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Exchange Rate and Monetary Fundamentals: Long Run Relationship Revisited

Summary: This study re-examines the long run validity of the monetary approach to exchange rate determination for India. In particular, the long run association of bilateral nominal exchange rate of Indian rupee vis-à-vis USD, Pound-sterling, Yen and Euro against the corresponding monetary fundamentals that the model underlines has been tested using Johansen-Juselius maximum likelihood framework and Gregory-Hansen co-integration approach. Irrespective of the exchange rates the study finds a co-integrating relationship among the variables using Johansen-Juselius maximum likelihood approach. The Gregory-Hansen co-integration method allows for one break determined endogenously in three specifications also confirms the long run relationship. Our results, hence, suggest that the monetary model is a valid theory of long run equilibrium condition for the rupee-dollar, rupee-pound, rupee-yen and rupee-euro exchange rates.

Key words: Monetary approach, Exchange rate determination, India.

JEL: F31, F15.

For decades the determination of exchange rate has been an issue of intense research interest. Considerable research analysis of the complex interactive behaviour among the foreign exchange rates and the macroeconomic fundamentals has led to development of a rich theoretical literature in the area of exchange rate determination. Today, the literature on international finance offers a number of competitive theoretical models for analyzing exchange rate behaviour. Yet, there is no single theory that can understand exchange rate behaviour in its entirety.

This study analyzes the behaviour of exchange rate in the light of a prominent theory of exchange rate determination, namely, the monetary approach. The monetary approach of exchange rate (MAER) explains the dynamics between nominal exchange rate and monetary fundamentals. The MAER emerged as the dominant exchange rate model in the early 1970s. Over time the MAER flourished into various forms viz., the flexible-price model, the sticky-price model and ultimately the real interest rate differential model and received decent empirical support in the early stage.

The monetary model to exchange rate offers a crucial referral point to policy makers in targeting exchange rate behaviour. This is because it links macroeconomic fundamentals with exchange rate and explains the intricacies of exchange rate determination through the monetary channel. It further establishes the significance of money supply in determination of domestic price level and thereby the equilibrium exchange rate. Albeit, the research devoted to test the validity of monetary model is intense, in the existing literature very few studies accommodate for structural changes in the data generating process (DGP) or in the economic relationship. In this respect, Pierre Perron (1990) observed that the power to reject a unit root in DGP decreases significantly when the stationary alternative is true and a structural break is ignored. Further, the power of conventional co-integration tests falls sharply when co-integrating relationships are subject to structural changes. In this respect Allan W. Gregory, James M. Nason, and David G. Watt (1996) observed: “lack of careful investigation of potential structural breaks may thus lead to misspecification of the long run properties of a dynamical system and inadequate estimation and testing procedures”.

Moreover, in the Indian context the overhaul of financial system following economic crisis since early 1990s has led Indian foreign exchange market to undergo structural changes at various stages. There has been an introduction of market-driven flexible exchange rate system on March 1993 followed by gradual opening of capital accounts coupled with emergence of 24-hour online based trading system. Moreover, since 1990s Indian economy has been exposed to several external shocks and other policy shifts that are expected to cause structural shifts in the exchange rate relationship. The external shocks include the Asian Crisis of 1997, global financial crisis of 2007, the disintegration of the erstwhile USSR, etc. In the light of above developments, the analysis of exchange rate behaviour under structural break framework offers an interesting field of enquiry for India.

Thus, a re-examination of the strength of relationship between exchange rates and macroeconomic fundamentals in the emerging market economies e.g. India from the long run perspective under the structural break framework is critical issue to be assessed. The existence of structural break implies the possibility of time varying parameters in the exchange rate model. Recent studies such as Joscha Beckmann, Ansgar Belke, and Michael Kühl (2011) have addressed this issue using econometric techniques such as Bai-Perron test to identify structural breaks in the data. While, studies like Augustine C. Arize, John Malindretos, and Kiseok Nam (2010) use conventional co-integration method to test relationship between exchange rate and macroeconomic variables, yet other studies like R. Scott Hacker, Hyunjoo Kim Karlsson, and Kristofer Månsson (2012) and Aviral K. Tiwari et al. (2014) use frequency based approaches to test the relationship between exchange rate and number of macroeconomic variables. However, in our study we employ the novel test proposed by Junsoo Lee and Mark C. Strazicich (2003, 2004) that detects up to two break points endogenously along with presence of unit root in the time series. The methodology found its application relatively more recently in the field of exchange rate theory e.g. the testing of mean reversion of real exchange rate or alternatively testing of the purchasing power parity hypothesis (Paresh K. Narayan and Biman C. Prasad 2005; Narayan 2006; Saadet Kasman, Adnan Kasman, and Duygu Ayhan 2010) and in testing the monetary approach (Ahmet Ugur, Yusuf Ekrem Akbas, and Mehmet Senturk 2014). Of late, studies e.g. Hassan Mohammadi and Mohammad R.

Jahan-Parvar (2012) and Tiwari, Dar, and Bhanja (2013) also utilize the methodology to test the unit root property of oil prices and exchange rates. A detailed survey of unit root test under the framework of structural break has been forwarded by Joseph P. Byrne and Roger Perman (2007). Further, the long run relationship is tested using co-integration test proposed by Gregory and Bruce E. Hansen (1996).

The rest of the paper is structured as follows. Section 1 presents a brief review of empirical literature on the MAER. Section 2 explains the model and methodologies employed in the study and outlines the testing strategies. Section 3 gives details of the data used in the empirical analysis and reports the estimated results. Section 4 gives the conclusion of our research study.

