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Abstract: This paper investigates the relationship among monetary aggregates, prices, and aggregate output using Thailand' quarterly data from 1993:Q1 to 2006:Q4. The estimates of money demand function based on the quantity theory indicate a stable long-run relationship between real money demand and aggregate output when M3 is used as monetary aggregate. The estimates of the prices and output equations show that cointegration of the general price level, money stock and aggregate output exists when M1 is used as monetary aggregate. Results suggest that only M3 can be used in the real money demand function while M1 is a key determinant of prices and output. The success of monetary policy should depend on M1 and M3, but not M2 if the target is to stimulate growth and to control inflation.

Keywords: Money, Price Level, Aggregate Output, Cointegration.

JEL Classification Number: E31; E41; C32

1. Introduction

Besides analyzing the real demand for money, the relationship between monetary aggregates, prices, and aggregate output can possibly be explained by the classical quantity theory of money. The theory predicts that in the long-run monetary expansion will affect the price level, but leave real aggregate output unaffected. Neutrality of money can be evidenced by the same growth rate of money and prices. Previous empirical studies concentrate on the relationship between money growth and inflation and between money growth and aggregate output. The evidence on the long-run relationship between money growth and inflation by Dwyer and Hafer (1988) using five-year average cross-sectional data shows that countries with higher money growth on average have higher rate of inflation. Barro (1990) finds a high correlation between money growth and inflation. Rolnick and Weber (1994) investigate the relationship between money and inflation under commodity and fiat monetary regimes. Their results show that this relationship is almost unity for the fiat monetary regimes, but much lower for the commodity monetary regimes. McCandless and Weber (1995) use the sample of 110 countries to examine this relationship and find high correlation between money growth and inflation for both narrow and broad definitions of money for the full sample. The results from subsamples of OECD and Latin American countries also indicate high correlation, but is weaker when narrow definition of money is used. For the studies of the relationship between money growth and real output growth, the results are still inconclusive. The results of Dwyer and Hafer (1988) show a negative relationship between money growth and output, but with insignificant estimated coefficient. Geweke (1986) finds that money growth has no relationship with output growth in the United States. However, Poirier (1991) indicates the neutrality of money in some countries and not in others. Some researchers (Baba el al., 1992 and Cochrane, 1998, among others) argue that the income velocity of money is not stable, and thus money growth is not a reliable explanation of inflation. In a time series analysis, there exists a controversial issue concerning a stable long-run relationship among money, prices, and output. Swanson (1998) and Carlson et al. (2000) find evidence of cointegration among these variables, but Friedman and Kuttner (1993) and Thoma (1994) find no evidence of cointegration. Aksoy and Piskorski (2006) contend that currency corrected for foreign holdings of dollars has increased marginal predictive content for U. S. inflation and output relative to standard unadjusted money series. Their results comfirm those of Friedman and Kuttner (1992) and Estrella and Mishkin (1997) who indicate the importance of information content of the uncorrected monetary aggregates after the 1980s.

Some empirical studies of the direction, strength, and stability of the relationship among money, output, and prices have been focused on some Asian developing economies. In a high-inflation economy like Indonesia, Masih and Masih (1996a) apply Johansen's cointegration test and Granger temporal sense among output, money, prices, interest rate, and exchange rate and find that monetary expansion (M1 and M2) is likely to be dissipated in terms of relatively higher prices rather than output. On the contrary, Masih and Masih (1996b) using similar technique in the cases of Thailand and Malaysia, but the finding show that a monetary expansion (M1) will not necessarily be dissipated prices and other nominal variables, but will help stimulating growth in these two economies. Hasan (1999) reexamines the relationship between monetary aggregate (M3) and inflation in mainland China and the results show a reliable long-run relationship between price level and money stock, as well as between inflation and monetary growth. Ramachandran (2004) find a stable relationship among M3 money, output, and prices in India and suggests that the growth of M3 can be used as one of the potential indicators of future movement in prices.

The paper examines the validity of the classical quantity theory using Thailand data. The analysis is trying to answer two main questions: (1) whether the success of monetary policy depends on the relationship between monetary aggregate, prices, and output and (2) whether different definitions of money matter, which stems from the controversy concerning whether M1, M2 or M3 should be used as monetary aggregate. The next section presents the methodology used in the analysis. Section 3 presents the empirical results, and the last section concludes with some policy implications.

