency; p is the natural logarithm of price (CPI); An asterisk ($*$) denotes foreign variable.[2]

[1] We are constrained to use bank rate as the short-term interest rate because of non- availability of quarterly data relating to other short-term interest rate for India. Consideration of this rate does not, however, appear to be inappropriate in view of the evidence that the estimated coefficient of interest rate differential is consistent with the monetary model of exchange rate determination.

[2] In describing the monetary model of exchange rate, we have followed the framework generally used in the literature which considers the assumption of absolute PPP. However, when the model is tested empirically, we have considered the *relative* rather than absolute PPP by including a constant term in equation 4 (see Table 2). This is done in view of the evidence in favour of long-run relative rather than absolute PPP. In testing the empirical validity of the long-run PPP hypothesis, we have used both CPI and WPI data. However, since both indices offered identical results, we have reported the evidence based on CPI only. The choice of CPI or any other price index does not, however, affect the conclusion about monetary exchange rate model as the price index does not enter into equation 4.

The model adds to PPP a monetary equilibrium condition conventionally represented by money demand function at home and abroad

$$m-p=\theta y-\lambda i \tag{2}$$

$$m^*-p^*=\theta y^*-\lambda i^* \tag{3}$$

The reduced-form exchange rate equation is

$$s=(m-m^*)-\theta(y-y^*)+\lambda(i-i^*) \tag{4}$$

where m and y are natural logarithms of money supply and real income respectively; i is the short-term nominal interest rate. The parameters θ and λ respectively denote income-elasticity and interest rate semi-elasticity of the demand for real balance. The model predicts that, in the long-run, the rate of change of the exchange rate will be equal to the rate of change of money supply differential, and that a decline in real income differential or an increase in relative nominal interest rate would lead to a depreciation of the exchange rate. The empirical validity of the model as a theory of long-run equilibrium condition for the exchange rate would depend on the evidence of cointegration (with appropriate sign of the coefficients) among the variables included in equation 4.

3. UNIVARIATE TIME SERIES PROPERTIES AND COINTEGRATION TESTS

Before testing for multivariate cointegration, we need to test the univariate time series properties and the order of integration of the variables included in equation 4. This is performed by using augmented Dickey–Fuller (ADF) test for a unit root (Dickey and Fuller, 1979, 1981; Said and Dickey, 1984).

The results presented in Table 1 show that the null hypothesis of a unit root cannot be rejected for any of the series at 5 per cent level. However, when the test is applied to the first-difference of the series, we find that the null hypothesis can be rejected for all the series. These results suggest that the variables included in equation 4 are all I (1).

Empirical performance of the monetary model has been evaluated in this section in the light of the results of Engle–Granger(Engle and Granger, 1987; Engle and

TABLE 1. ADF TEST FOR THE ORDER OF INTEGRATION.

Variable	Level (τ_τ)	First-difference (τ_μ)
s	−1.398	−4.649*
$m-m^*$	−0.849	−3.126**
$y-y^*$	−3.211	−4.123*
$i-i^*$	−2.402	−3.143**

Notes: * and ** denote significant at 1% and 5% levels respectively. 1% and 5% critical values of τ_τ for 100 observations are −4.04 and −3.45 respectively ; Corresponding critical values of τ_μ are −3.51 and −2.89.

TABLE 2. REGRESSION ESTIMATES AND ENGLE–GRANGER TEST OF COINTEGRATION (ESTIMATED EQUATION–4).

(1)	(2)	(3)
Constant	2.355*	2.682*
	(21.827)	(37.22)
Trend	0.007*	—
	(3.856)	—
$m-m^*$	0.529*	0.802*
	(4.988)	(9.413)
$y-y^*$	−0.129	0.231**
	(−0.855)	(1.807)
$i-i^*$	0.043*	0.039*
	(9.366)	(8.095)
$\bar{R}^2$	0.953	0.945
DW	0.328	0.460
CRADF	−2.714	−2.775

Notes: Figures in parentheses are t-values; * and ** respectively denote significant at 1% and 5% levels by conventional t-test; Number of observations = 89.

Yoo, 1987) and maximum likelihood (Johansen, 1988; Johansen and Juselius, 1990) tests of cointegration. The results of cointegration tests are contrasted with the regression evidence to show that estimated regressions can be "spurious" in the sense of Granger and Newbold (1974).[3]

The results of the Engle–Granger cointegration test along with the OLS estimates of the cointegrating regressions are reported in Table 2. The cointegrating regression is estimated with and without a trend term inclusion of which enables us to see if the variables are cointegrated or not even after detrending. Apparently, the regression estimates offer mixed support to the monetary model. What appears quite consistent with the prediction of the monetary model is the evidence that the coefficient of interest rate differential is significantly positive in both the equations. Moreover, the coefficient of money supply differential, although below unity particularly in the equation which includes a trend, is significantly positive in both the equations. What, however, goes against the model is the evidence that the coefficient of real income differential, although insignificantly negative in the equation with a trend, turns out to be significantly positive in the equation that does not include a trend.

