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March 2014

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ABSTRACT:

The present study uses the most recent time series data obtained from the Bank of Thailand during the first quarter of 1993 and the fourth quarter of 2012 to investigate the long-run relationship between M1, M2, and M3 money demands and the two determinants (real GDP and interest rate). We use the model specification of Stock and Watson (1993) and Ball (2001). Our estimation techniques include Johansen cointegration test and the dynamic ordinary least squares (DOLS). We find that the DOLS procedure is not applicable for our data set. However, our results from Johansen cointegration test reveal that there is only a long-run relationship between M1 money demand, real GDP and interest rate. In the short run, only a change in real GDP affects M1 money holding. The instability of M1 money demand function makes it difficult for monetary authority to pursuit meaningful conducts of monetary policy.

Keywords: Money Demand, Real Income, Interest Rate, Cointegration, Dynamic OLS

1. Introduction

Empirically, researchers have long been searching for explanatory variables that can influence the function of real demand for money. Two of various determinants of real money demand function are real income (or real GDP) and interest rate. Ericsson [1998] examines several central issues in empirical modeling money demand, which includes the issues of theory, measurement, parameter consistency, the opportunity cost of holding money, estimations and diagnostic tests and inferences for monetary policy. He points out that interaction between these issues can be subtle. In spite of the fact that different econometric techniques are used to estimate the money demand functions in both advanced and developing countries, the estimations give different results. In other words, the elasticity of the money demand with respect to real income (or real GDP) and interest rate varies across countries and across the regimes considered. Besides real income and domestic interest rate, other variables may play an important role in money demand functions.

Goldfeld (1973) finds the long-run relationship between the narrowly-defined money demand (M1), output and interest rate as well as short-run dynamics with partial adjustment.[1] Barnett et al. (1992) indicate that the results of stability in money demand stem from the use of a linear model. Empirical studies also focus on the Asian economies. Arize (1989) estimates real money demand in Pakistan, Philippines, South Korea, and Thailand and finds that other variables (e.g., foreign interest rate, exchange rate and technology) are main determinants of money demand functions. Bahmani-Oskooee and Rhee (1994) find that M1 money demand and its determinant are cointegrated, but this is not true for the broadly-defined (M2) money demand. Inoue and Hamori (2008) find that M1 and M2 money demand functions exhibit long-run relationship with output and interest rates in India while another broadly-defined (M3) money demand function does not.

Empirical studies in some advanced economies also give mixed results. Stock and Watson (1993) find that the long-run US money (M1) demand is stable over the 1990-1989 period, but not in the postwar period alone. However, Ball (2001) uses the postwar US data to examine the long-run demand for M1 and finds that the absolute sizes of elasticities are smaller than those reported in previous studies. Lutkepohl et al. (1999) find that the M1 demand function of Germany is both linear and stable. Golinelli and Patorello (2002) estimate demand for money in the Euro area and find that M3 money demand function is more smooth and less subject to shocks in an area-wide money demand function than in a single country's money demand funtion. Most recent study by Setzer and Wolff (2013) estimates the standard money demand equation in a panel cointegration framework in the Euro area and find that real income elasticity is significant while the semi-elasticity of the interest rate is insignificant. Jawadi and Sousa (2013) use some of the latest testing and nonlinear modeling methods to estimate the long-run money demand equation in the Euro area, the US and the UK. They find that there are non-linear dynamics associated with the money demand function. Furthermore, the elasticity of money demand with respect to inflation, real GDP and exchange rate varies not only in accordance with the regime considered, but also across the counties.

In the present study, we use the most recent time series data obtained from the Bank of Thailand during the first quarter of 1993 and the fourth quarter of 2012 to investigate the long-run relationship between M1, M2, and M3 money demands and the two determinants (real GDP and interest rate). We use the model specification of Stock and Watson (1993) and Ball (2001). Our estimation techniques include Johansen cointegration test and the dynamic ordinary least squares (DOLS). We find that the DOLS procedure is not applicable for our data set. However, our results from Johansen cointegration test reveal that there only exists a long-run relationship between M1 money demand, real GDP and interest rate. In the short run, only a change in real GDP affects M1 money holding. The instability of M1 money demand function makes it difficult for monetary authority to pursuit meaningful conducts of monetary policy.

