Using multivariate cointegration methodology, this paper examines the long-run stability of the U.S. money demand function using both nominal and real M1, and M2 monetary aggregates. The estimated results, based on the Johansen and Juselius maximum likehood method, found evidence that the U.S., nominal or real, M1 and M2 demand functions, have long-run stability. The magnitudes of the estimated parameters are different for different specifications of the models. The estimated real income elasticity and interest rate elasticity, over the specifications of the money demand functions, are more sensitive to the choice of the interest rate and less sensitive to the scale variable. The empirical results of this study, with respect to M1 money demand, are in contrast with the empirical evidence presented in some of the earlier studies.

Introduction

Demand for money occupies a central role in monetary economics as well as in macroeconomics. Modeling, estimating, and testing for the stability of the long-run money demand function is very important for effective monetary policy formulation. That is why this is the most extensively researched question not only in the U.S. but also in every developed and developing country during the past four decades. Recent advances in time series econometrics has allowed researchers to reexamine the question of the stability of the money demand function. The models and estimation methods employed in the studies between mid-1960s to early 1980s are questioned by researchers using the more sophisticated econometric time series modeling and estimation techniques of the late 1980s and early 1990s.

However, empirical evidence on the U.S. money demand function, reported studies during the 1990s, employing cointegration and error-correction methodology, is at best, 'mixed'. This question whether the long-run U.S. money demand function is stable or not is still 'inconclusive and unresolved'. For a review of these studies we refer the reader to Sriram (2001). The purpose of this study is to revisit this issue employing the cointegration methodology, extending the sample period data from the first quarter of 1959 to the third quarter of 2003 (sample period in the earlier studies ranged from 1959 to 1996), and by proper selection of the scale, price, and opportunity cost (proxy) variables, and appropriate specification of the model that is free of estimation problems. The rest of the paper is organized as follows. Section 1 presents a review of some selected previous empirical studies and evidence, section 2 contains a brief review and implications of Fisher's (1911) equation of exchange followed by the long-run money demand model employed in this study along with the empirical estimation, results, and some concluding remarks in section 3.

Section 1: Review of Empirical Evidence in Recent Studies

A brief review of some selected studies by Engle and Granger (1987), Hoffman and Rasche (1989) Johansen and Jesulius (1990), Dickey, D., D.W. Jansen, and D.L. Thornton (1991), Miller (1991), Hafer & Jansen (1191), Bab, Hendry, and Starr (1992), Ball (2001), and Choi (2003), that employed cointegration and error-correction modeling and used either Engle-Granger methodology or Johansen and Juselius maximum likelihood estimation technique, is provided below. The results of these empirical studies are different regarding the long-run stability of the U.S. money demand function, irrespective of the monetary aggregate used. Further, the estimated parameters, income and interest elasticities or interest semi-elasticities, reported in each of these studies, are markedly different.

The study by Engle and Granger examined several monetary aggregates to test for cointegration between the nominal monetary aggregates, nominal GNP, and nominal interest rates, using the sample period 1959.1 to 1981.2. Their study reported cointegration between the log of nominal M2, (but not the log of nominal M1), nominal GNP and nominal interest rate.

The study by Dickey et al., employing the JJ procedure, reported one cointegrating vector for real M1 (and for real M2 also), real income (RGNP), and either of the nominal interest reates (yields on 3-month T-bills or yields on 10-year Treasury notes). Their results are similar to the results reported by Hoffman and Rasche study, which also used monthly time series data. The Dickey et al. study concluded that there is a stable long-run relationship between real monetary aggregates (both real M1 and real M2) and real income and nominal interest rates.

The study by Miller reported cointegration between the natural log of nominal M2, natural log of real GNP, the natural log of the implicit GNP deflator, and nominal interest rate (four-to-six-month commercial paper rate). The Miller study found no cointegration between the natural log of nominal M1 and other variables. Baba and Hendry study, using quarterly data from 1960.3 to 1988.3, estimated the U.S. M1 money demand function. Their study used two proxies for the opportunity of holding money, namely, 1-month T-bills, and 20-year T-bond yields. Their study reported stable cointegrating demand function for M1.