1. Review of Literature

The relationship between exchange rate and macroeconomic fundamentals has generated a flurry of research interest. Using a new bootstrapping methodology to infer small sample inferences in long horizon regression, Lutz Kilian (1999) analyzed the long run predictability of four major exchange rates. The study offered some evidence of exchange rate predictability; however in the longer horizon no evidence of higher predictability was observed. In an analytical paper Charles Engel and Kenneth D. West (2005) showed the disconnection between the exchange rate and macro fundamentals like relative money supplies, outputs, inflation, and interest rates through the evidence of near random walk behaviour of asset prices and argued that these macro variables provide little help in predicting changes in exchange rate. Examining whether macroeconomic monetary fundamentals e.g. money supply, interest rate offer any explanation for exchange rate in USA, Euro Area and Japan, Yutaka Kurihara (2012) confirms the influence of monetary policy on the exchange rate accounting for structural breaks in underlying parameters. Recently, Philippe Bacchetta and Eric van Wincoop (2013) through their analysis argued that the wide and frequent variation in the relationship between exchange rate and macroeconomic fundamentals is the outcome of unknown structural parameters and their slow change. Further, the study found parameter instability to have negligible effect on the volatility of exchange rates, the in-sample explanatory power of macro fundamentals and the ability to forecast out of sample.

Nevertheless, over last three decades the existing theoretical exchange rate models including the monetary approach have been put to the rigorous empirical testing for assessing their empirical validity. The findings of these researches have revealed high inconsistency across countries, methodologies and sample periods (Ronald MacDonald and Mark P. Taylor 1992). Despite early conformity on the validity of various monetary models, in subsequent period the support remained largely muted.

Against this backdrop, several studies in the subsequent period have empirically tested the variant of MAER models and their extensions. In recent years specifically since the seminal papers of MacDonald and Taylor (1992, 1994), the long run properties of monetary model of exchange rate have been scrutinized in the light of Johansen-Juselius and panel co-integration methodologies and, in sharp contrast to earlier studies that made use of Engle-Granger two-step co-integration method, these studies produced strong evidence favoring the MAER (Tatsuyoshi Miyakoshi 2000; Jan J. J. Groen 2002; Idil Uz and Natalya Ketenci 2008 among others). Under the VAR framework Ian Wilson (2009) reported validity of long run monetary model between USD and currencies of its trade partners. The study found the fiscal variables e.g. government debt and deficits exerting significant impact on the exchange rates in the long run.

Recently, Junaid Abbasi and Sadia Safdar (2014) and Ugur, Akbas, and Senturk (2014) endeavored to test the validity of monetary model of exchange rate for Pakistan and Romania respectively. For Pakistan the empirical findings confirm the existence of long equilibrium relationship among exchange rate and monetary fundamentals with domestic interest rate and income bearing negative association and money supply a positive correlation with the exchange rate. Under structural VAR framework, Ugur, Akbas, and Senturk (2014) found no correlation between nominal exchange rate and money supply, GDP and interest rate for the Turkish Liras.

In the Indian context, however, handful of studies analyzed the exchange rate vis-à-vis the monetary fundamentals. Among others Renu Kohli and Kenneth Kletzer (2004) using a VECM representation found that the monetary model performed well in explaining behaviour of the Rupee/USD exchange rate. Of late, Pami Dua and Rajiv Ranjan (2011) have modeled the Rupee/USD exchange rate against monetary fundamentals to test the forecasting ability of the monetary models. The Bayesian VAR was found to predict the exchange rate better than the conventional VAR. Nevertheless, all these analyses have ignored the issues of the presence of structural break and confined themselves only to the one exchange rate i.e. Rupee/USD.

Moreover, the available empirical literature are highly lop-sided towards the currencies of developed economies like USD, Yen, Pound-sterling, Swiss Franc and Deutsche Mark while the currencies of transition and developing economies have not received due attention. In light of this fact, the present study attempts to extend the pool of existing literature further by addressing the issue of long run validity of monetary model of exchange rate, for the Indian rupee vis-à-vis some of the major traded currencies of the world, namely USD, Japanese Yen, British Pound and European Unions' Euro. The major contribution of the study lies with the application of Lee and Strazicich (2003, 2004) LM unit root test that detects the presence of unit root considering structural breaks and subsequently structural break co-integration test due to Gregory and Hansen (1996) to test for long run association between bilateral nominal exchange rate and monetary fundamentals of domestic and foreign country. Details of these methods are discussed in the following section.

2. The Model and the Econometric Methodology

A compact unrestricted and reduced equation of monetary model can be expressed as follows (for further discussions see MacDonald and Taylor 1992):

$$e_t = \zeta_0 + \zeta_1 m_t + \zeta_2 m_t^* + \zeta_3 y_t + \zeta_4 y_t^* + \zeta_5 r_t + \zeta_6 r_t^* + u_t \tag{1}$$

where, e_t is the nominal bilateral exchange rate, m_t denotes domestic money supply, y_t denotes domestic real income, r_t is the domestic interest rate and u_t is an error term. The foreign counterparts are denoted with an asterisk.

The reduced form equation presented in Equation (1), was formulated to evaluate empirically the long run property of the monetary model, for it nests both the flexible-price as well as the sticky-price version of the model. While the former predicts instantaneous adjustment in the real exchange rate in response to monetary shocks, the latter holds real exchange rate as fixed, thereby allowing overshooting of both the nominal and the real exchange rates over their long run equilibrium levels, as defined by the PPP, in the short run. Both forms of monetary model, however, produce same long run equilibrium condition between the exchange rate and the monetary variables predicted as through Equation (1). The pattern of coefficient signs in Equation (1) as predicted by the monetary model can be summarized as follows: (a) $\zeta_1 > 0$ and $\zeta_2 < 0$, because a rise in Indian (foreign) money supply is expected to cause the depreciation (appreciation) of the Indian rupee; (b) $\zeta_3 < 0$ and $\zeta_4 > 0$, for an increase in Indian (foreign) real income cause rise in money demand and hence appreciation (depreciation) of the rupee; (c) finally, $\zeta_5 > 0$ and $\zeta_6 < 0$, as interest rate rise in India (foreign economy) would lead to fall in money demand and thereby rupee depreciation (appreciation). However, as per the prediction of sticky price version of the model the coefficient signs should be $\zeta_5 < 0$ and $\zeta_6 < 0$.