Our paper is organized as follows. Section 2 describes the data and methodology. Section 3 presents our empirical results and the last section gives concluding remarks.

[1] However, Goldfeld (1976) admits that his specification can be misleading under the case of missing money.

2. Data and Methodology

The stationarity property of time series data is crucial in using cointegration test proposed by Johansen and Juselious (1990) and dynamic OLS estimation proposed by Stock and Watson (1993). In what follows, the data, the empirical models, and estimation methods will be described.

2.1 Data

The Bank of Thailand' website provides quarterly data on monetary aggregates (M1, M2, and M3), real GDP, interest rates (saving deposit rate and 10-year government bond yield, and consumer price index. The period of investigation is from the first quarter of 1993 to the fourth quarter of 2012. Real M1, M2 and M3 are calculated by deflating the nominal values with the consumer price index.

2.2 Empirical Model

Theoretically, real money demand is affected by real income (proxied by real GDP, and interest rate. The functional form of multiple regression that is widely used in empirical studies is:[2]

$$(m - p)_t = a_0 + a_1 y_t + a_2 r_t + e_t \qquad (1)$$

where *(m-p)* is the logarithm of real money demand measured by nominal M1, M2, and M3 divided by consumer price index, *y* represents real income which can be proxied by real GDP, and *r* is the interest rate representing the opportunity cost of holding money, and *e* is the error term.

The explanatory variables in equation (1) are real GDP and interest rate. Real GDP should impose a positive impact on real demand for money while the interest rate should impose a negative impact on it.

2.3 Estimation Methods

2.3.1 Johansen Cointegration Test

The Johansen cointegration test employs the maximum likelihood procedure to determine the existence of cointegrating vectors in non-stationary time series as a vector autoregression (VAR) in the form:

$$\Delta x_t = \mu + \Gamma_1 \Delta x_{t-1} + ... + \Gamma_{t-p-1} \Delta x_{t-p-1} + \alpha\beta' x_{t-1} + e_t \qquad (2)$$

where x is a vector of non-stationary variables, Γ_i is the matrix of short-run parameters and $\alpha\beta'$ is the information on the coefficient matrix between the level of the series. Equation (2) is the AR(p) model under the assumption of cointegration of order *p*. According to Johansen and Juselius (1990), there are two likelihood ratio test

[2] This specification is employed by Stock and Watson (1993) and Ball (2001).

statistics to test for the number of cointegrating vectors (the maximum eigenvalue and trace statistics). The two test statistics are compared with the critical values provided by MacKinnon et al. (1999). If the two statistics are greater than the critical values at least at the 5% level, cointegrating relation(s) will be present. For short-run relationship, the procedure is based on the error correction mechanism (ECM) representation of the vector autoregressive model.

The functional form of the ECM model of real money demand based on equation (2) can be expressed as:

$$\Delta(m-p)_t = \alpha_1 + \sum_{i=1}^{p}[\beta_{1i}\Delta(m-p)_{t-i} + \gamma_{1i}\Delta y_{t-i} + \phi_{1i}\Delta r_{t-i}] + \lambda e_{t-1} + u_t \qquad (3)$$

The coefficient of the error-correction term (e_{t-1}) captures the long-run adjustment while the short-run dynamics are depicted by the coefficients of the lagged values of the first difference terms in equation (3).[3]

