Structural break, stability and demand for money in India

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Abstract

This paper attempts to take a meticulous look on stability of money demand in India Using annual data for period 1953-2007 and the Hansen (1992) and Gregory Hansen (1996) co-integration approaches with structural break. Results of the Gregory Hansen (1996) cointegration analysis show the presence of cointegration in demand for money, real GDP and nominal interest rate with structural break at 1965. Further, study also suggests for downward shift of about 0.33 % around 1965 in the demand for money function and put forward that demand for money is stable except for the period of 1975-1998.

Keywords: Money Demand, Cointegration with Structural Break, Stability, Choice of Monetary Instrument

JEL classification: E41, E52

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1. Introduction

The issue of long run relationship among broad money and its determinants and the stability of the demand for money have always been in the centre of conduct of the monetary policy and it has gained currency due to increased financial innovations, reforms in financial sector, shift in exchange rate policy world-wide and increased financial integration. However, theoretical and empirical approaches have been complex and multi-directional. In Indian context too, this issue is quite comprehensive and extensive and well studied by many researchers (Vasudevan, 1977; Arif, R.R. 1996; Mohanty, and Mitra, 1999; Bhanumurthy, 2000; and Ramachandran, 2004). In last 40 years, India has witnessed so many ups and downs in macroeconomic policy framework. During this period, determinants of demand for money e.g. GDP, interest rates, inflation etc., have changed drastically responding to changed political and economic climate. For example, India experienced two consecutive famine and wars with China and Pakistan during 1960-65; political instability in the form of two general elections in three years (during 1977-79). Generally it is believed that element of uncertainty introduced by war and other factors reduces the efficiency of the financial system. In 1980, RBI moved to monetary targeting as recommended by the Chakravarty Committee (1985). Furthermore, in 1980s financial deregulation took place and in 1990's deregulation of deposit rates influenced interest-rate structure. The year 1986-87 was the time when India had its first stroke of hesitant reform. Again in early 1990's amid the reserve crisis and pressures from external international agencies (IMF and World Bank), India was forced to devaluate its currency and move to a flexible exchange rate regime from fixed one. In 1994, Reserve Bank of India (RBI) got some mussel to exercise monetary policy independently in the form of its agreement with government of India to bear fiscal burden only through issuance of 91 days ad-hoc Treasury bills. Again in 1998, RBI moved to multiple indicator approach[2] for the conduct of monetary policy from a regime of monetary targeting approach (RBI; 1998-99).

Macroeconomic theory suggests that the use monetary targeting or money supply as intermediate target by central bank to realise the output growth and price stability as long term goal depends upon stability of the money demand function. The RBI adopted monetary targeting in the middle of 1980 as the intermediate target. Available literature for India does suggest that empirical results on stability of money demand are sensitive to the methodology and variables used in the analysis. As in Pradhan and Subramanian (1997), Das and Mandal (2000), Ramachandran (2004) and Rao & Singh (2006), it is stable whereas Bhanumurthy (2000) concludes that demand for money in India is not stable. Motivated by the mixed results of stable and unstable scenario of demand for money in India, increased capital inflow in the economy during the recent past; this study is an attempt to re-look the issue using annual data for period 1953-2007 by applying the Gregory and Hansen (1996) co-integration approach with structural break.

Contribution of the present study comes from the use of Hansen (1992) and Gregory-Hanson (1996) co-integration approach with structural break as it helps in determining in the presence of cointegration among the variables while adjusting the possible structural

[2] The Reserve Bank, formally adopted a multiple indicator approach in April 1998 whereby interest rates or rates of return in different financial markets along with data on currency, credit, trade, capital flows, fiscal position, inflation, exchange rate, etc., are juxtaposed with the output data for drawing policy perspectives.

break endogenously where most of the study fails to accommodate this approach as they have used only co-integration tests, ECM, ARDL models or combination of these to estimate money demand function but they do not use Hansen (1992) to test parameter instability in I(1) processes and consequently, Gregory and Hanson (1996). Further, we have used two different specifications to estimate the money demand function. In one specification demand for money is function of inflation and real output where as in the second specification it is function of nominal interest rate and real output.

The structure of the rest of the paper is as follows: section 2 attributes to the review of literature and section 3 discusses methodological approaches the study adopt to estimate demand for money in India. The data and variables are discussed in section 4 and section 5 outlined the estimation results. The paper ends with section 6 where implications of the study on India's monetary policy and conclusions are briefly discussed.

