E c o n o m i c s B u l l e t i n

The Quantity Theory of Money: Evidence from the United States

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Abstract

In this paper cointegration analysis is used to examine the long−run relationship between money, prices, output, and interest rates. This paper finds convincing evidence in support of the quantity theory of money using time series data from the United States.

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1. Introduction

This paper is concerned with testing the main implications of the quantity theory of money. These implications have been tested, at least partially, using many different data sets, for example, Moosa (1997), Whitesell (1997), Miyao (1996), Moazzami and Gupta (1996), McCandless and Webber (1995), Duck (1993), and Friedman and Schwartz (1982). Miyao (1996) and Whitesell (1997) investigated these issues for the United States. Miyao (1996) used quarterly data for the period 1959 through 1993 to investigate the long run relationship between M2, the price level, output, and interest rates. Miyao (1996) found that there was mixed evidence of a cointegration relationship for subsamples prior to 1990 and almost no evidence of a long-run cointegration relationship for the entire sample. Whitesell (1997) used annual data for the period 1962 through 1991 and found a long-run relationship for the periods 1962-1979 and 1980-1991. A structural break in the velocity of M2 (which was modeled as a function of the federal fund rate and the inflation rate) was necessary to model the long-run steady state.

This paper expands upon these (and other) results by using cointegration analysis to examine the long-run relationship between money, prices, output, and interest rates in the United States using quarterly data for the period 1959 to 2004. Since this paper incorporates 10 more years of data than Miyao (1996), long-run cointegration relationships can be identified for the entire sample. Further, by using quarterly data and incorporating 12 more years of data than Whitesell (1997), this paper is able to estimate a long-run relationship for the entire sample without requiring the inclusion of a structural break to identify the long-run steady state. Once the long-run cointegration relationships are estimated, restrictions can then be imposed on the parameters of the model to test the implications of the quantity theory of money.

The quantity theory of money identity can be written as

$$p_t + y_t \equiv m_t + v_t, \qquad (1)$$

where p is the natural logarithm of the price level, y is the natural logarithm of real output, m is the natural logarithm of the money stock, and v is the natural logarithm of the velocity of money.

The simplest way of converting this identity into a testable theory is to assume that the velocity of money is constant. This paper adopts a slightly more sophisticated model of the velocity of money by making the natural logarithm of the velocity of money a function of the nominal interest rate:

$$v_t = \beta_0 + \beta_1 R + e_t, \qquad (2)$$

where β_0 and β_1 are coefficients and e_t is a random error.

Combining (1) and (2) gives

$$p_t = m_t + \beta_0 + \beta_1 R + e_t – y_t. \qquad (3)$$

Many works treat output and the quantity of money (and their growth rates) as exogenous variables (see for example, Duck (1993)). In that case, we could just estimate (3). However, this paper does not make any initial assumptions about the exogeneity of these variables. Therefore, the following model is of interest:

$$p_t = \beta_0 + \beta_1 R + \beta_2 m_t + \beta_3 y_t + e_t. \qquad (4)$$

The definitions of the variables are given in the data section of the paper.

After estimating the long-run relationship represented by (4), the main implications of the quantity theory of money can be tested. In terms of equation (4), we want to test the joint hypothesis that $\beta_2 = 1$ and $\beta_3 = -1$.

2. Data

This paper uses United States quarterly data obtained from the Federal Reserve Bank of St. Louis (FRED). This data spans the period 1959:1 – 2004:1. The following variables are considered: p is the natural logarithm of the seasonally adjusted GDP chain type price index (GDPCTPI); R is the nominal interest rate as measured by Moody's seasoned corporate bond yield (AAA); m is the natural logarithm of seasonally adjusted M2 money stock (M2SL); and y is the natural logarithm of seasonally adjusted real GDP (GDPC96). Monthly series (M2SL and AAA) were converted to quarterly series using the conversion tool in EViews 4.

Augmented Dickey-Fuller unit root tests carried out using EViews 4 suggest that y, m, and R are likely to be integrated of order one {I(1)}. The ADF test suggests that p may be integrated of order two for the period under consideration. Therefore, the Phillips-Perron test using the Bartlett Kernel with automatic Newey-West bandwidth selection is also used to test each of the series for unit roots. The Phillips-Perron tests suggest that all of the series can be treated as I(1) series. Further, none of the data series appear to be trend stationary. Therefore, the trends in the data are assumed to be stochastic trends. In other words, the trends are not restricted to be in the cointegration space.

3. Initial Results

All estimation was carried out using EViews 4. The Johansen procedure (Johansen 1991, 1995) was used in analyzing the cointegration relationships. Trace statistics were used to determine the number of long-run cointegration relationships in each specification. All of the specifications considered include 12 lags in the level data.