2.3.2 Dynamic Ordinary Least Squares

The dynamic ordinary least squares (DOLS) proposed by Stock and Watson (1993) has been one of popular methods for estimation of equilibrium parameters in long-run relationships between variables that contain a unit root. The DOLS estimation can be specified in the form:

$$(m-p)_t = b_0 + b_1 y_t + b_2 r_t + \sum_{i=1}^{k}\gamma_{1i}\Delta y_{t+i} + \sum_{i-1}^{k}\gamma_{21}\Delta y_{t-i} + \sum_{i=1}^{k}\phi_{1i}\Delta r_{t+i} + \sum_{i-1}^{k}\phi_{2i}\Delta r_{t-i} + v_t \quad (4)$$

This procedure includes leads and lags of first differences of explanatory variables. This is different from the ordinary least squares method that may cause spurious regression or unreliable results. These leads and lags operators are used for adjustment and to improve the estimation results. The DOLS method also deals with the problems of simultaneity and serial correlation in the residuals

3. Empirical Results

3.1 Results of Unit Root Test

We first perform the unit root test using the Phillips and Perron (1988) or PP test with a constant for all variables that are used in our estimations. Table 1 presents the PP test for the null hypothesis that each series contains a unit root against the alternative hypothesis that it does not.

[3] The maximum number of ECM models are three, but the other twos are not of interest in analyzing the money demand function in the present study.

Table 1 Results of Unit Root Test

Variable	PP Test with Constant
A. Level of Series	
Real Money Supply (m-p): M1	-0.059 [47] (0.950)
M2	-1.423 [11] (0.567)
M3	-0.947 [8] (0.759)
Real GDP (y)	-0.542 [25] (0.876)
Interest Rate (r): Saving Deposit Rate	-1.557 [3] (0.499)
Ten-Year Government Bond Yield	-1.437 [1] (0.560)
B. First Difference of Series	
Δ(m-p): M1	-21.048 [77] (0.000)***
M2	-11.679 [11] (0.000)***
M3	-11.928 [3] (0.000)***
Δy	-10.628 [24] (0.000)***
Δr: Saving Deposit Rate	-7.297 [1] (0.000)***
Ten-Year Government Bond Yield	-9.827 [4] (0.000)***

Note: The number in bracket is the optimal bandwidth determined by the Bartlett kenel. The number in parenthesis is the p-value of rejecting the null hypothesis of unit root. *** denotes significance at the 1 percent level.

The results from PP test with a constant show that all variables contain a unit root in level since the null hypothesis of unit root cannot be rejected. However, the test rejects the null hypothesis of unit root in first differences of all series. We therefore conclude that all series are integrated of order one, or they are I(1) series. When they integrated, they might or might not be cointegrated. In view of the fact that the series are cointegrated, Johanson cointegration test can be applied. The DOLS procedure can be applied in both cointegrated and integrated series.

3. 2 Results of Cointgration Test

Johansen cointegration test is performed using level of series of three variables in each equation In M1 demand equation, the opportunity cost of holding money is the saving deposit rate, while the opportunity cost of holding money in M2 and M3 equations is the 10-year government bond yield. The VAR(p) model of three variables is used to determine the optimal lag order p. Based upon the Akaike information criterion (AIC), The optimal lag length is four. The results from Johansen cointegration test are reported in **Table 2**.

Table 2 Results of Johansen Cointegration Test

A. Demand for M1				
Trace Test				
Hypothesis	Eigenvalue	Trace Statistic	5% Critical Value	Prob.
None	0.290	35.728	29.797	0.009
At Most 1	0.125	9.997	15.495	0.281
Maximum Eigenvalue Test				
Hypothesis	Eigenvalue	Max-Eiegen Statistic	5% Critical Value	Prob.
None	0.290	25.731	21.131	0.011
At Most 1	0.125	9.977	14.625	0.551
B. Demand for M2				
Trace Test				
Hypothesis	Eigenvalue	Trace Statistic	5% Critical Value	Prob.
None	0.127	17.244	29.797	0.622
At Most 1	0.091	7.229	15.495	0.551
Maximum Eigenvalue Test				
Hypothesis	Eigenvalue	Max-Eigen Statistic	5% Critical Value	Prob.
None	0.127	10.016	21.132	0.743
At Most 1	0.091	7.096	14.265	0.778
C. Demand for M3				
Trace Test				
Hypothesis	Eigenvalue	Trace Statistic	5% Critical Value	Prob.
None	0.132	17.047	29.797	0.637
At Most 1	0.083	6.562	15.495	0.629
Maximum Eigenvalue Test				
Hypothesis	Eigenvalue	Max-Eigen Statistic	5% Critical Value	Prob.
None	0.132	10.485	21.132	0.698
At Most 1	0.083	6.433	14.265	0.558