Whatever little evidence the regression estimates offer in favour of the monetary model can, however, be treated at best as "spurious". The low values of the DW statistic relative to $\bar{R}^2$ are a clear indication that the estimated regressions are nothing but spurious. This is confirmed by the results of cointegration tests. The ADF test for a unit root in the cointegrating residuals (CRADF) fails to reject

[3] Spurious regression is particularly likely when $\bar{R}^2$ exceeds DW statistic. In such condition, conventional t-test tends to reject the null of no relation even when it is actually true.

the null of no cointegration in all the regressions, suggesting that there exists no long-run equilibrium relationship between the exchange rate and the explanatory variables of the model. Similar inference can be drawn from the likelihood ratio tests of cointegration. The *maximum eigen value* and the *trace* tests fail to reject the null hypothesis of zero cointegrating vector even at 10 per cent level of significance. These results are sufficient to establish that the monetary model does not provide a long-run equilibrium condition for the rupee-dollar exchange rate.[4] This casts doubt about the validity of the monetary model of exchange rate for a country experiencing chronic and at times accelerating inflation.

4. COINTEGRATION TEST WITH STRUCTURAL BREAK

While performing the cointegration tests in the preceding section, we have not allowed for any structural shift in the cointegrating relationship between the exchange rate and the explanatory variables of the monetary model. This, however, does not seem to be reasonable in view of the fact that the data used in the analysis span over a period of 22 years encompassing different policy regimes, oil price crises, devaluation of the Indian currency, etc. These are expected to cause structural shift in the exchange rate relationship. In view of this possibility, it seems useful to examine if the observed nonstationarity in the estimated residuals of the cointegrating regression implying the absence of long-run equilibrium relationship (Table 2) is the result of any *big shift* or accumulation of frequent shifts in the relationship. If the relationship does involve any shift large enough to be treated as structural shift, the estimated residuals of the cointegrating regression would turn out to be I(0) when the *big shift*s are appropriately incorporated in the testing procedure. This calls for testing the null hypothesis of no cointegration against the alternative of cointegration with structural break. In performing this test we follow the method suggested by Gregory and Hansen (1996) in which breakpoint of the long-run equilibrium relationship is estimated in an endogenous manner.

Following Gregory and Hansen (1996), we have used three single-equation regression models and various residual-based tests for the null hypothesis of no cointegration against the alternative of cointegration with structural change.

Model 1: Level shift (C)

$$y_{1t} = \mu_1 + \mu_2 D_{tr} + \alpha^T y_{2t} + e_t \, .$$

[4] Needless to say, cointegration is a long-run concept and hence requires long span of data to provide much power to the tests for it. We were, however, constrained to use the data for the period 1973–95, the maximum length of the period that can be used, as the flexible exchange rate regime starts from 1973. Naturally, we cannot use historical data before 1973 as it involves fixed exchange rate regime. We preferred to use quarterly data firstly, because of their easy availability, and more importantly, because of the fact that increasing the frequency (from quarterly to monthly) of sampled observations for a given period does not significantly change the power of the tests of cointegration (see Hakkio and Rush, 1991).

TABLE 3, MAXIMUM LIKELIHOOD TESTS OF COINTEGRATION.

Eigen value	Null	λ-max	90% λ-max	Trace	90% trace
0.193	r=0	16.94	24.73	37.00	43.95
0.144	r≤1	12.28	18.60	20.05	26.79
0.065	r≤2	5.31	12.07	7.77	13.33
0.031	r≤3	2.49	2.69	2.49	2.69

Notes: The likelihood ratio statistics are estimated using TSP 4.3A. The estimated VAR includes a constant and seasonal dummy. Optimal lag chosen is 1. The tests statistics include finite-sample correction suggested by Gregory (1994). The critical values are from Osterwald–Lenum (1992, Table 1, p. 468).

Model 2: Level shift with trend (C/T)

$$y_{1t}=\mu_1+\mu_2 D_{t\tau}+\beta t+\alpha^T y_{2t}+e_t\,.$$

Model 3: Regime shift (C/S)

$$y_{1t}=\mu_1+\mu_2 D_{t\tau}+\alpha_1^T y_{2t}+\alpha_2^T y_{2t} D_{t\tau}+e_t$$

where the observed data is $y_t=(y_{1t}, y_{2t})$, y_{1t} is real-valued and y_{2t} is an m-vector; $t=1, 2, \cdots, n$; $D_{t\tau}=1$ if $t>[n\tau]$, 0 otherwise; The unknown parameter $\tau\in(0, 1)$ is the break fraction, and $[n\tau]$ denotes integer part. Model 1 allows for a change in the intercept only indicating a level shift in the cointegrating relationship. Model 2 includes a time trend in the level shift model. Model 3 allows for a change in the intercept as well as in the slope of the cointegrating relationship.