The evaluation of long run properties of the monetary model presented in Equation (1) is, first, pursued following the tradition of MacDonald and Taylor (1991) within maximum likelihood testing framework developed by Søren Johansen and Katarina Juselius (1990). We consider the vector of the form $X_t = (m_t, m_t^*, y_t, y_t^*, r_t, r_t^*)'$, which is generated from a VAR (k) model with Gaussian error ε_t:

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + ... + \Pi_k X_{t-k} + \mu + \varepsilon_t . \tag{2}$$

The long run static equilibrium associated with Equation (2) is given as $\Pi_k X_{t-k} = 0$, where the long run coefficient matrix Π is defined as:

$$\Pi = I - \Pi_1 - \Pi_2 - .... - \Pi_k . \tag{3}$$

$\prod$ is defined as an $N \times N$ matrix and its rank decides the number of co-integrating vectors (r). The test has been popularized by many applications and is considered as standard procedures for testing co-integration. Detail discussion of the methodology is hence avoided. For details see Johansen and Juselius (1990).

However, a major shortcoming of the Johansen-Juselius technique is that it does not account for structural changes in the co-integrating vector. In view of the fact that the period of the study covers 18 long years encompassing different policy regimes and oil price shocks, we expect possibility of structural shift in the exchange rate relation. Hence we have examined the stationarity of all the time series applying much advanced Lee and Strazicich (2003, 2004) LM test that account up to two structural breaks. Further we make use of the Gregory and Hansen (1996) co-integration approach which tests for co-integration with one shift in the co-integrating vector at some unknown date. These two methodologies are discussed in detail below.

2.1 Lee and Strazicich (2003, 2004) LM Unit Root Tests

The DGP considered in the application of Lagrange Multiplier (LM) unit root tests; the Lee and Strazicich (2003) LM tests with two breaks and Lee and Strazicich (2004) LM tests with one break is given by:

$$y = \partial z_t + e_t, e_t = \beta e_{t-1} + \varepsilon_t \tag{4}$$

where z_t is a vector of exogenous variables, ∂ is a vector of parameters and ε_t is a white noise process, such that $\varepsilon_t \sim NIID\ (0, \sigma^2)$.

In the framework of one structural break analysis, the crash model that allows shift only in level is described by $Z_t = [1, t, D_t]'$ and the model that allows for shift both in level and trend is given as $Z_t = [1, t, D_t, DT_t]'$, where D_t and DT_t are two dummies defined as:

$$D_t = 1,\ if\ \ t \geq T_B + 1 = 0 \text{ otherwise, and } DT_t = t - T_B,\ if\ \ t \geq T_B + 1 = 0 \text{ otherwise}$$

where T_B is the time period corresponding to break date. On the other hand, under the framework of two structural breaks, the crash model that allows two changes in level is described as $Z_t = [1, t, D_{1t}, D_{2t}]'$, and the model that allows two shifts both in level and trend is given as $Z_t = [1, t, D_{1t}, DT_{1t}, D_{2t}, DT_{2t}]'$ where, D_{jt} and DT_{jt} for $j = 1,2$ are approximate dummies defined as:

$$D_{jt} = 1, if\ \ t \geq T_{Bj} + 1 = 0 \text{ otherwise,}$$
$$\text{and } DT_{tj} = t - T_{Bj}, if\ \ t \geq T_{Bj} + 1 = 0 \text{ otherwise}$$

where T_{Bj} is the j^{th} break date.

The Lee and Strazicich LM unit root test (2003, 2004) conduct breaks under the null $(\beta = 1)$ and alternative $(\beta < 1)$ in the data generating process defined in the Equation (4). The LM unit root test statistics is obtained using following regression:

$$\Delta y_t = \delta' \Delta Z_t + \phi \widetilde{S}_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta \widetilde{S}_{t-j} + u_t \tag{5}$$

where $\widetilde{S}_t = y_t - \widetilde{\psi}_t - Z_t \widetilde{\delta}$, $t = 2, \ldots, T$, $\widetilde{\delta}$ denotes the regression coefficient of Δy_t on ΔZ_t and $\widetilde{\psi}_t = y_t - Z_1 \widetilde{\delta}$, y_1 and Z_1 are first observations of y_t and Z_t respectively. The auto correlation problem is taken care by the inclusion of lagged term $\Delta \widetilde{S}_{t-j}$. The null hypothesis of unit root test ($\phi = 0$) is tested employing the above equation by the LM *t*-statistics. The location of structural break(s) is determined by selecting all possible breaks for the minimum *t*-statistics as follows:

$$\ln f\widetilde{\tau}(\overline{\lambda_i}) = \ln_{\lambda} f\widetilde{\tau}(\lambda), \text{ where } \lambda = T_B / T.$$

The trimming region over which selection process carried out is (0.15*T*, 0.85*T*), where *T* denotes sample size and T_B denotes date of structural break. The breaks are determined corresponding to which endogenous two-break LM *t*-test statistics is at a minimum. The critical values are tabulated in Lee and Strazicich (2003, 2004) for the two-break and one-break case respectively. Lag length (*k*) is selected using the "*t-sig*" approach proposed by Alastair Hall (1994). It starts with a predetermined upper bound *k* and if last lag included turns out to be significant, *k* is chosen. If *k* is insignificant, however, it is reduced by one lag until last lag becomes significant. In case of no significant lag *k* is set equal to zero.

2.2 Gregory and Hansen (1996) Co-integration Test

The Gregory and Hansen (1996) co-integration technique in the single equation framework allows for one endogenously determined structural break. The test puts forward three models whereby shifts can take place; either in intercept alone or, in level along with trend or, a full shift of the regime. The model that allows for shift in the intercept alone (Model C) is given by:

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \alpha^T y_{2t} + e_t \tag{6}$$

where $t = 1,2,\ldots,n$.

Accommodating a trend in the data, the second model (Model C/T) allows shift only to the change in level with a trend. This is defined as:

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \beta t + \alpha^T y_{2t} + e_t . \tag{7}$$

Finally, the full regime shift model (Model C/S) that allows for changes both in the intercept and slope of the co-integration vector is given as:

$$y_{1t} = \mu_1 + \mu_2 \varphi_{t\tau} + \alpha_1^T y_{2t} + \alpha_2^T y_{2t} \varphi_{t\tau} + e_t \tag{8}$$

where $t = 1,2,\ldots,n$ and μ_1, β_1 and α_1 are the intercept, trend and slope coefficient respectively before the shift in the regime and μ_2, β_2 and α_2 are the corresponding changes after the break. The dummy variable $\varphi_{t\tau}$ is defined as:

$$\varphi_{t\tau} = \begin{cases} 0, if\ t \le \{\eta\tau\} \\ 1, if\ t > \{\eta\tau\} \end{cases}$$

where unknown parameter $\tau \in (0,1)$ denotes the (relative) timing of the change point, and {} denotes integer part.