Note: The probability is the p-value provided by MacKinnon, et al. (1999).

The question is whether all three variables enter into the VAR(4) model are cointegrated or exhibit a long-run equilibrium relationship. The likelihood ratio tests, which is asymptotically distributed with the degree of freedom of three, show that the trace and maximum eigenvalue statistics are greater than the 5% critical value in M1 money demand equation, but they are lower than the 5% critical value in M2 and M3 money demand equations. Therefore, the null hypothesis that real money demand, real GDP, and interest rate are not cointegrated is rejected in the case of M1 money demand. We conclude that cointegration does not exist in M2 and M3 money demand equations, but it does exist in M1 money demand equation.

3.3 Results from DOLS Estimation

We use truncation lags for leads and lags first differences of explanatory variables upto 10. The estimates of equation (4) are reported in Table 3.

Table 3 Results of DOLS estimation

M1 Demand:

$(m\text{-}p)_t = -1.331 + 0.020DUM + 1.189y_t - 0.097r_t$

(-2.460)** (0.890) (15.470)*** (-4.530)***

$R^2 = 0.987$ F = 149.958 D-W = 1.732

Diagnistic Tests:

BG-LM Test = 0.557(p=0.757) JB=15.545(p=0.000) ARCH = 0.242(p=0.622)

No. of leads and lags are 5.

M2 Demand:

$(m\text{-}p)_t = 8.796 - 0.144DUM + 0.016y_t - 0.263r_t$

(7.733)*** (-2.661)** (0.423) (-2.794)**

$R^2 = 0.968$ F = 10.582 D-W = 1.594

Diagnistic Tests:

BG-LM Test = 7.246(p=0.027) JB=0.866(p=0.648) ARCH = 0.298(p=0.622)

No. of Leads and Lags =10

M3 Demand:

$(m\text{-}p)_t = 3.184 - 0.065DUM + 0.761y_t - 0.075r_t$

(7.241)*** (-2.575)** (11.382)*** (-1.725)*

$R^2 = 0.995$ F = 70.450 D-W = 1.521

Diagnistic Tests:

BG-LM Test = 6.942(p=0.031) JB=3,202(p=0.202) ARCH = 0.230(p=0.631)

No. of Leads and Lags =10

Note: DUM stands for the 1997 Asian financial crisis dummy variable. The number in parenthesis in each equation is t-statistic. P-value in parenthesis is the probability of acceptance of the null hypothesis. D-W is the Durbin-Watson statistic. BG-LM test is the Breusch-Godfrey test for serial correlation. JB is the Jarque-Bera statistic for non-normality of the residuals. ARCH is the Lagrange Multiplier (LM) test for first order autoregressive conditional heteroskedasticity in the residuals.

The estimated coefficients of the equilibrium relationship for M1, M2 and M3 real money demand function resulting from DOLS procedure have the expected signs of conventional money demand theory, i.e., positive income elasticity and negative interest rate elasticity. However, the leads and lags of 10 are not sufficient to produce residuals that are serially correlated for M2 and M3 equations as shown by the Durbin-Watson and Breusch-Godfrey test statistics. For the M1 equation, a significant Jarque-Bera test indicates an evidence of model misspecification, but that should not be as serious as the presence of serial correlation in M2 and M3 equations. The M1 equation exhibits income elasticity of 1.189 and interest elasticity of -0.097. This implies that real income plays more significant role on real money demand than interest rate.