2. Review of Literature

Numerous quantitative research efforts have been made to analyze demand for money and related issues for India and other developed and developing countries. Nag and Upadhyay (1993), Parikh (1994), Sriram (1999), Ghatak and Ghatak (1994) and Rao and Shalabh (1995) are some of the examples. All of these have utilized different forms of variables, econometric methods and tests to estimate money demand function for India. However results are not consistent. Some earlier studies support the hypothesis that narrower definitions of money supply are better for pursuing monetary policy as it provides stability over long term (e.g. Moosa, 1992; Bhattacharya, 1995) while recent studies refute this and suggest to use M3 as indicator of money supply, though holding that India's money demand function is stable (e.g. Pradhan and Subramanian, 1997; Das and Mandal, 2000; Ramachandran, 2004).

Moosa (1992) found that the money balance had co-integrating relationship with output and interest rates for all the three types of money supply and argues that as greater numbers of co-integrating vectors were detected for cash and M1 than for M2, narrower definitions of money supply are better for pursuing monetary policy. However, Bhattacharya (1995) concluded that a co-integrating relationship exist among variables only if money supply is M1. A negative and significant error correction term, estimated using error correction model (ECM) based on Johansen’s co-integration test (1991) showed that long-term interest rates are more sensitive to money demand than short-term interest rates which suggests that money demand in India is stable over the long term only when money supply is narrowly defined. Further, Bahmani-Oskooee and Rehman (2005) analyzed the money demand functions for seven Asian countries including India and found that for India, co-integrating relationships were detected only for M1 as money supply not for M2 and therefore, concluded that M1 is the appropriate money supply definition to use in setting monetary policy.

Pradhan and Subramanian (1997) suggested that money demand function is stable not only with M1 but also with M3 and the error correction term for both M1 and M3 money supply definitions was found out to be negative and significant. However, Rao & Singh (2006) highlights some of its limitations. Further, Das and Mandal (2000) and

Ramachandran (2004) suggest using M3 money supply definition by mentioning that India's money demand function is stable.

The recent empirical results of Inoue and Hamori (2008) indicate that an equilibrium relation in money demand exists, only when money supply was defined as M1 and M2, not for M3. Cointegration test result indicates that a co-integrating vector is detected among real money balance, interest rates, and output when money supply is represented by M1 and M2 but no long-run equilibrium relationship is found for M3. Moreover, Inoue and Hamori (2008) claim that when the money demand function was estimated using dynamic OLS, the sign conditions of the coefficients of output and interest rates were found consistent with theoretical rationale, and statistical significance was confirmed when money supply was represented by either M1 or M2. Consequently, they suggested that India’s central bank should focus on M1 or M2, rather than M3, in managing monetary policy.

Many studies reveal that interest rate is an important predictor of money demand function but there is a debate over use of its form: real or nominal. Till late 70’s, there was no single opinion about what constitutes money and what is the correct specification for the rate of interest (Vasuvedan, 1979). Some studies during early 2000 in developing nations have used real rate of interest while modeling demand for money, in particular, Jayaraman and Ward (2000) for Fiji, Ahmed (2001) for Bangladesh. However, Rao and Singh (2006) take on these studies for using real rate of interest and argue that inspite of showing insignificant effect in money demand functions due to less variation in the nominal rate of interest for developing countries, nominal rate is an ideal explanatory variable for demand for money. Further, they justify for inclusion of the real rate, along with other nominal rates and the expected rate of inflation in the situations where substitution between money and real assets is important. The role of interest rate becomes important when demand for money is unstable and under these circumstances it is more appropriate to target interest rate (Poole, 1970). Further, there was a long debate over the use of proper income variable as it can be expressed in nominal or real terms or as a combination of lagged agricultural and non-agricultural incomes (Rangarajan, 1977; Vasuvedan, 1979). Methodologically, though there are studies based on Gregory and Hansen (1996) framework with structural break for other Asian countries (see for example, Rao and Kumar, 2007 for Bangladesh), there is no such literature available for India to our knowledge.