2. Methodology

2.1. Model Specification

The classical quantity theory of money of Fisher (1991) proposes the quantity equation of exchange in the following form:

$$MV = PY \quad (1)$$

where M is the money stock, V is the velocity of money, P is the price level, and Y is real income or real output.In terms of growth rate, equation (1) becomes:

$$m + v = p + y \quad (2)$$

where m is the money growth rate, p is the inflation rate, y is the growth rate of real output, and v is the growth rate of velocity of money. If v and y are constant in the long run, there should be a linear relationship between money growth and inflation with a slope coefficient of unity.

The real demand for money can be specified as:

$$(M / P) = f(Y) \quad (3)$$

while the output function is in the following form:

$$Y = g(P, M, V) \quad (4)$$

and the prices function is:

$$P = h(Y, M, V) \quad (5)$$

The success of monetary policy depends on the strength and stability of the relationship among money, output and prices. The empirics need work.

2.2. Cointegration Test

Pesaran, et al. (2001) proposed a new method for testing cointegration called a conditional autoregressive distributed lag (ARDL) and error correction mechanism. This is known as "ARDL bounds testing procedure." The ARDL model for equation (3) is specified as

$$\Delta(M / P)_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta(M / P)_{t-i} + \sum_{j=0}^{q} \gamma_i \Delta Y_{t-i} + e_t \quad (6)$$

where p and q are the optimal number of lagged differences of real money supply and and real money income respectively. The grid search methods for selecting p and q start from the most parsimonious ARDL(1,1). Suppose the ARDL(1,1) does not show serial correlation at the 5% level using LM serial correlation test, then the model is suitable for testing for cointegration. However, if the serial correlation is present, the number of lagged differences will increase. The search continues for all combinations of p and q until a model that is free of serial correlation is detected. By adding the lagged level variables into equation (6), the computed F-statistic is obtained from equation (7).

$$\Delta(M/P)_t = \alpha_0 + \alpha_1(M/P)_{t-1} + \alpha_2 Y_{t-1} + \sum_{i=1}^{p}\beta_i \Delta(M/P)_{t-i} + \sum_{j=0}^{q}\gamma_i \Delta Y_{t-i} + e_t \qquad (7)$$

If cointegration exists, replacing the lagged level variables with the one-period lagged residuals from the estimate of equation (3) will give the error correction term (ECT). Unlike other techniques of cointegration test, re-parameterize the model into the equivalent vector error correction model (VECM) is not required.

Similarly, the ARDL approach for testing for cointegration of equation (4) can be expressed as:

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{p}\beta_i \Delta Y_{t-i} + \sum_{j=0}^{q}\gamma_j \Delta P_{t-i} + \sum_{k=0}^{r}\phi_k \Delta M_{t-k} + \sum_{l=0}^{s}\varphi_l \Delta V_{t-l} + e_t \qquad (8)$$

and

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 P_{t-1} + \alpha_3 M_{t-1} + \alpha_4 V_{t-1} + \sum_{i=1}^{p}\beta_i \Delta Y_{t-i} + \sum_{j=0}^{q}\gamma_j \Delta P_{t-i} + \sum_{k=0}^{r}\phi_k \Delta M_{t-k} + \sum_{l=0}^{s}\varphi_l \Delta V_{t-l} + e_t \qquad (9)$$

The first equation is the ARDL model, and the latter equation is the conditional ARDL-ECM model. For the prices equation, the two equations can be expressed as:

$$\Delta P_t = \alpha_0 + \sum_{i=1}^{p}\beta_i \Delta P_{t-i} + \sum_{j=0}^{q}\gamma_j \Delta Y_{t-i} + \sum_{k=0}^{r}\phi_k \Delta M_{t-k} + \sum_{l=0}^{s}\varphi_l \Delta V_{t-l} + e_t \qquad (10)$$

and

$$\Delta P_t = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 Y_{t-1} + \alpha_3 M_{t-1} + \alpha_4 V_{t-1} + \sum_{i=1}^{p}\beta_i \Delta P_{t-i} + \sum_{j=0}^{q}\gamma_j \Delta Y_{t-i} + \sum_{k=0}^{r}\phi_k \Delta M_{t-k} + \sum_{l=0}^{s}\varphi_l \Delta V_{t-l} + e_t \qquad (11)$$

The ECT can be obtained by the same procedure.