3. 4 Long-Run Relationship and Short-Run Dynamics

Based upon the results of Johansen cointegration test, only narrowly defined money (M1) should be considered.

The long-run relationship between real money demand, real GDP as a proxy of real income, and interest rate is shown in equation (5):

$$(m\text{-}p)_t = -\ 0.154 + \underset{(8.327)^{***}}{0.983y_t} - \underset{(-6.224)^{***}}{0.170r_t} + e_t \qquad (5)$$

[t-statistic in perenthesis, and *** denotes significance at the 1% level.]

The estimated coefficient of y_t is 0.983, which shows that a 1 percent increase in real income will cause real money demand to increase by 0.983 percent.[4] The estimated coefficient of r_t is -0.170, which is slightly greater in the absolute value than that of DOLS estimates. It seems that the narrowly defined money demand responds more strongly to real income than to interest rate.

Having established a valid long-run relationship among the three variables in the model, there exists an error-correction mechanism (ECM) or short-run dynamics in the narrowly-defined money demand function. The result of short-run dynamics is shown in equation (6).

$$\begin{aligned}(m\text{-}p)_t =\ & \underset{(1.622)^{*}}{0.011} - \underset{(-1.768)^{*}}{0.254(m\text{-}p)_{t-1}} - \underset{(-1.150)}{0.168(m\text{-}p)_{t-2}} + \underset{(1.488)^{*}}{0.211(m\text{-}p)_{t-3}} + \underset{(2.349)^{**}}{0.316(m\text{-}p)_{t-4}} \\ & + \underset{(2.690)^{**}}{0.056y_{t-1}} - \underset{(-1.497)^{*}}{0.311y_{t-2}} - \underset{(-0.605)}{1.128y_{t-3}} + \underset{(1.095)}{0.221y_{t-4}} - \underset{(-0.206)}{0.005r_{t-1}} + \underset{(0.357)}{0.008r_{t-2}} \\ & + \underset{(0.423)}{0.010r_{t-3}} + \underset{(0.856)}{0.022r_{t-4}} - \underset{(-1.257)}{0.131e_{t-1}} + u_t \qquad (6)\end{aligned}$$

[t-statistic in parenthesis.** and * denote significance at the 5% and 10%, respectively.]

$R^2 = 0.596$ F= 6.932 S. E. of Regression = 0.046

The results from short-run dynamics show that the impact of real income change is more pronounced that that of a change in interest rate. The coefficient of the error correction term (e_{t-1}) is – 0.131, which is less than 1 in the absolute value. This implies that there seems to be an adjustment toward the long-run equilibrium. However, this coefficient is not statistically significant, which implies that the M1 money demand is not stable.

4. Concluding Remarks

This paper investigates the money demand functions in Thailand during the first quarter of 1993 and the fourth quarter of 2012. In doing so, we use two econometric

[4] This estimated coefficient from DOLS procedure is 1.189, which is greater than unitary.

methods: (1) Johansen cointegration tests; and (2) the DOLS procedure. Our findings show that the DOLS procedure is not applicable for the data set and that cointegration exists for M1 money demand function, but not for M2 and M3 money demand functions. Other variables (exchange rate and inflation rate) are also included in the money demand equations, but these variables do not play any important roles as the determinants of money demand in Thailand. Therefore, we exclude these variables from our estimations. The short-run dynamics show that real GDP is a crucial factor, but this is not true for the interest rate considered. Since time deposits in M2 and M3 are less liquid than the money in circulation, they do not respond to a change real income. Therefore, M2 and M3 demands cannot be seen as a link in monetary transaction mechanism. Even though there is cointegrating relation in the demand for M1, the instability of money demand function is observed from the error-correction mechanism in the short-run dynamics. Unstable money demand function can cause difficulties in the persuit of a meaningful monetary policy.

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