Hafer and Jansen investigated the same question and reported evidence, based on their quarterly sample data (1915:1-1988:4), that real M2 and real income, and interest rate (commercial paper rate) are cointegrated. Choi and Jung examined the structural changes in the U.S. money demand function, using quarterly data from 1959 to the fourth quarter of 2000. Their study did not report a stable long run money demand function for the U.S. They estimated the 'unknown' structural break points using Bai and Perron's (1998) methodology. However, their results indicated that a stable relationship existed for each sub-sample period but not the whole sample data period they had used. The estimated elasticities (income and interest) of their study were smaller than Ball's estimates. Choi and Jung reported, in their study, that a number of studies by Lucas (1988), poole (1988) Stock and Watson (1993), Hoffman, Rasche, and Tieslau (1995) found that the U.S. long-run money demand function was stable.

Section 2: Fisher's Equation of Exchange

Fisher's equation of exchange has been the foundation for the theory of money demand. Every empirical model's specification is based on some variation of the equation of exchange. A brief review of equation its implications is provided below:

Fisher's equation of exchange (MV = Py), in natural logs, (see Dickey et al., 1991), is:

ln M + In V- In P - In y = 0 (2.1)

where, M is nominal money, V is its velocity. P is the price level, and y, real income. The theory of money demand transformed this identity into an equation by making V a function of some economic variables. However, the form and the arguments of the money demand function are different for different theoretical specifications. Since V is not observable, it is proxied as [V.sup.*].

ln [V.sup.*] = ln V + e (2.2)

where e is the random error associated with [V.sup.*]. It is postulated that [V.sup.*] is a function of some observable variables other than y, M, or P.

ln M + ln [V.sup.*] - ln P - ln y = e (2.3)

If [V.sup.*] is a perfect proxy for V, the expected value of e should be zero, i.e. e is stationary. However, the proxy, [V.sup.*], may deviate from its true value in the short run, but should converge to its true value in the long run. If the relationship among the variables in (2.3) is not stationary it implies that either [V.sup.*] is not a good proxy for V or that there is no long-run relationship among these variables, i.e. the long-run money demand function does not exist.

However, the Fisher equation, in essence, implies a long-run relationship between money, real income, opportunity cost of holding real money balances, and velocity. This theoretical assertion has been tested since the late 1960s with limited success. As a matter of fact, the empirical literature on money demand function is voluminous and also contentious.

Empirical Money Demand Model

There is a wide range of empirical money demand models, based either on the 'motives' for holding money, such as, transactions, precautionary, or speculative, or for some other consideration, like, utility. A common thread that connects these theories is the variables identified and employed in each of these empirical models. However, all the empirical models stipulate that the demand for money is a function of a few variables, namely, a scale variable, price variable, and an opportunity cost (proxy) variable, usually, a short-term or long-term interest rate.

We begin our empirical model of the long-run U.S. money demand function with a general functional relationship.

The long-run nominal [M.sup.d] function, following Dickey et al., is:

[M.sup.d] = f(P, Y, Z) (2.4)

Where, M and Y are nominal money and nominal income, and Z stands for all other variables that have an impact on the opportunity cost and velocity, which, in turn, influence [M.sup.d].

The real money demand, [M.sup.d], is a function of the variables representing the real domestic economic activity and the opportunity cost of holding real money balances. Real money demand specification implicitly implies the absence of money illusion as well as price homogeneity. There may be less estimation problems if real money balances are used rather than nominal money balances as the dependent variable (Boughton, 1981, and Johansen, 1992). Further, more empirical studies that have employed real money balances found significant empirical evidence compared to those that have used nominal money balances. Fisher's equation of exchange suggestes a long-run money demand function, so it is appropriate to use real money balances and not nominal money balances. However, we prefer to estimate both the nominal and real money demand functions using the nominal M1 and M2 as well as real M1 and M2, in their natural logs so that the estimated coefficients can be interpreted as income, price, and interest elasticities.