3. Empirical Results

The Dickey-Fuller and Phillips-Perron-type tests are mainly criticized because of their low power of tests. These tests are of low power when the series is stationary but with a root close to non-stationary boundary, especially with small sample sizes. Therefore, KPSS (Kwiatkowski, et al., 1992) test for unit root is used in this study. The null hypothesis is rejected when KPSS statistic is large, and vice versa. The test is performed to the log of each series. The quarterly data are retrieved from Bank of Thailand (M1, M2, and M3) and IMF international financial statistics (CPI, GDP at current price, and GDP deflator) from 1993:Q1 to 2006:Q4.

Table 1: KPSS Tests for Unit Root

	LM Statistic (Constant)		LM Statistic (Constant+Trend)	
	Level	**First Difference**	**Level**	**First Difference**
Real GDP (Y)	0.880 (5)	0.167 (19)	0.150 (5)	0.157 (19)
Price Level (P)	0.863 (6)	0.343 (4)	0.189 (6)	0.132 (4)
Money Supply				
Nominal: M1	0.880 (6)	0.158 (18)	0.145 (5)	0.136 (18)
M2	0.859 (6)	0.204 (23)	0.213 (6)	0.138 (7)
M3	0.855 (6)	0.551 (2)	0.211 (5)	0.203 (4)
Real: M1	0.839 (6)	0.500 (54)	0.126 (5)	0.166 (22)
M2	0.863 (6)	0.571 (5)	0.252 (5)	0.169 (20)
M3	0.839 (6)	0.487 (2)	0.195 (5)	0.122 (10)
Velocity of Money				
V1	0.876 (5)	0.183 (17)	0.178 (5)	0.137 (16)
V2	0.437 (6)	0.393 (2)	0.213 (6)	0.088 (6)
V3	0.373 (6)	0.380 (18)	0.232 (6)	0.171 (19)

Note: The number in parenthesis is the optimal bandwidth. Critical Value (constant): 1% Level = 0.739, 5% Level = 0.463, 10% Level = 0.347. Critical Value (constant and trend): 1% Level = 0.216, 5% Level = 0.416, 10% Level = 0.119.

The results of KPSS with constant, and with constant and a linear trend seem to give mixed results. Some variables are I(0) or I(1), and in some cases uncertain between I(0) and I(1). The results show a complex nature of time series data. Therefore, the bounds testing for cointegration by Pesaran, et al. (2001) is used. The results are shown in Tables 2 and 3.

Estimations of ARDL-ECM equations are carried out in the log of each series. The Estimates of ARDL-ECM equation for the real demand for money is presented in Table 2. The lag length of the ARDL equation is (1,1) for all definitions of money.

Table 2: Cointegration between Variables in the Real Demand for Money of the Quantity Theory

Definition of Money	Computed F-Statistic	$\chi^2_{(2)}$
M1	1.394	5.186 (p=0.075)
M2	2.248	1.374 (p=0.503)
M3	7.019	1.316 (p=0.183)

Note: Chi-square statistics show that there are no serial correlation in the ARDL equations at the 5% level.

Only M3 gives the calculated F-statistics above the upper bound critcal value of 5.73 at the 5% level of significance and indicates the existence of cointegration or long-run relationship between real money demand and aggregate output. It should be noted that the existence of cointegration is obtained by comparing the test statistics with the critical values provided by Pesaran, et al. (2001)'s Table CI(iii) Case III: unrestricted intercept and no trend.

The estimates of real money demand equation is shown in equation (12):

$$(M/P) = 1.094^{*} + 1.053Y^{***} + e_t$$
$$R^2 = 0.727, F = 143.476 \quad (12)$$

The long-run relationship between real M3 and aggregate output does exist with the estimated coefficient of aggregate output of 1.053, which indicates the income elasticity of money demand close to unity. The error correction term (ECT) obtained from the estimate is -0.071 with the probability of the t-statistic of 0.037 showing the 5% level of significance. Since the absolute value of ECT is less than one, any deviation from the long-run relationship will be corrected. The coefficient of determination in equation (12) shows that the output alone can explain the variation of real money demand by almost 73 percent implying that other determinants of real money demand might not play important roles. Since cointegration exists, the real money demand function is stable.