3. Methodology

Hansen (1992) made an important contribution in the existing literature of the cointegration study by setting a stage that parameters should be allowed to change over time in non stationary time series. Thus, Hansen (1992) suggests tests for parameter instability as an alternative test for cointegration between I(1) variables. Hansen (1992) test is based on the fully modified OLS methodology of Hansen (1990) and uses three test statistics for testing the parameter instability and cointegration among the variables, namely; Sup*F* test, the Mean*F* test, and the *Lc* test. Null hypothesis is same for all the three tests, but differs in alternative hypothesis. Given the rejection of cointegration with unknown break in the parameter we have also adopted a different test to see the presence of cointegration among the variables namely, Gregory and Hanson (1996) technique which allows us to test the null of no cointegration for the listed variables with I(1) order in the presence of structural break in the cointegrating relationship. Gregory–Hansen (1996) (GH henceforth) methodology is an extension of the Engle-Granger (1987) cointegration analysis (EG approach) and can be seen as a multivariate extension of the endogenous break test for univariate series. The GH test allows to test the presence of cointegration among the variables of interest given the variables are integrated of order I(1) i.e. difference stationary, with regime shift in the long run relationship at an unknown point. Gregory and Hansen introduce four different models to take into account for the structural change in the cointegrating relationship under the alternative. The first model is a level shift model, denoted as C and defined as:

$$Y_t = \alpha + \beta D_t + \delta X_t + u_t \qquad (1)$$

where Y_t is a scalar variable, X_t is an vector of explanatory variables (as explained both Y_t and X_t are supposed to be I(1)), u_t is the disturbance term, D_t is a step dummy variable defined as: $D_t=1(t>Tb)$, where 1(.) denotes the indicator function. Parameters α and β measure respectively the intercept before the break in Tb and the shift occurred after the break, while a are the parameters of the cointegrating vector

The second model is the level shift with trend model, denoted as C/T

$$Y_t = \alpha + \beta D_t + \phi t + \delta X_t + u_t \qquad (2)$$

Here t is time trend. Next model allows for shift in the parameter of cointegrating vector i.e. shift in regime.

$$Y_t = \alpha + \beta D_t + \delta X_t + \phi X_t D_t + u_t \quad (3)$$

Where ϕ measure the change in the cointegrating vector after the regime shift. In addition to these three models Gregory-Hansen added fourth model where the model allows for shift in both regime and trend. We have not used this model to test the presence of cointegration due to software limitation.

$$Y_t = \alpha + \beta D_t + \phi t + \delta X_t + \varphi X_t D_t + u_t \quad (4)$$

The reason we have chosen GH method instead of using unit root test with structural break is that it is likely that variables will have different structural break dates and thus it will be empirically difficult to test the null of no cointegration with regime shift. Additionally, as we are interested to see the long run behaviour of the variables, GH will perform better than other cointegration test when it is expected that there will be shift in the regime of long run relationship too.

All the GH tests are residual based, and the null hypothesis of no cointegration corresponds to a unit root in the OLS residuals of models *C*, *C/T*, *C/S* and *C/S/T,* break point in the cointegrating relationship is calculated at the point where t-statistics is minimum. Further, ADF test statistics is used to calculate test statistic.

4. Data Description and Model Specifications

Present study uses yearly data from 1952-53 to 2006-07. The source of data is handbook of statistics on Indian economy published by RBI for different years. Real GDP is GDP at constant prices of 1999-2000, M3 is the broad money supply deflated by WPI to get the real money supply. WPI is whole sale price index used for inflation measure. For short term nominal interest rate we have used bank rate data. All the variables used are in their logarithmic form, except bank rate. We have used two model specifications initially to estimate the demand for money in Indian context. In the first case, we have utilised specifications used in Ramachandran (2004), Bhanumurthy (2000), and Mohanti and Mitra (1999) where they have defined demand for broad money (M3) as the function of real GDP and WPI whereas in the second model we borrowed specification from Rao and Shalabh (1995) and Rao and Singh (2006) where, the demand for money is a function of real GDP and short term nominal interest rate. We specify two models:

Model I: $M = f(Y, P)$ and

Model II: $M = f(Y, r)$

where M is real money balance ($M3$ deflated by WPI), Y is real GDP, P is whole sale price index (WPI) and r is nominal interest rate (bank rate).

In the first model coefficient of real GDP is expected to have positive sign and coefficient of WPI (price) is supposed to have negative sign. Similarly, in the second model coefficient of real GDP is supposed to be positive and nominal interest rate variable i.e. bank rate is believed to have negative sign. The reason we have taken nominal interest rate instead of real interest is that nominal interest show considerable low variability than that of that of real interest due to the volatile nature of inflation in developing countries.

Including real interest thus will not capture the true effect of interest rate in the estimation of demand for money. Again M3 will explain the demand for money more batter instead of M1 and M2.