We have estimated all the models for each possible break date (each τ) in the data set, following Dierk Herzer and Nowak-Lehmann Felicitas (2006), followed by unit root test on the on the estimated residuals $\hat{e}_{t\tau}$. For testing the null hypothesis of *no co-integration* against the alternative hypothesis of *co-integration* in the presence of endogenous structural break, the smallest value of the unit root test statistics is used. The asymptotic critical values are tabulated by Gregory and Hansen (1996). The lag-length in the co-integration equation is based on SIC and AIC criterion.

3. Data and Results and Discussion

The study makes use of data of the monthly frequency spanning from 1993:M3 to 2011:M3. The choice of sample period is dictated by the emergence of market-determined exchange rate regime in India. Exchange rates are bilateral nominal exchange of Indian rupee vis-à-vis four major-traded currencies of the world viz. USD, Japanese Yen, British Pound and European Unions' Euro. Before emergence of Euro (Jan. 1999), the Rupee-Euro exchange rate series was constructed against Deutsche Mark. These countries are also important trade partners of India as well as major traded currencies of the world. For money supply, M1 of all the countries are considered except for United Kingdom (M_4 is taken as proxy of money supply for UK). The index of industrial production (IIP) is taken as the proxy for real income. Interest rates are Fed fund rate of USA, money market rate of UK, Japan and European Union and lending rate of India. Both money supply and output variables are adjusted seasonally with Census X-12 method. All the variables except for interest rate are transformed into logarithmic form. Data has been collected from *IFS CD-ROM-2012* published by the IMF and the *Handbook of Statistics on Indian Economy* compiled by the Reserve Bank of India.

Table 1 Unit Root Test Results

Country	Series	Phillip-Perron value		KPSS test value	
		Level	First diff.	Level	First diff.
USA	EXR	-1.82 (0.37)	-10.79 (0.00)	1.247*	0.225
	MS	2.18 (0.99)	-14.72 (0.00)	0.340*	0.109
	IIP	-2.71 (0.07)	-14.24 (0.00)	0.372*	0.058
	INT	-1.15 (0.69)	-6.883 (0.00)	0.814*	0.155
UK	EXR	-2.16 (0.22)	-12.62 (0.00)	1.494*	0.312
	MS	-1.35 (0.60)	-14.44 (0.00)	1.861*	0.223
	IIP	-4.37 (0.00)	-89.91 (0.00)	0.381*	0.059
	INT	-1.32 (0.62)	-22.03 (0.00)	1.000*	0.122
Japan	EXR	-1.23 (0.65)	-11.58 (0.00)	1.347*	0.060
	MS	-1.45 (0.55)	-14.59 (0.00)	1.846*	0.432
	IIP	-2.68 (0.24)	-16.06 (0.00)	0.092*	0.039
	INT	-3.20 (0.08)	-10.26 (0.00)	0.358*	0.132
EU	EXR	-1.82 (0.36)	-10.80 (0.00)	1.247*	0.225
	MS	-0.17 (0.93)	-16.02 (0.00)	-1.912*	0.136
	IIP	-1.98 (0.29)	-15.36 (0.00)	1.468*	0.221
	INT	-2.33 (0.16)	-11.56 (0.00)	1.425*	0.212
India	MS	-6.03 (0.86)	-19.33 (0.00)	1.904*	0.121
	IIP	-1.34 (0.99)	-33.88 (0.00)	1.889*	0.287
	INT	-1.930 (0.32)	-14.76 (0.00)	1.265*	0.070

Notes: Figures in (#) are *p*-values and the values higher than 0.05 (5%) show that unit root hypothesis is not rejected. For KPSS test (*) denotes rejection of null hypothesis of no unit root at 1 percent level of significance.

Source: Authors' own estimation.

The pricing of exchange rate on the basis of monetary model under maximum likelihood framework implies that the logarithm of the exchange rate and the logarithms of the domestic and foreign money supply, real income and interest rate are co-integrated with at least one co-integrating vector. As convention goes, before conducting co-integration test, the non-stationarity behaviour of the time series in their autoregressive representation has been carried out with the help of standard

Phillip and Perron (PP for short) and KPSS tests. The unit root results are presented in Table 1.

All the variables, apart from output variable of UK in PP test, were found to be stationary at their first difference. Thus we conducted the Johansen co-integration test; the results of which are tabulated in Table 2. As evident from the table, the null hypothesis of co-integrating vector ($r = 0$) has been rejected for all the country under consideration; implying long run association among exchange rate and the monetary fundamentals. In case of USA the presence of two co-integrating vectors was detected both by the trace and max-eigen statistics, while for UK and EU the trace statistics indicated four co-integrating vectors and for Japan two co-integrating vectors. The detection of at least one co-integration vector in all cases is evidence to support the unrestricted reduced form of the monetary model as the long run equilibrium theory in case of the rupee exchange rates.