Our multivariate cointegration regressions, in terms of the natural logs of nominal M1 and M2, are specified as:

LM[1.sup.d.sub.t] = [[alpha].sub.0] + [[alpha].sub.1] L[Y.sub.t] + [[alpha].sub.2] L[P.sub.t] + [[alpha].sub.3] L[I.sub.t] + [[epsilon].sub.t1] (2.5)

LM[2.sup.d.sub.t] = [[beta].sub.0] + [[beta].sub.1] L[Y.sub.t] + [[beta].sub.2] L[P.sub.t] + [[beta].sub.3] L[I.sub.t] + [[epsilon].sub.t2] (2.6)

Where, M1, Y, P and I, are nominal monetary aggregate, nominal GDP, and nominal interest rate, respectively. Most of the earlier studies specified a log linear money demand function. We have used two different interest rates, the 3 month t-bill rate, and the 'own rate' on M2.

And, in terms of natural logs of real [M.sub.1] and [M.sub.2] are:

lm[1.sup.d.sub.t] = [[alpha].sub.0] + [[alpha].sub.1] [ly.sub.t] + [[alpha].sub.2] [li.sub.t] + [li.sub.t] + [[epsilon].sub.t1] (2.5a)

lm[2.sup.d.sub.t] = [[beta].sub.0] + [[beta].sub.1] [ly.sub.t] + [[beta].sub.2] [li.sub.t] + [li.sub.t] + [[epsilon].sub.t2] (2.6a)

Section 3: Data, Unit Root and Cointegration Tests, and Results

The sample data for the variables M1, M2, real GDP, GDP deflator, 3-month and 1-year T-bill rates are quarterly, from 1959.1 to 2003.3, collected from the Web site of St. Louis Federal Reserve Bank (www.research.stlouisfed.org/fred2/). M1, M2 and GDP data are seasonally adjusted. The sample data (monthly/quarterly) used in the studies reviewed earlier ranged from 1959 to 1996. We extended the sample period from the first quarter of 1959 to the third quarter of 2003.

Unit Root Tests

The initial step in the estimation involves the determination of the time series property of each Variable individually by conducting unit root tests. The most popular unit root test, the ADF (augmented Dickey-Fuller, 1979) test. The test involves running one of the following regressions:

[y.sub.t] = [alpha] [y.sub.t-1] + [SIGMA]di[DELTA] [y.sub.t-i] (3.1)

[y.sub.t] = [mu] + [alpha] [y.sub.t-1] + [SIGMA]di[DELTA] [y.sub.t-i] (3.2)

[y.sub.t] = [mu] + [beta]T + [alpha][y.sub.t-1] + [SIGMA]di[DELTA] [y.sub.t-i] (3.3)

The null hypothesis is that |[alpha]| = 1 against the alternative that |[alpha]| < 1. The correct specification of the equation is determined based on the data generating process (DGP). If it is determined that the DGP is a random walk without a drift and a mean, then the unit root test is based on (3.1). If the DGP is a random walk with a drift and zero mean, then we have to use (3.2). Equation (3.3) is appropriate if the series has a non-zero drift and non-zero mean. A time plot of the series in question would provide an initial view of the DGP.

Another popular unit root test is the KPSS (Kwiatkowski, Phillips, Schmidt, and Shin, 1992) test. The KPSS test differs from the ADF unit root test. In the KPSS test, the series, [y.sub.t], is assumed to be trend-stationary under the null. The KPSS statistic is based on the residuals from the OLS regression of [y.sub.t] on the exogenous variables, xt: ([y.sub.t] = [x.sub.t'] [delta] + [u.sub.t]). The null hypothesis is different for the ADF and the KPSS tests. For the ADF test the null hypothesis is: [H.sub.0]: I(1), and for the KPSS test, the null is: [H.sub.0]: I(0).

The first step in the estimation process is the determination of the order of integration of the individual time series of the system to be estimated. Unit root tests are performed on each of the time series using two different procedures, namely, the ADF test, and the KPSS test, on the log levels, nominal and real, as well as the log first differences of the each time series, M1, M2, GDP, implicit GDP deflator, 3-month T-bill rate, and 1-year T-bill rate. The notation for each series in log levels is: lm1, lm2, lrm1, lrm2, lrgdp, l 3-mtbr, and l 1-yr for, respectively. Unit root test results are presented in Table 1. The details of these tests including assumptions are in the 'note' under Table 1.