The implied specification for the three Gregory and Hansen equation with structural break are as follows:

$$\ln M_t = \alpha + \mu\varphi_{tk} + \phi_1 \ln Y_t - \phi_2 r_t / P_t + \varepsilon_t \tag{5}$$

$$\ln M_t = \alpha + \mu\varphi_{tk} + \beta_t t + \phi_1 \ln Y_t - \phi_2 r_t / P_t + \varepsilon_t \tag{6}$$

$$\ln M_t = \alpha + \mu\varphi_{tk} + \beta_t t + \phi_1 \ln Y_t + \phi_{11} \ln Y_t \varphi_{tk} - \phi_2 r_t / P_t + \phi_{22} r_t / P\varphi_{tk} + \varepsilon_t \tag{7}$$

5. Estimation Results

It is essential to check the unit root properties of individual series before going for time series study to avoid spurious regression. We have examined the order of integration of the individual series using Phillips-Perron (PP) test of unit root, result of which is reported in the table 1. Result of the PP test indicates presence of unit root at level but all the series are stationary at difference[3]. We have also used the unit root test of Lee and Strazicich, 2003 (hanceforth,LS) which allows the endogenous breaks in constant and trend term of the series. We have not used the results of the LS test because the breaks dates for different series are not coinciding. Results and details of the test is given in appendix.

[3] we have used constant and trend at level but only constant at difference series while testing the null of unit root with PP test, as it is believed that differencing of the series takes away trend from the series

Table 1: Unit Root Test Result

Variables	PP test critical values	
	Level	1^{st} Diff
Y	1.94	-8.62*
M	-0.74	-6.68*
r	-0.48	-6.74*
P	-3.13	-5.18*

* indicate significance at 1 % level of significance

Now as the variable follow same order of integration I (0) at difference and I (1) at level, we can use different cointegration methods for testing presence of cointegration. Before applying Gregory-Hansen (1996) test for cointegration with structural break, we have used Hansen (1992) tests for parameter instability in regression with I (1) processes in both the specifications of money demand equation.

Result for specification 1, in the equation form is as follows:

$$M3 = -269.866 + 32.864{*}T - 0.496{*}Y - 0.470{*}R$$
$$\quad\;\; (152.52) \quad (5.03) \quad (0.094) \quad (0.087)$$

$\hat{M}$ = 12.14

L_C = 396501.08 [p=0.01]

Mean$F$ = 10729037 [p=0.01]

Sup$F$ = 17498070 [p=0.01]

Result for specification 2, in the equation form is as follows:

$$M3 = -186.673 + 27.280*T - 0.348*Y - 0.347*P$$
$$(91.16) \quad (3.03) \quad (0.06) \quad (0.05)$$

$\hat{M}$ = 1.88

L_C = 937.76 [p=0.01]

Mean$F$ = 26297.41 [p=0.01]

Sup$F$ = 42370.20 [p=0.01]

where $\hat{M}$, L_C, Mean$F$ and Sup$F$ are the estimated bandwidth parameter, fixed known breakpoint, average and largest F- values. Where values in ( ) parenthesis indicates t-statistics values corresponding to the variable and p stands for probability values given in in [] parenthesis.

It is clear from the above that in both the specifications, Hansen (1992) test rejects the null of co-integration at 1% level of significance. However, this test cannot distinguish between lack of co-integration per se or a regime shift, and a further test is necessary to establish this distinction. So, next we move to apply Gregory and Hansen (1996) test which is a residual-based test for co-integration and allow for structural break/regime shifts.

In this, first we have tested the null hypothesis of no cointegration using G-H method of cointegration with the model specification used in Sriram (1999) and Rao and Singh (2006), where real broad money demand is a function of real GDP and nominal interest rate. Result of the G-H co-integration suggests presence of cointegration among real broad money, real income and nominal interest rate in all the three models of structural break (see table 2 and 3). Whereas, with the specification as in Ramachandran (2004) and Bhanumurthy (2000), (where demand for money is a function of real GDP and inflation), we failed to get the cointegration with break in intercept and break in regime i.e. null of no cointegration is not rejected. With this specification, cointegration is present only with the break in trend. Year 1965, is the common date of break for both the models.