Table 2 Johansen Co-integration Test Results

Johansen co-integration tests within a UVAR(2) model: USA							
r	*r* = 0	*r* ≤ 1	*r* ≤ 2	*r* ≤ 3	*r* ≤ 4	*r* ≤ 5	*r* ≤ 6
λ_{max}	58.08 (0.00)	45.79 (0.01)	20.41 (0.73)	17.96 (0.49)	10.85 (0.66)	9.45 (0.25)	0.07(0.79)
Trace	162.62(0.00)	104.54(0.01)	58.75 (0.27)	38.34 (0.29)	20.37 (0.40)	9.52 (0.32)	0.07 (0.79)
Johansen co-integration tests within a UVAR(2) model: UK							
r	*r* = 0	*r* ≤ 1	*r* ≤ 2	*r* ≤ 3	*r* ≤ 4	*r* ≤ 5	*r* ≤ 6
λ_{max}	50.43 (0.01)	42.63 (0.03)	38.34 (0.01)	21.76 (0.23)	16.64 (0.19)	10.17(0.20)	1.84 (0.17)
Trace	181.81(0.00)	131.38(0.00)	88.74(0.00)	50.40 (0.02)	28.65 (0.07)	12.01(0.15)	1.84 (0.17)
Johansen co-integration tests within a UVAR(2) model: JAPAN							
r	*r* = 0	*r* ≤ 1	*r* ≤ 2	*r* ≤ 3	*r* ≤ 4	*r* ≤ 5	*r* ≤ 6
λ_{max}	36.73 (0.35)	0.14 (0.25)	0.10 (0.51)	0.09 (0.28)	0.05 (0.69)	0.03 (0.43)	0.004 (0.33)
Trace	132.74(0.02)	96.01 (0.04)	62.99 (0.15)	39.80 (0.22)	18.96 (0.49)	8.48 (0.41)	0.93 (0.33)
Johansen co-integration tests within a UVAR(2) model: EU							
r	*r* = 0	*r* ≤ 1	*r* ≤ 2	*r* ≤ 3	*r* ≤ 4	*r* ≤ 5	*r* ≤ 6
λ_{max}	57.29 (0.00)	42.86 (0.02)	36.45 (0.02)	21.33 (0.25)	14.05 (0.36)	11.53(0.12)	2.54 (0.11)
Trace	186.08(0.00)	128.79(0.00)	85.93 (0.00)	49.47 (0.03)	28.14 (0.07)	14.08(0.08)	2.54 (0.11)

Notes: Figures in (#) are *p*-values.

Source: Authors' own estimation.

Although there is presence of co-integrating relationship among nominal exchange rate and monetary variables, it is still possible that there could be a shift in the co-integrating vector in response to deregulations and growing openness in foreign exchange markets, oil price shocks, and other shifts in policy regimes. This makes us cast doubt on the reliability of Johansen results and to test for long run equilibrium relationship in the light of structural breaks. Nevertheless, the robustness of the non-stationarity characteristics of the data in the level form as yielded from the traditional unit root tests (PP and KPSS tests), again have been conducted accounting for the structural shifts using powerful Lee and Strazicich (2003, 2004) LM unit root test. The LM unit root test considers up to two breaks in intercept as well as in intercept and trend both, in each series. The LM unit root results are presented in Table's 1A-8A (see the Appendix). Tables 1A to 4A report unit root results at *level* series, while Table 5A to 8A *first difference* series. Model A corresponds to *one break* and the Model AA to *two breaks* in intercept. On the other hand, Model C represents *one break* and Model CC denotes *two breaks* in the intercept and trend.

Irrespective of the models, the exchange rate and money supply series of all countries, except for exchange rate of EU and money supply of Britain in Model CC, are found to be non-stationary at the level. However, all the series attain stationarity at their first difference. For level series of IIP, Models A and AA, detect presence of unit root in all cases but, Models C and CC, in some cases show series is stationary. At their first difference, nevertheless, all the models detect stationarity of IIP series, except for India, in Model A and AA. In level, interest rate series are non-stationary in most cases, with some exceptions e.g. Fed fund rate in Model A and AA significant at 10 percent level; rejecting null of non-stationarity. However, irrespective of models interest rate series in their first difference are stationary for all countries. Moreover, the dummy variables for structural breaks are also significant in most of the models for variables under consideration, indicating prominence of shifts in the data series.

Having tested the unit root in the presence of significant breaks, we proceed to examine the long run equilibrium relationship between nominal exchange rate and monetary fundamentals using an alternative approach to Johansen-Juselius co-integration forwarded by Gregory and Hansen (1996). This novel approach provides an alternative that involves testing of one unknown shift in the co-integrating vector by testing the null of no co-integration against the alternative of co-integration with a break. The procedure of Gregory and Hansen can be applied at different steps to detect the shift in the parameters of the monetary model. A shift in the intercept of the model can be tested by testing the co-integrating relationship between nominal exchange rate and monetary variables (Model C), shift in intercept with the trend (Model C/T) and finally a more generic formulation involving a "regime shift" (Model C/S).

Table 3 Gregory and Hansen Co-integration Test Results

	Model 2 Break in intercept: no trend (C)			Model 3 Break in intercept: with trend (C/T)			Model 4 Regime shift (C/S)		
	Break date	Lag length	Test statistics	Break date	Lag length	Test statistics	Break date	Lag length	Test statistics
USA	2007:02	0	-7.372*	2007:02	0	-8.458*	2004:07	0	-8.569*
UK	1997:11	4	-6.538*	1997:11	4	-6.601*	2005:09	0	-7.747*
Japan	2001:05	4	-6.821*	2001:04	3	-6.863*	2001:04	3	-8.491*
EU	1998:11	1	-7.072*	1998:11	1	-7.225*	1998:11	0	-11.601*

Notes: The critical values for the Gregory-Hansen tests are drawn from Gregory and Hansen (1996). The approximate asymptotic critical values are -6.05 and -5.56 at 1 percent and 5 percent, respectively, for break in intercept and the no trend model; -6.36 and -5.83 at 1 percent and 5 percent, respectively, for break in intercept when the trend is included in the model and critical values are -6.92 and -6.41 at 1 percent and 5 percent, respectively, for the full structural break (regime shift) model.

Source: Authors' own estimation.

The results reported in Table 3 reveal that the null hypothesis of no co-integration is rejected for all the countries irrespective of the models at 1 percent level of significance. This suggests that there is a long run relationship among the variables with structural break. Hence, we conclude that our co-integration results emanated from the maximum likelihood that Johansen methodology is also robust to structural shifts. Moreover, since the estimated break points correspond to the minimum values of test statistics, these break points may be treated as time points at which the exchange rate functions have strongest tendency to shift. It can be seen that the break points do not occur in a particular year; rather vary across the models. Nevertheless, most of the break points cluster around some critical economic events. In case of USA, the break date corresponds to the period prior to global financial crisis. On the other hand, for European Union the break point is in consonance with emergence of Euro currency. The break date corresponding to UK corroborates with strong recovery of the British economy from recession of early 1990s.