The test results, both ADF and KPSS, indicate that the null hypothesis (null of 'unit root' in the case of ADF test, and the null of 'no unit root', in the case of KPSS test) is not rejected for each of the series in their log levels, nominal or real. Then, unit root tests are performed on the log first differences of the individual series. The null hypothesis is rejected for each of the time series in the log first differences at 1% level of significance. KPSS test results validated the ADF test results.

Cointegration Tests and Results

Since each of the time series is integrated of the same order, there is a very nigh likelihood that they may be cointegrated. Cointegration tests, employing the JJ procedure, are conducted on the nominal and real M1 and M2 (in the first differences of their nominal and real natural logs), as the dependent variable (equations 2.5, 2.6, 25a, and 2.6a). Details regarding the cointegration tests, including the assumptions, are given in the tables.

We experimented with several proxies for the opportunity cost of holding money. Not all these rates indicated cointegration, though. By comparing our estimated results for various interest rates, (3-month, 6-month, 1-year T-bill rates, 2-and 3-month AA financial commercial paper rates, 5-year and 10-year Treasury constant maturity rates, and the 'own rate' on M2 components), we decided, based on diagnostics as well as on theoretical grounds, that for the nominal and real M1 functions, the best proxy is the 3-month T-bill rate, and for nominal and real M2, the best proxy is the 1-year T-bill rate. Based on the diagnostics (not presented here but are available from the authors upon request), the test results obtained, when the log of 3-month T-bill rate series, in first differences, are used for opportunity cost, and for the nominal and real M2 demand functions, when the log of 1-year T-bill rate series are used, passed all the diagnostic tests. Only those results are presented in Tables 2a through 2d.

In three of the four estimated functions, namely, the nominal and real M1 and nominal M2, both trace test and the maximum eigenvalue test indicated one cointegrating vector at 5% level of significance.

For the real M2 money demand function, the trace test indicated two cointegrating equations at 5%, while the maximum eigenvalue test indicated one cointegrating vector at 5%. We decided to go with the trace test result and accepted two cointegrating vectors instead of one.

For the nominal M1 and M2 demand functions, there is (r = 1) one cointegrating relationship among the (k = 4) variables. The variables are: nominal monetary aggregate (M1 or M2), real GDP, GDP deflator, and one of the nominal interest rates, 3-month T-bill rate (in M1), and 1-year T-bill rate (in M2). Tables 2a and 2c clearly reject the null of no cointegration at the conventional level of significance, and fails to reject one cointegrating vector in both the cases.

For the real M1 and M2 demand functions, Tables 2b and 2d, there is, (r = 1), one cointegrating relationship among the (k = 3) variables, namely, real M1 (or real M2), real GDP, and the relevant nominal interest rate, all series in their natural logs. The k = 3 variables are jointly driven by (k - r = 3 - 1 = 2) two distinct stochastic trends, one common stochastic trend driving the cointegrated variables, and the other one driving the nominal 3-month or 1-year T-bill rate. So, the real M1 and M2 demand functions, in natural logs, have a long-run equilibrium relationship with the relevant scale (real GDP) and nominal interest rate variables.

We performed the Chow test to examine whether the estimated coefficients are stable or not over the sample period. We found that both M1 and M2 (nominal or read are stable. However, the test results are not presented in this paper but are available from the authors.

To enable interpretation of our results, in economic terms, the normalized cointegrating coefficients, with standard errors in parenthesis, are reported at the bottom part of Tables 2a through 2d. The estimated coefficients are generally interpreted as long-run elasticities. However, there is no guidance from theory regarding the acceptable values for these elasticities.