Table 2: Gregory -Hanson Cointegration Test Result with WPI

Model	Break date	GH test statistic	5% critical value
GH-I	1965	-4.15	-4.92
GH-II	1965	-5.85	-5.29
GH-III	1975	-5.12	-5.50

Table 3: Gregory-Hanson Cointegration Test Results with RBR

Model	Break date	G-H test statistic	5% critical value
GH-I	1965	-5.12	-4.92
GH-II	1965	-6.79	-5.29
GH-III	1973	-6.20	-5.50

We further proceed with the second model specification[4] which uses demand for money as the function of real GDP and interest rate rather than real GDP and WPI (prices). In order to select the best possible model of structural break, we have estimated all the three cointegrating equations with breaks using Engel–Granger method. Results of the

[4] Coefficient of income elasticity in the cointegrating equation of model I with break in trend is very low (0.4457) and got rejected in the Wald test of restriction that is why we have rejected the model I for further estimation.

estimation with OLS have been presented in table 4. Result of the estimation suggests that GH-II is the most possible model as income elasticity of demand for money is negative for GH-I and GH-III. Wald test statistic for the null of unit elasticity of the coefficient of income elasticity of demand for money failed to reject it in GH-II[5]. Further, coefficients of all the other variables are with expected sign and magnitude. Thus, we discard the estimate of GH-I and GH-III as it is not in accordance with economic theory. We now use the residual obtained in the cointegrating equation of GH-II specification for estimating the short run dynamics of the demand for money with error correction term (ECM).

Table 4: Co-integrating Equations

Variables	GH-I(1965)	GH-II(1965)	GH-III(1973)
Intercept/constant	8.91	-4.55	13.76
Trend		0.04	
Break date dummy	-0.40	-.33	-6.62
LY	-0.36	0.82	-0.72
Break date dummy*LY			0.44
r	-0.05	-0.01	-0.15
Break date dummy*r			0.12

In the next stage we have used LSE – Hendry general to specific modeling framework to develop the short term ECM model. To obtain the ECM model we have regressed differenced series of money demand (M) on differenced terms of real GDP, nominal

[5] The Wald test statistic is 0.884074 with p-value of 0.35.

interest rate, their lagged terms and with lagged terms of M. We initially took 4 lags of all the variables and then using LSE Hendry methodology we reduced the no of lags to get best representative model. Result of the best and most parsimonious model is following:

$$\Delta M_t = -0.203*ECM_{t-1} + 0.462*\Delta Y_t + 0.735*\Delta Y_{t-1} - 0.025*\Delta r_t$$

$$(-2.032^{**}) \quad (2.5397^{**}) \quad (3.200^{*}) \quad (-2.5542^{**})$$

$$+ 0.224*\Delta M_{t-1}$$

$$(1.815^{**})$$

$R^2 = 0.44032$, Adj $R^2 = 0.39368$

t-values of the coefficients are in parentheses * and** indicates significance at 1% and 5% level of significance, respectively. Results of serial correlation test and ARCH-LM test show that model is robust[6].

5.1 Testing Stability of the Demand for Money

This section presents the test for the stability of the demand for money estimate. Test for stability of demand for money is important as supply of money is one of the key instruments of monetary policy conduct by RBI. If the demand for money is stable then money supply is the most suitable monetary policy instrument but if the money demand function is not stable central bank should use interest rate as the more appropriate instrument for the conduct of monetary policy (as evident from the central bank

[6] F-statistic and its probability (in []) of the serial correlation test and ARCH effect test is respectively: 2.6287[0.112] and 2.2538[0.140]

behaviour in industrial economies, where the demand for money found to be unstable since late 80's). It is argued that evolution and development of the financial market together with innovation in information technology brings in element of sensitivity in the demand for broad money in the economy but except for Bhanumurthy (2000) and Ramachandran (2004), studies on demand for money in India largely depicts stability in the broad money demand, even considering for reforms. Income velocity of broad money shows a clear declining trend which is possibly due to the shift in the demand function, though not supported by empirical studies for India. After estimating the demand for money function, we have used the conventional methods for the test of stability of the demand for money function; these tests include CUSUM, CUSUMSQ and recursive estimation technique.

[Figure 1 about here]

Figure 1 and 2 presents the plot of CUSUM and Cumulative sum of squares with 5% level of significance, plot of the CUSUM shows instability of the demand for money function during the period 1975-1997. Result of the CUSUM and CUSUM of Square are little surprising as Indian economy did not went for reform till the beginning of 90's. But this instability in the demand for money may be due to the fact that during this time Indian economy has seen political uncertainties (Indian economy has of the seen war with Pakistan, two frequent general elections, change in the central policy under Janata Party government and first phase of hesitant reforms in 1985-86). We have also seen in the beginning of 90's wave of financial reforms, devaluation of the currency and also shift in the exchange rate regime. Transmission of the financial reforms can also be considered as one of the reason for money demand function stability after late 90s.