4. Summary and Conclusion

This study re-examined the long run validity of the monetary approach to exchange rate determination using data from a developing country i.e. India. The long run association of bilateral nominal exchanges rates of Indian rupee vis-à-vis USD, Pound-sterling, Yen and Euro against the corresponding monetary fundamentals that the model underlined has been tested using two distinct co-integration techniques. First, the issue was analyzed under the Johansen-Juselius maximum likelihood framework and irrespective of the exchange rates; the results suggest presence of co-integrating relationship among the variables. So we argue that unrestricted reduced form monetary model is a valid framework for the analysis of long run exchange rate behaviour. However, recognizing possible shifts in the co-integrating vector we proceeded further for robustness check of Johansen results applying test of Gregory and Hansen co-integration. Nevertheless, pre-test of non-stationarity of all the series in the presence of up to two structural breaks has been carried out with recent methodology of Lee and Strazicich (2003, 2004) LM unit root test. After confirming that all series are integrated of order one in the presence of significant structural breaks, we checked for their long run relationship with Gregory-Hansen co-integration method that allows for one break determined endogenously. Confirming the long run relationship, all the *three* models of the test rejects the null of *no co-integration* accepting alternative of *co-integration with one shift*. This set of results suggests that the monetary model is a valid theory of long run equilibrium condition for the Rupee-USD, Rupee-Pound, Rupee-Yen and Rupee-Euro exchange rates.

Summing up, the study provides evidence for monetary approach as a valid long run relation for the four exchange rates considered against Indian rupee. As a policy prescription the study, therefore, suggests the monetary authorities to ensure price stability and stable monetary conditions so as to ensure stable exchange rate in the long run. The major limitations of the study, however, remain on the front of generalization of results and the data issues. As the analysis is undertaken exclusively against four exchange rates measured against Indian rupee, it will be fallacious to generalize the empirical findings to other currencies experience. Moreover, for the empirical analysis, the present study utilizes the monthly IIP as a proxy for twelve GDPs of the respective countries. Albeit for developed economies a major share of

GDP comes from industrial sector, for emerging economies like India the share of industrial production in total GDP stands merely at 20 percent. Thus, use of IIP as a proximate variable for income of the Indian economy can be counted as a major limitation of this study. Given that the GDP data is available only in annual or quarterly frequencies for the countries, the study could not exploit it in the empirical analysis. Moreover, with the use of annual or quarterly data, the study would have ended up with very limited data-points for the post-reform period in India.

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Appendix

Table 1A Univariate Unit Root Tests of Exchange Rates: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LEXU (Model A)	1996:02	---	*5*	-0.0190 [-2.0695]
LEXU (Model AA)	1996:02	2005:12	*5*	-0.0215 [-2.2469]
LEXB (Model A)	2008:07	---	*1*	-0.0390 [-2.2054]
LEXB (Model AA)	1998:05	2008:07	*1*	-0.0468 [-2.4167]
LEXJ (Model A)	2008:02	---	*1*	-0.0399 [-2.3538]
LEXJ (Model AA)	2005:06	2008:02	*1*	-0.0435 [-2.4522]
LEXE (Model A)	1998:12	---	*1*	-0.0704 [-3.0868]
LEXE (Model AA)	1998:12	2003:04	*1*	-0.0820 [-3.3491]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LEXU (Model C)	2000:11	---	*1*	-0.0596 [-2.8559]
LEXU (Model CC)	1996:02	2000:11	*6*	-0.1032 [-4.5888]
LEXB (Model C)	2005:02	---	*1*	-0.1090 [-3.7115]
LnEXB (Model CC)	1999:10	2006:08	*1*	-0.1990 [-5.0682]
LEXJ (Model C)	2006:12	---	*1*	-0.0744 [-3.0711]
LEXJ (Model CC)	2006:04	2009:07	*11*	-0.1294 [-4.3572]
LEXE (Model C)	1998:09	---	*0*	-0.089 [-3.0709]
LEXE (Model CC)	1998:11	2000:11	*9*	-0.3588* [-6.7610]

Source: Authors' own estimation.

Table 2A Univariate Unit Root Tests of Money Supply: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LMSU (Model A)	2008:08	---	*6*	-0.0200 [-2.2768]
LMSU (Model AA)	2001:09	2008:08	*6*	-0.0198 [-2.3757]
LMSB (Model A)	2009:06	---	*11*	-0.0155 [-1.9352]
LMSB (Model AA)	1997:08	2009:06	*10*	-0.0147 [-2.0572]
LMSJ (Model A)	2003:03	---	*9*	-0.0127 [-1.6929]
LMSJ (Model AA)	2001:06	2003:03	*9*	-0.0129 [-1.7467]
LMSE (Model A)	2004:08	---	*3*	-0.0164 [-1.3548]
LMSE (Model AA)	1996:02	2004:12	*3*	-0.0186 [-1.4647]
LMSI (Model A)	2006:10	---	*6*	-0.0372 [-1.9752]
LMSI (Model AA)	1999:11	2006:10	*6*	-0.0475 [-2.1888]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LMSU (Model C)	2005:09	---	*6*	-0.0312 [-2.7063]
LMSU (Model CC)	1998:11	2009:02	*6*	-0.0648 [-3.5275]
LnMSB (Model C)	2008:05	---	*0*	-0.0715 [-2.6743]
LMSB (Model CC)	2004:11	2009:05	*7*	-0.4522* [-8.0177]
LMSJ (Model C)	2003:03	---	*9*	-0.0956 [-3.5274]
LMSJ (Model CC)	2002:01	2003:12	*0*	-0.2220 [-4.9034]
LMSE (Model C)	2005:06	---	*0*	-0.0784 [-2.8982]
LMSE (Model CC)	1998:06	2004:11	*6*	-0.1042 [-4.0632]
LMSI (Model C)	2004:11	---	*6*	-0.0436 [-2.0041]
LMSI (Model CC)	1995:12	2004:12	*6*	-0.2099 [-4.1430]

Source: Authors' own estimation.