The ARDL order for the output equation is (3,3,2,2) when M1 is used, but is (2,1,1,1) when M2 and M3 are used. The results of cointegration are reported in Table 3.

Table 3: Cointegration among Variables in the Output Equation

Definition of Money	**Computed F-Statistic**	$\chi^2_{(2)}$
M1	12.268	4.583 (p=0.101)
M2	4.134	0.826 (p=0.662)
M3	3.291	3.254 (p=0.197)

Note: Chi-square statistics show that there are no serial correlation in the ARDL equations at the 5% level.

For all three definitions of money, only the computed F-statistic when M1 is used is above the upper bound critical value of 4.35 at the 5% significance level. For M2 and M3 as money stock in the equation, the computed F-statistic is above the lower bound critical value of 3.23 but is below the upper bound critical value of 4.35. Therefore, the results of cointegration test are inconclusive. The estimated long-run output equation using M1 as monetary aggregate is:

$$Y = 6.103^{***} - 0.374P + 0.045^{**}M + 0.068^{***}V + e_t$$
$$R^2 = 0.994, F = 2{,}990.669 \qquad (13)$$

The results from estimated output equation show that money stock M1 and velocity of money impact the real aggregate output while the price level does not impact it. The estimated ECT is -0.022 but is not significant even at the 10% level. However, cointegration of money, prices, and output indicates stability of the output equation. The results from the estimates of equation (5) are shown in Table 4. The grid search method is used. The determination of the ARDL model is (1,1,1,1) for all definitions of money.

Table 4: Cointegration among Variables in the Price Equation

Definition of Money	Computed F-Statistic	$\chi^2_{(2)}$
M1	4.787	0.019 (p=0.991)
M2	3.740	2.579 (p=0.275)
M3	3.817	2.705 (p=0.259)

Note: Chi-square statistics show that there are no serial correlation in the ARDL equations at the 5% level.

Similar to the output equation, for all three definitions of money, only the computed F-statistic when M1 is used is above the upper bound critical value of 4.35 at the 5% significance level. For M2 and M3 as money stock in the equation, the computed F-statistic is above the lower bound critical value of 3.23 but is below the upper bound critical value of 4.35. Therefore, the results of cointegration test are inconclusive. The long run relationship when M1 is the money stock in the estimated price equation is:

$$P = 13.973 - 0.374Y + 0.563^{***}M - 0.018V + e_t$$
$$R^2 = 0.910, F = 174.628 \qquad (14)$$

In equation (14), only the coefficient of money supply (M1) is significant at the 1% level while those of aggregate output and velocity of money are insignificant. A one percent increase in money supply will cause a 0.563 percent increase in the price level. The estimated ECT is -0.05 with the t-statistic of -1.640 is significant at the 10% level. Therefore, any deviation from the long-run relationship can be corrected. This indicates the stable price equation because cointegration of the variables exists.

4. Conclusion

The notion that monetary expansion affects the price level, but leaves output unaffected is examined in this study by using the model specification from the well-known Classical quantity theory of money. Using the ARDL approach for cointegration, the direction and strength of the relationship between real money demand and aggregate output, and the relationship among prices, output, monetary aggregate, and money velocity are discovered. The existence of cointegration implies stable real money demand, output and prices equations.

Results give some policy implications. First, the monetary authorities in Thailand should use the broad definition of money (M3) when trying to control the level of interest rate via real money demand and its supply. Second, if the main target is inflation, the narrow definition of money (M1) will play an important part. By controlling M1 expansion, the target can be achieved. Third, the efficacy of monetary policy depends on expansion of M1 and its velocity, which can have a positive impact on aggregate output in the long run. Based upon cointegration test result of the long-run price equation, a one percent increase in money supply causes a 0.563 percent increase in the price level. Results from this study is contraditory to those of Masih and Masih (1996b) who use Thailand's annual data from 1955-1991. Therefore, inflation targeting can be achieved via controlling M1 money.

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