The cointegrating models are estimated by OLS method and then the standard unit-root tests—ADF and Phillips–Perron (PP) (Phillips, 1987; Phillips and Perron, 1988)—are performed on the residuals of the regressions. Since the breakpoint is assumed to be unknown *a priori*, Gregory and Hansen(1996) proposed an approach in the spirit of Christiano (1992), Banerjee *et al.* (1992) and Zivot and Andrews (1992) that considers the selection of the breakpoints as the outcome of an estimation procedure that does not require prior information regarding the timing of break. The test statistics for a unit root in the cointegrating residuals for each regime shift $\tau\in T$ are estimated, and the breakpoint is chosen in such a manner that the test statistics are minimized. If ADF* and Z_p^* represent such minimizing values of ADF and PP statistics respectively, then it follows that

$$\mathrm{ADF}^*=\inf_{\tau\in T}\mathrm{ADF}(\tau)$$

$$Z_p^*=\inf_{\tau\in T} Z_{\hat{p}}(\tau)\,.$$

The test statistics so obtained provide least favourable weight to the null hypothesis of no cointegration. Rejection of the null by either ADF or ADF* implies that some long-run relationship exists. If ADF fails to reject but ADF* rejects the null, then it may be argued that the cointegrating relation has undergone a

TABLE 4. TESTS OF COINTEGRATION WITH STRUCTURAL BREAK.

Regime shift model	ADF*	$\hat{T}_B$	Z_ρ^*	$\hat{T}_B$
C	−3.608	1976:1	−32.027	1976:2
C/T	−3.829	1990:2	−32.781	1977:3
C/S	−4.139	1982:2	−47.230	1979:3

structural change. But no inference that structural change has occurred can be drawn if both ADF and ADF* reject the null.

The reduced-form monetary model (equation 4) is estimated for each of the regime shift models for all possible breakpoints in the interval $[0.15n]$, $[0.85n]$. The test statistics for a unit root in the cointegrating residuals reported in Table 4 are the minimum values over all the estimated ones, and the break years ($\hat{T}_B$) correspond to these minimum values. It can be seen that the breakpoint that minimizes the test statistics does not occur in a particular year. The estimated breakpoint varies across the regime shift models and the test statistics used. However, most of the estimated breakpoints cluster around some important economic events such as drought (1977–78), second oil price crisis (1979) and devaluation of Indian currency (July 1991).

To assess the significance of the test statistics, the approximate asymptotic critical values reported in Gregory and Hansen (1996, Table 1, p. 109) are used. The results reported in Table 4 clearly show that the null hypothesis of no cointegration cannot be rejected (even at 10 per cent level) in favour of the alternative of cointegration with structural break by either of the test statistics in any of the regime shift models. Earlier in Table 2, we have found that ADF test failed to reject the null of no cointegration. Based on this result in conjunction with the ADF*, it may be argued that there had not been any structural change in the long-run equilibrium relationship between the exchange rate and the explanatory variables of the monetary model. Since both ADF and ADF* fail to reject the null of no cointegration, it may be strongly argued that there exists no long-run equilibrium relationship between the exchange rate and the differentials of money, real income and nominal interest rate. This set of results suggests that the monetary model is not a valid theory of long-run equilibrium condition for the rupee-dollar exchange rate.

5. CONCLUDING OBSERVATIONS

A number of cointegration tests have been used to examine the empirical validity of the monetary model as a theory of long-run equilibrium condition for the exchange rate of a developing economy experiencing chronic and at times accelerating inflation. The Engle–Granger and maximum likelihood tests of cointegration provide no evidence of long-run equilibrium relationship among the variables of the monetary model. Moreover, cointegration tests in the presence of structural break do not provide any evidence of structural shift in the underlying equilibrium relationship at any endogenously determined breakpoint during the sample period. These results contradict McNown and Wallace (1994) who found ample evidence of cointegration among the variables of the monetary model for three high inflation countries. Our results, thus, cast doubt about the validity of the monetary model as a theory of long-run equilibrium condition for the rupee-dollar exchange rate.

The deviations of the exchange rate from its equilibrium values may be considered as an evidence favouring the random walk and speculative bubble hypotheses offered in several studies analyzing the behaviour of the exchange rates of the major industrialized countries (see, for example, Boughton, 1987; Meese, 1986; Meese and Rogoff, 1983a, 1983b).

One possible source of failure of the monetary model to provide long-run equilibrium condition for the rupee-dollar exchange rate, despite the evidence of long-run relative PPP, can be found in unstable money demand function. Cointegration tests offered no evidence of cointegrating relationship among the variables of money demand function of the domestic country. The ADF statistic for a unit root in the estimated residuals from a cointegrating regression involving $(m-p)$, y, i, and a constant turned out to be -2.654. The *trace* and $\lambda-\max$ statistics for the null hypothesis of zero cointregrating vector turned out to be 18.23 and 12.26 respectively. These results lead to the rejection of the assumption of monetary equilibrium condition on which the monetary model is based.

Although our exercise for identifying structural break in the long-run equilibrium relationship among the variables of the monetary model of exchange rate does not provide evidence of structural shift in the said relationship for the Indian economy, similar exercise for other countries might bring out encouraging evidence for the monetary model.

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