Table 3A Univariate Unit Root Tests of IIP: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LIIPU (Model A)	2008:12	---	*7*	-0.0150 [-1.9810]
LIIPU (Model AA)	2005:04	2005:04	*7*	-0.0156 [-2.0514]
LIIPB (Model A)	2007:08	---	*9*	-0.0859 [-2.0848]
LIIPB (Model AA)	2004:04	2007:08	*12*	-0.1427 [-2.9856]
LIIPJ (Model A)	2003:08	---	*5*	-0.1353 [-2.3123]
LIIPJ (Model AA)	1996:02	2009:06	*21*	-0.1589 [-2.8058]
LIIPE (Model A)	1997:12	---	*3*	-0.0348 [-2.5766]
LIIPE (Model AA)	1997:12	2008:04	*3*	-0.0439 [-2.9255]
LIIPI (Model A)	1997:02	---	*1*	-0.0951 [-2.6177]
LIIPI (Model AA)	1997:02	2000:03	*1*	-0.1244 [-3.0003]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LIIPU (Model C)	1999:06	---	*3*	-0.0332 [-2.4622]
LIIPU (Model CC)	1998:05	2008:06	*9*	-0.1409** [-5.8461]
LIIPB (Model C	2008:03	---	*12*	-0.2999 ** [-5.1026]
LIIPB (Model CC)	1998:12	2008:03	*12*	-0.6647* [-8.7029]
LIIPJ (Model C)	2008:08	---	*9*	-0.1867* [-5.3302]
LIIPJ (Model CC)	2003:07	2008:09	*9*	-0.2651* [-6.4645]
LIIPE (Model C	2008:08	---	*3*	-0.0689 [-3.2138]
LIIPE (Model CC)	1997:12	2008:08	*9*	-0.2146* [-6.3553]
LIIPI (Model C)	2001:07	---	*7*	-0.2406 [-4.0847]
LIIPI (Model CC)	1997:02	2001:07	*7*	-0.3764 [-5.1025]

Source: Authors' own estimation.

Table 4A Univariate Unit Root Tests of Interest Rate: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LINTU (Model A)	2001:01	---	*6*	-0.0224*** [-3.3223]
LINTU (Model AA)	2001:11	2008:03	*8*	-0.0249 *** [-3.5391]
LINTB (Model A)	2008:09	---	*1*	-0.0975 [-2.8662]
LINTB (Model AA)	1999:11	2008:09	*4*	-0.1070 [-3.2576]
LINTJ (Model A)	2009:01	---	*3*	-0.0062 [-1.0213]
LINTJ (Model AA)	1997:11	2009:01	*3*	-0.0066 [-1.0800]
LINTE (Model A)	1995:11	---	*3*	-0.0317 [-2.1269]
LINTE (Model AA)	1996:09	2007:05	*3*	-0.0375 [-2.2990]
LINTI (Model A)	2007:03	---	*0*	-0.0430 [-2.1748]
LINTI (Model AA)	1996:10	2007:03	*0*	-0.0502 [-2.3940]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LINTU (Model C)	2009:06	---	*6*	-0.0264 [-3.5771]
LINTU (Model CC)	2002:06	2007:09	*8*	-0.0683 [-5.2631]
LINTB (Model C)	2008:08	---	*4*	-0.1166 [-3.5130]
LINTB (Model CC)	2000:11	2008:08	*12*	-0.3180* [-6.0897]
LINTJ (Model C)	1997:11	---	*5*	-0.0674 [-3.7613]
LINTJ (Model CC)	1996:07	2006:06	*5*	-0.1490*** [-5.6436]
LINTE (Model C)	1997:04	---	*3*	-0.1067** [-4.5951]
LINTE (Model CC)	1997:04	2007:05	*3*	-0.1247 [-5.0103]
LINTI (Model C)	2006:12	---	*0*	-0.1006 [-3.1910]
LINTI (Model CC)	2005:05	2008:09	*0*	-0.1589 [-4.1994]

Notes: T_{B1} and T_{B2} are the dates of the structural breaks; *k* is the lag length. Figures in [#] are LM test statistics. Critical values of test statistic of both test (that is when breaks occur intercept and intercept and trend jointly) are reported in Lee and Strazicich (2003, 2004) two-break and one-break cases respectively. *, **, *** denote statistical significance at the 1%, 5% and 10% levels respectively.

Source: Authors' own estimation.

Table 5A Univariate Unit Root Tests of Exchange Rate Difference: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LDEXU (Model A)	2008:09	---	*0*	-0.7825* [-11.320]
LDEXU (Model AA)	2002:02	2008:09	*0*	-0.7921* [-11.4069]
LDEXB (Model A)	2001:06	---	*0*	-0.7106* [-10.5362]
LDEXB (Model AA)	2001:06	2006:03	*0*	-0.7493* [-10.9828]
LDEXJ (Model A)	1995:12	---	*0*	-0.7047* [-10.4344]
LDEXJ (Model AA)	2007:05	2009:01	*0*	-0.7615* [-11.0552]
LDEXE (Model A)	1997:07	---	*0*	-1.0057* [-14.22]
LDEXE (Model AA)	1997:10	1999:08	*0*	-1.0226* [-14.4269]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LDEXU (Model C)	2007:10	---	*0*	-0.7618* [-11.0407]
LDEXU (Model CC)	2007:03	2008:11	*0*	-0.8223* [-11.7211]
LDEXB (Model C)	1996:07	---	*0*	-0.8548* [-12.1765]
LDEXB (Model CC)	1997:11	2000:06	*0*	-0.8831* [-12.3180]
LDEXJ (Model C)	1997:02	---	*0*	-0.7765* [-11.2366]
LDEXJ (Model CC)	2005:08	2008:12	*0*	-0.7956* [-11.3916]
LDEXE (Model C)	1997:08	---	*0*	-1.0113* [-14.2738]
LDEXE (Model CC)	1997:06	1999:04	*0*	-1.0506 * [-14.7712]

Source: Authors' own estimation.