[Figure 2 about here]

Plot of recursive residual does not clearly show any presence of instability as it only touches the upper band around 1975 (see figure-3). Other than these periods demand for money has been stable in India, even in the post reforms period as evident from the CUSUM, CUSUM square and recursive estimation with structural break in the co-integration.

[Figure 3 about here]

6. Conclusions

RBI followed monetary targeting approach during the period of 1985 to 1998. After this period RBI moved to a multiple indicator approach based monetary policy approach, wherein not only the growth rate of money supply but also the movement of a host of economic variables would be monitored for policy initiatives. Possibly in response to the instability of the money demand and kind of changes happening in financial market (increased financial innovations, shift in exchange rate policy and global financial integration and East-Asian crisis). However, during 1985-1998, an increase in money supply was seen, possibly due to international oil price shocks. It is suspected that financial innovations make demand for money unstable and thus makes supply of money as an instrument of monetary policy by central banks obsolete. In this regard, most of the studies show that there is no significant effect of reforms on the stability of the money demand function and it remained stable during the post reforms period in India. Hence present study has made an effort to look in the issue of stability and long run relationship of money demand in India using different approaches and methodologies.

Using cointegration approach developed by Gregory-Hansen (1996) findings of the study shows that both income and interest rate elasticity's are significant and carry expected signs. Demand for money function has seen a downward shift of about 0.33 % around 1965; this downward shift can be attributed to the spill over effect of reforms in the financial sector world wide and the liberalization policies. Study result reflects that demand for money was unstable during the period of 1975-1998 but it is stable after few years of reform period. Stability of the money demand function in the post reforms era indicates that supply of money can still be used as key instrument of the monetary policy but it requires some caution as the instability may turn back due to high inflow of international capital. Instability in the money demand function during the period could be attributed to the policy reforms, fiscal expansion, crisis in the balance of payment situation and currency devaluation and other changes in the monetary policy front.

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Appendix

Lee and Strazicich (2003) Test for Unit Root Test with Possible Endogenous Structural Break in the Series

We use the minimum LM unit root tests of Lee and Strazicich (2003) hereafter LS—to test for stationarity in the presence of possible structural breaks. The minimum LM tests may be fairly compared with the one-break minimum unit root test by Zivot and Andrews (1992) or the two-break minimum test by Lumsdaine and Papell (1997). These comparable tests, while commonly used in the literature, typically assume no breaks under the null. Although these minimum tests can be valid if the null hypothesis does not imply any break, their test statistics diverge when possible breaks exist under the null. This causes size distortions leading to frequent spurious rejections (Lee & Strazicich, 2001; Nunes, Newbold and Kuan, 1997). In many applications using these tests, the unit root null is often rejected and this result has been regarded as evidence supporting stationarity. Rejection of the null from these tests, however, does not necessarily imply rejection of a unit root per se, but may suggest rejection of a unit root without break. Conversely, the minimum LM tests of LS are free of such criticism as their tests allow for possible structural breaks in a consistent manner under both null and alternative hypotheses. Lumsdaine and Papell (1997) and Perron (1997) tests, which are DF-type tests, have size distortion problem. Furthermore, Lee and Strazicich (2001) found that the asymptotic null distributions of the DF-type endogenous break test statistics are affected by nuisance parameters indicating the magnitude and location of the break.

In the single break in the series model considers three structural breaks as follows. The "crash" Model A allows for a one-time change in level; the "changing growth" Model B allows for a change in trend slope; and Model C, which allows for a change in both the level and trend. Consider the data generating process (DGP) as follows for single break in the series model:

$$Y_t = dZ_t + e_t, e_t = be_{t-1} + \varepsilon_t \tag{a.1}$$

where Z_t is a vector of exogenous variables and $\varepsilon_t\, t \sim$ iid $N(0, \sigma^2)$. Now two structural breaks can be considered on the line of one structural break model as follows. Model A allows for two shifts in level compared to only one in the one break model and is described by $Z_t = [1, t, D_{1t}, D_{2t}]'$, where $D_{jt} = 1$ for $t \geq T_{Bj} + 1$, $j=1,2$, and zero otherwise. T_{Bj} denotes the time period when a break occurs. Model C includes two changes in level and trend and is described by $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$, where $DT_{jt} = t$ for $t \geq T_{Bj} + 1$, $j=1, 2$, and zero otherwise. Note that the DGP includes breaks under the null ($b = 1$) and alternative ($b < 1$) hypothesis in a consistent manner. For instance, in Model A (a similar argument can be applied to Model C), depending on the value of b, we have:

$$H_o: \quad y_t = \mu_o + d_1 B_{1t} + d_2 B_{2t} + y_{t-1} + v_{1t} \tag{a.2}$$

$$H_1: \quad y_t = \mu_1 + \gamma.t + d_1 D_{1t} + d_2 D_{2t} + y_{t-1} + v_{2t} \tag{a.3}$$

where v_{1t} and v_{2t} are stationary error terms, $B_{jt} = 1$ for $t = T_{Bj} + 1$, $j=1,2$, and zero otherwise, and $d = (d_1, d_2)'$. In Model C, D_{jt} terms are added to equation a.2 and DT_{jt} terms to equation a.3, respectively. Note that the null model in the equation a.2 includes dummy variables B_{jt}. Perron (1989, p. 1393) showed that including B_{jt} is necessary to insure that the asymptotic distribution of the test statistic is invariant to the size of breaks (*d*) under the null.

Variables	**LS unit root test with structural breaks (Two-break)**	
	Level	1^{st} Diff
Y (1980, 1998)	-5.14	-8.20*
M (1982, 1997)	-6.88*	-8.60*
r (1973, 1995)	-5.95*	-8.20*
P (1964, 1996)	-5.50	-6.64*

Note: * indicates significance at 1% level of significance and (.) in the 'variables' column gives two break dates

Results of the LS unit root test indicates that M3 and bank rate are level stationary against PP unit root test results where all the variables are stationary only at first difference. One thing very interesting came in this result is the second date of structural break in the series. All the series shows second structural break between 1995 and 1998, possibly which can be attributed to effect of economic reforms in India during 1991-92.

Table a.1: Summary of Literature Review for Demand for Money in India

Reference	Period/Frequency	Dependent Variable(s)	Explanatory Variable(s)	Methodology used	Conclusion
Moosa (1992)	1972Q1:1990Q4, Quarterly	Cash, M1, M2	Short-Term Interest Rates, and Industrial Production	Co-integration Tests	Co-integrating relationship of money balance found with output and interest rates for all the three types of money supply
Bhattacharya (1995)	1950:1980, Yearly	Real Money Balances	Real GNP, and Long-term and Short-term Interest Rates	Co-integration Tests	Co-integrating relationship exist among variables only for M1
Bahmani-Oskooee and Rehman (2005)	1972Q1:2000Q4, Quarterly	Real Money Supplies	Industrial Production, Inflation Rates, and Exchange Rates(in US dollar)	Auto Regressive Distributed Lag Model (ARDL) and the Bond Test based Co-Integration Tests	Co-integrating relationships for M1 but not for M2

Continued….

Reference	Period/ Frequency	Dependent Variable(s)	Explanatory Variable(s)	Methodology used	Conclusion
Pradhan and Subramanian (1997)	1960: 1994, Yearly	Money Balances	Real GDP, and Nominal Interest Rates	Co-integration Tests and an Error Correction Model	Money demand function is stable for M1 and M3
Das and Mandal (2000)	1981 April: March 1998, Monthly	Money Balance,	IIP, Short-Term Interest Rates, WPI, Share Prices, and REER	Co-integration Tests	Broad money in stable and exogenous in India for the period 1981-1998.
Ramachandran (2004)	1951: 2000, Yearly	Nominal Money Supply	Output, and Price Levels	Co-integration Tests	Given the stability of the Growth of Broad Money (M3) can be used as instrument of monetary policy conduct in India.
Inoue and Hamori (2008)	1980:2007, Monthly and 1976: 2007, Yearly	Real Money Balance	Interest Rates, and Output	Co-integration Test, Dynamic OLS	Equilibrium relation in money demand exists for M1 or M2, but not for M3