The estimated values of the elasticities for the nominal M1 are: income elasticity 1.1, price elasticity 0.53, and interest elasticity -0.38, and for nominal M2, these values are, 1.1, 0.82, and -0.05, respectively. For the real M1, the income elasticity is, 1.2, interest elasticity is, -0.34, and for real M2, these elasticities are, 1.17, and -0.20, respectively. The signs of these coefficients are consistent with Fisher's equation, although our results do not agree with the cointegating vector, hypothesized to be a one-to-one relationship, by the equation of exchange. Our results, however, come close to the one-to-one relationship in the case of nominal M2 demand function. The fact that some studies reported values close to or slightly above 0.5, for income elasticity, implies that money, representing either M1 or M2, does perform functions other than transactions. The results reported in our study, regarding elasticities, come close to the reported results in earlier studies for nominal and real M2 but not for nominal or real M1 demand function.

Concluding Remarks

Since cointegration of variables means long-run equilibrium relationship among the variables in the system, we need to further examine this finding of one cointegrating vector among the 3 or 4 variables in the estimated equations. Among the four equations reported, the most acceptable result, that is consistent with the fact that nominal variables cannot influence real variables in the long-run, it is the real M2 demand function. In the real M2, real GDP, and nominal 1-year T-bill rate equation, all variables in their natural logs, the nominal interest rate variable cannot influence the real M2 in the long-run. Our result, (k - r = 1), shows one common trend driving cointegrated variables, and one stochastic trend driving the nominal interest rate. The Federal Reserve has been employing the nominal interest rate, the fed funds rate, for conducting monetary policy in recent years. That nominal variable can be expected to influence the other key nominal and real variables in the short-run but not in the long-run.

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Table 1: Augmented Dickey-Fuller (ADF) and KPSS Unit Root Tests

[Test results of nominal M1 and M2 are not reported. However, both nominal M1 and M2, in logs, are 1(1)]

Time Series	Lags (SBIC Criterion)	Intercept	Intercept & Trend	ADF Test Statistic

lrm1	2	yes		-1.5149
[DELTA]lrm1	1	yes		-4.9156 *
lrm2	2	yes		-2.0471
[DELTA]lrm2	1	yes		-3.6724 *
lrgdp	2	yes		-2.3412
[DELTA]lrgdp	2	yes		-4.8253 *
lgdpdfl	2		yes	-1.6817
[DELTA]lgdpdfl	2		yes	-4.3381 *
1 3-m tbr	3	yes		-2.3219
[DELTA]l 3-m tbr	2	yes		-6.1386 *
1 1-yr tbr	3	yes		-1.0252
[DELTA]l 1-yr tbr	2	yes		-5.6973

Time Series	Swartz Bayesian Information Criterion (SBIC)	Mackinnon (1996) p-values (For ADF test)	KPSS Test: LM-Statistic
lrm1	-6.3931	0.5239	0.3762
[DELTA]lrm1	-6.4093	0.0001	0.2397 *
lrm2	-6.7731	0.2666	0.3997
[DELTA]lrm2	-6.7784	0.0053	0.1713 *
lrgdp	-6.1945	0.4049	0.4049
[DELTA]lrgdp	-6.1924	0.0053	0.2031
lgdpdfl	-7.7010	0.7554	0.3974
[DELTA]lgdpdfl	-7.7141	0.0035	0.1919 *
1 3-m tbr	-1.7219	0.1663	0.2975
[DELTA]l 3-m tbr	-1.7195	0.0000	0.0346 *
1 1-yr tbr	-1.5800	0.7349	0.3494
[DELTA]l 1-yr tbr	-1.6036	0.0000	0.0608

* Note: lrm1 = natureal log of real ml, lrm2 = natural log of real m2, lrgdp = natural log of real gross domestic product, lrgdpdfl = natural log of gdp deflator, 13mtbr, = natural log of nominal 3-month T-bill rate, l 1-yr T-bill rate. Lag length selection for the ADF test is based on Schwartz Information Crietrion (SIC), and for the KPSS test, the spectral estimation methods selected is the Bartlett kernel, and for bandwidth it is the Newey-West method. For the ADF Test, the null hypothesis is: [H.sub.0]: 1(1), and, for the KPSS Test: [H.sub.0]: 1(0). For the ADF test, the critical values used are the Mackinnon (1991) critical values (1% critical value is-3.4679), and Mackinnon (1996) one-sided p-values. For the KPSS test, both the intercept and trend are included in each case. The 1% critical value for the KPSS, LM statistic, with an intercept and trend in the equation, is, 0.2160.
* significant at 1% level.