Table 6A Univariate Unit Root Tests of Money Supply Difference: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LDEXU (Model A)	2008:09	---	*0*	-0.7825* [-11.320]
LDEXU (Model AA)	2002:02	2008:09	*0*	-0.7921* [-11.4069]
LDEXB (Model A)	2001:06	---	*0*	-0.7106* [-10.5362]
LDEXB (Model AA)	2001:06	2006:03	*0*	-0.7493* [-10.9828]
LDEXJ (Model A)	1995:12	---	*0*	-0.7047* [-10.4344]
LDEXJ (Model AA)	2007:05	2009:01	*0*	-0.7615* [-11.0552]
LDEXE (Model A)	1997:07	---	*0*	-1.0057* [-14.22]
LDEXE (Model AA)	1997:10	1999:08	*0*	-1.0226* [-14.4269]
LDEXU (Model A)	2008:09	---	*0*	-0.7825* [-11.320]
LDEXU (Model AA)	2002:02	2008:09	*0*	-0.7921* [-11.4069]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LDMSU (Model C)	2008:07	---	*12*	-1.2335* [-7.1519]
LDMSU (Model CC)	2001:01	2008:05	*0*	-1.1389* [-16.0896]
LDMSB (Model C)	2009:06	---	*12*	-1.5950 * [-16.3564]
LDMSB (Model CC)	2004:11	2009:06	*12*	-1.6573 * [-17.1070]
LDMSJ (Model C)	2002:04	---	*0*	-0.8643* [-12.354]
LDMSJ (Model CC)	2000:11	2004:06	*0*	-0.9903* [-13.9075]
LDMSE (Model C)	2005:12	---	*0*	-1.1408 * [-16.254]
LDMSE (Model CC)	2005:04	2008:07	*0*	-1.1972 * [-17.140]
LDMSI (Model C)	2002:10	---	*0*	-1.2854 * [-18.9715]
LDMSI (Model CC)	2005:08	2008:10	*0*	-1.2982 * [-19.1587]

Source: Authors' own estimation.

Table 7A Unit Root Tests of IIP Difference: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LDIIPU (Model A)	2009:04	---	*2*	-0.4706* [-4.7975]
LDIIPU (Model AA)	2007:09	2009:06	*2*	-0.6792* [-5.9703]
LDIIPB (Model A)	2004:04	---	*8*	-1.0979*** [-3.3142]
LDIIPB (Model AA)	2001:11	2007:03	*0*	-1.1826*** [-3.5862]
LDIIPJ (Model A)	2009:01	---	*9*	-0.1484* [-4.4119]
LDIIPJ (Model AA)	2003:08	2009:01	*9*	-0.1910* [-5.0314]
LDIIPE (Model A)	2008:11	---	*2*	-0.6631* [-6.0113]
LDIIPE (Model AA)	2001:03	2008:11	*2*	-0.7009* [-6.1957]
LDIIPI (Model A)	1997:03	---	*7*	-0.0517 [-1.9169]
LDIIPI (Model AA)	1997:07	2005:10	*2*	-0.0886 [-2.1294]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LDIIPU (Model C)	2008:04	---	*0*	-1.0601* [-14.991]
LDIIPU (Model CC)	2007:01	2009:04	*0*	-1.0994* [-15.519]
LDIIPB (Model C)	2009:07	---	*12*	-2.7309* [-8.6526]
LDIIPB (Model CC)	2000:03	2008:11	*10*	-2.2123 * [-13.136]
LDIIPJ (Model C)	2008:10	---	*12*	-0.7306 * [-7.2636]
LDIIPJ (Model CC)	2007:05	2009:01	*12*	-1.4659* [-11.5706]
LDIIPE (Model C	2008:09	---	*2*	-0.7783* [-6.1741]
LDIIPE (Model CC)	2007:04	2009:03	*0*	-1.1980 * [-17.1145]
LDIIPI (Model C)	1997:05	---	*2*	-1.4207 * [-10.456]
LDIIPI (Model CC)	1997:05	2003:06	*0*	-1.5160 * [-23.3682]

Source: Authors' own estimation.

Table 8A Univariate Unit Root Tests of Interest Rate Difference: Constant and Trend Included in the Model with Structural Breaks

Country	Lee-Strazicich's LM unit root test			
	T_{B1}	T_{B2}	*k*	*Test statistics*
	Results for univariate LM unit root test with one and two structural break in intercept/constant only (i.e. Model A and AA)			
LDINTU (Model C)	2007:10	---	*0*	-0.4148* [-7.2224]
LDINTU (Model CC)	2000:12	2007:07	*0*	-0.5165* [-8.2937]
LDINTB (Model C)	2007:12	---	*0*	-1.4257* [-22.2262]
LDINTB (Model CC)	2007:04	2008:12	*0*	-1.4550* [-22.9322]
LDINTJ (Model C)	1996:02	---	*0*	-0.7132 * [-10.4874]
LDINTJ (Model CC)	1995:12	1999:04	*0*	-0.7242* [-10.5509]
LDINTE (Model C)	1998:09	---	*0*	-0.8450 * [-12.0517]
LDINTE (ModelCC)	1995:12	2000:03	*0*	-0.8918* [-12.524]
LDINTI (Model C)	2008:09	---	*0*	-1.0265* [-14.558]
LDINTI (Model CC)	2006:03	2008:09	*0*	-1.0426 * [-14.721]
	Results for univariate LM unit root test with one and two structural break in intercept/constant and trend both (i.e. Model C and CC)			
LDINTU (Model C)	2007:10	---	*0*	-0.4148* [-7.2224]
LDINTU (Model CC)	2000:12	2007:07	*0*	-0.5165* [-8.2937]
LDINTB (Model C)	2007:12	---	*0*	-1.4257* [-22.2262]
LDINTB (Model CC)	2007:04	2008:12	*0*	-1.4550* [-22.9322]
LDINTJ (Model C)	1996:02	---	*0*	-0.7132 * [-10.4874]
LDINTJ (Model CC)	1995:12	1999:04	*0*	-0.7242* [-10.5509]
LDINTE (Model C)	1998:09	---	*0*	-0.8450 * [-12.0517]
LDINTE (ModelCC)	1995:12	2000:03	*0*	-0.8918* [-12.524]
LDINTI (Model C)	2008:09	---	*0*	-1.0265* [-14.558]
LDINTI (Model CC)	2006:03	2008:09	*0*	-1.0426 * [-14.721]

Notes: T_{B1} and T_{B2} are the dates of the structural breaks; *k* is the lag length. Figures in [#] are LM test statistics. Critical values of test statistic of both test (that is when breaks occur intercept and intercept and trend jointly are reported in Lee and Strazicich (2003, 2004) two-break and one-break cases respectively. *, **, *** denote statistical significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' own estimation.