Figures

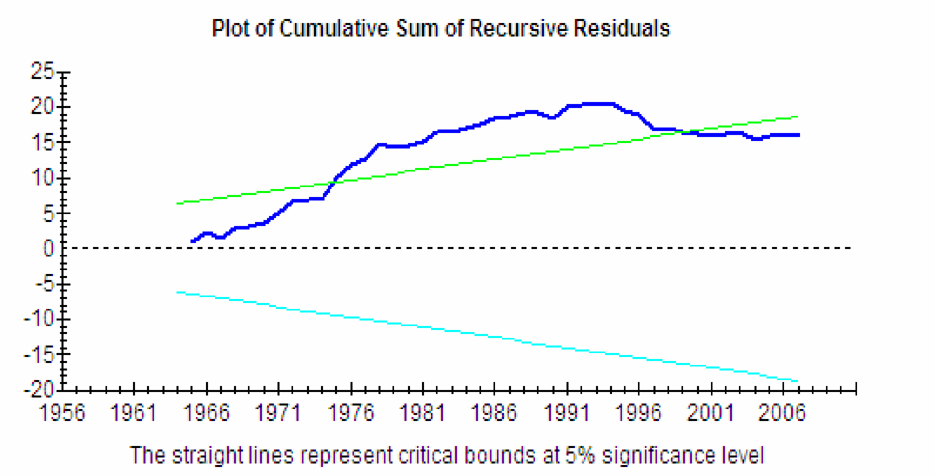

Figure-1. Cumulative Sums of Recursive Residuals

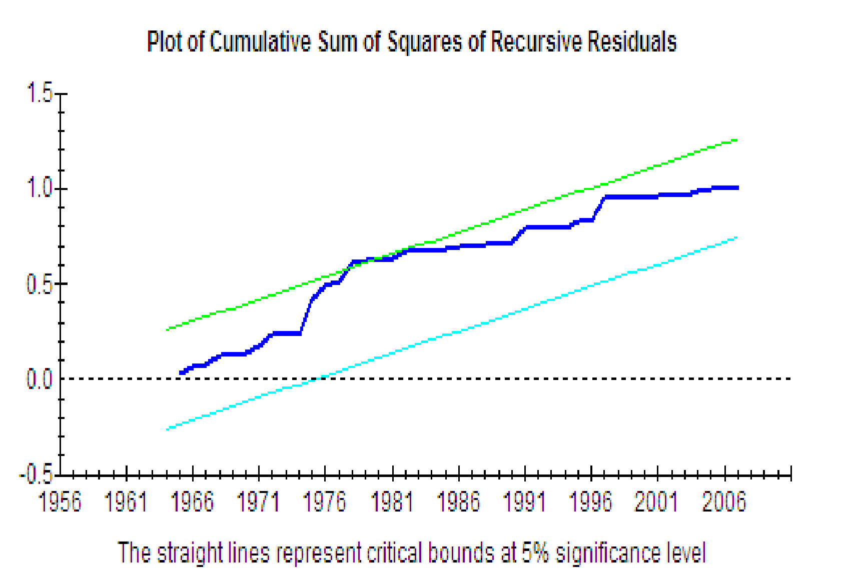

Figure-2. Cumulative Sums of Squares of Recursive Residuals

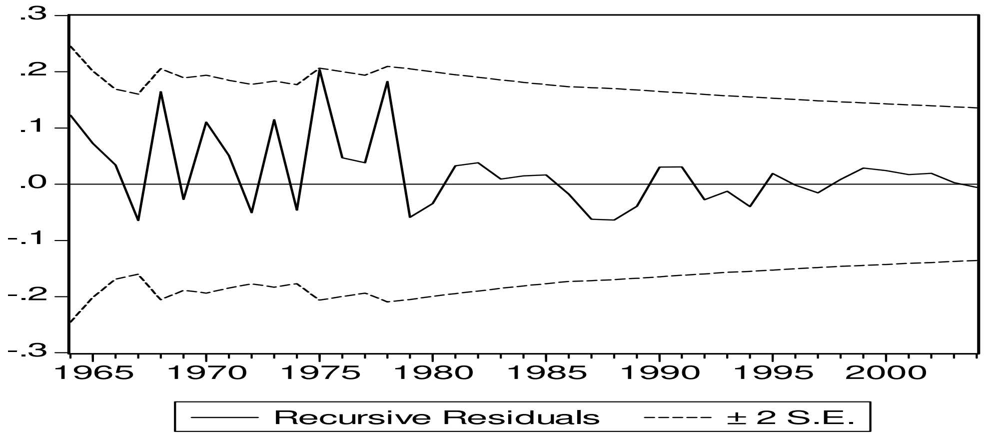

Figure-3. Recursive Residual Plots