Table 2a: JJ Cointegration Test Results

Series: [DELTA]lm1, [DELTA]lrgdp, [DELTA]lgdpdfl, [DELTA]l 3-m tbr

Lags interval: 1 to 8

Assumptions: No deterministic trend in the series in levels and no intercept in the cointegrating equation

Hypo.# of CEs	Trace Statatistic	5% Crit. Val.	Max Eigen. Val.	5% Crit. Val.
None	51.3767	40.1749	33.0471	24.1592
At most one	18.3295	24.2760	14.7538	17.7973
At most two	3.5758	12.3209	3.3148	11.2248

Both Trace test and Maximum eigenvalue tests indicate one cointegrating equation at 5% level

Normalized Cointegrating Coefficients: (standard errors in parenthesis)

[DELA]lml	[DELTA]lrgdp	[DELTA]lgdpdfl	[DELTA]l 3-m tbr	Log Likelihood
1.0000	1.1053	0.5331	-0.3823	1952.816
	(0.2057)	(0.2075)	(0.0689)	

Table 2b
Series: [DELTA]lml, [DELTA]lrgdp, [DELTA]l 3-m tbr

Lags interval: l to 8

Assumptions: No deterministic trend in the series in levels and intercept in the cointegrating equation

Hypo.# of Ces	Trace Statistic	5% Crit. Val.	Max Eigen. Val.	5% Crit. Val.
None	45.0505	35.1928	26.6809	22.2996
At most one	18.3696	20.2618	15.3800	15.8921
At most two	2.9896	9.1645	2.9896	9.1645

Both the Trace and Maximum Eigen Value Tests indicate 1 cointegrating equation at 5% level.

Normalized Cointegrating Coefficients: (standard errors in parenthesis)

[DELTA]lml	[DELTA]lrgdp	[DELTA]l 3-m tbr	C	Log Likelihood
1.0000	1.2468	-0.3408	0.0061	1252.246
	(0.1891)	(0.0493)	(0.0022)	

Table 2c

Series: [DELTA]lm2, [DELTA]lrgdp, [DELTA]lgdpdfl, [DELTA]l 1-yr tbr

Lags interval: l to 7

Assumptions: No deterministic trend in the series in levels and no intercept in the cointegrating equation

Hypo.# of CEs	Trace Statistic	5% Crit. Val.	Max Eigen. Val.	5% Crit. Val.
None	48.1571	39.89	26.2660	23.80
At most one	21.8910	24.31	17.0835	17.89
At most two	4.8075	12.53	4.5627	11.44

Both the Trace and Maximum Eigen Value Tests indicate 1 cointegrating equation at 5% level

Normalized Cointegrating Coefficients: (standard errors in parenthesis)

[DELTA]lm2	[DELTA]lrgdp	[DELTA]lgdpdfl	[DELTA]l 1-yr tbr	Log Likelihood
1.0000	1.1058	0.8195	-0.0487	-2118.308
	(0.0820)	(0.0867)	(0.0223)	

Table 2d: JJ Cointegration Test Results

Series: [DELTA]lm2, [DELTA]lrgdp, [DELTA]lgdpdfl, [DELTA]l l-yr tbr

Lags interval: 1 to 9

Assumptions: No deterministic trend in the series in levels and no intercept in cointegrating equation

Hypo.# of CEs	Trace Statistic	5% Crit. Val.	Max Eigen. Val.	5% Crit. Val.
None	31.0870	24.2760	18.1445	17.7973
At most one	12.9425	12.3209	9.8096	11.2248
At most two	3.1328	4.1299	3.1328	4.1299

Trace test indicates 2 cointegrating equations at 5%, and Maximum Eigen Value Tests indicate 1 cointegrating equation at 5% level

Normalized Cointegration: (standard errors in parenthesis)

[DELTA]lm2	[DELTA]lrgdp	[DELA]l 1-yr tbr	Log Likelihood
1.000	1.1752	-0.1950	1348.870
	(0.0952)	(0.0327)	