The preliminary results of model (4) are presented in Table 1. No restrictions are imposed on the long-run cointegration relationship in Table 1. It appears that the main implication of the quantity theory of money is likely to hold, i.e., the coefficient on m is significant and close to 1 and the coefficient on y is significant and close to –1. The results presented in Table 1 also suggest that the coefficient on R is not significantly different from zero. In fact, this restriction would not be rejected at any relevant significance level (p-value = 0.49). However, it is important to test the hypotheses implied by the quantity theory of money before we impose any additional restrictions on the nominal interest rate. It also appears that m is not weakly exogenous in this relationship.

Next, the main results of this paper are presented. As mentioned previously, by placing restrictions on the coefficients in the long-run cointegration relationship, the main implications of the quantity theory of money can be tested. These results are presented in Table 2. The coefficient on m is restricted to be 1 while the coefficient on y is restricted to be –1. A likelihood ratio test is used to determine if these restrictions are reasonable. The joint hypothesis is not rejected even at a 10% significance level (p-value = 0.23). With these restrictions imposed, the coefficient on the interest rate is now highly significant and it now appears that m is weakly exogenous in this relationship.

Now, any additional restrictions on the nominal interest rate can be considered. The additional restriction considered here is that the coefficient on the nominal interest rate is also equal to 1. This additional restriction is imposed on the coefficients of the long-run cointegration relationship and the results are reported in Table 3. There are now three restrictions on the cointegration relationship and we test these restrictions jointly using a likelihood ratio test. These joint restrictions are not rejected at any relevant level of significance (p-value = 0.40).

It is also worth noting that in Tables 2 and 3, while m can reasonably be treated as weakly exogenous, y cannot also be treated as weakly exogenous. The results of this paper could also have implications concerning the long-run neutrality of money. However, the purpose of this paper is not to tackle the issue of long-run neutrality of money, but to test the quantity theory of money. The issue of long-run neutrality of money within this framework is left for future research.

4. Investigating Structural Changes

It is well known that both unit root and cointegration tests can be affected by structural breaks in the time series data. In this section, the graphical method of testing for parameter constancy in cointegrated VAR models, suggested by Hansen and Johansen (1999), is used to address the issue of possible structural changes. Following the presentation of the graphical tests for structural change, the analysis of the previous section will be applied to several sub-samples of the data set.

PcGive10.0 is used to carry out the recursive estimation that is used to address the issue of parameter constancy. Figure 1 presents the recursive estimates of the eigenvalues with complete re-estimation ate each sample size. The base period includes 53 observations. As pointed out by Hansen and Johansen (1999), evaluating the recursive estimates of the eigenvalues is not a formal test of parameter constancy. However, Figure 1 clearly does not support a hypothesis of constant eigenvalues.

To investigate the effects of the non-constant eigenvalues on the unit root tests and cointegration tests, we will repeat the analysis carried out in section 3 for several sub-samples. First, following Miyao (1996), the sub-periods 1959:1 – 1988:4 and 1959:1 – 1990:4, and 1959:1-1993:4 are considered. Second, following Whitesell (1997) and allowing a break at the end of 1979, the sub-periods 1959:1 – 1979:4 and 1980:1 – 2004:1 will be considered. Finally, additional sub-periods based on the recursive eigenvalue estimates presented in Figure 1 are considered, namely 1959:1 – 1984:2 and 1984.3 – 2004:1.

5. Results for Sub-Samples

The results for the Miyao (1996) sub-periods are summarized in tables 4 and 4A. Augmented Dickey-Fuller unit root tests suggest that p, y, m, and R are likely to be integrated of order one {I(1)} for the sub-period 1959:1 – 1988:4. For this sub-sample six lags are included in the model (based on LR test). The trace statistic (47.17) suggests one cointegration relationship at the 10% significance level (none at the 5% level). Next, we test the restrictions imposed by the quantity theory of money. The LR test of the restrictions gives: $\chi^2(2) = 1.93$; p-value = 0.38, thus the restrictions are not rejected.

For the sub-period 1959:1 – 1990:4, Augmented Dickey-Fuller unit root tests suggest that y, m, and R are likely to be integrated of order one {I(1)}. The ADF test suggests that p may be integrated of order two for the period under consideration. Therefore, the Phillips-Perron test using the Bartlett Kernel with automatic Newey-West bandwidth selection is also used to test each of the series for unit roots. The Phillips-Perron tests suggest that all of the series can be treated as I(1) series. For this sub-sample eight lags are included in the model (based on LR test). The trace statistic (62.45) suggests one cointegration relationship at the 5% significance level. Next, we test the restrictions imposed by the quantity theory of money. The LR test of the quantity theory of money restrictions gives: $\chi^2(2) = 10.69$; p-value = 0.005, thus the restrictions are rejected. This suggests that the restrictions imposed by the quantity theory of money do not hold for this sub-period. Even though the restrictions do not hold in an absolute sense, the coefficients on m and y are very close to the values of unity predicted by the quantity theory of money.

Finally, for the sub-period 1959:1 – 1993:4, Augmented Dickey-Fuller unit root tests suggest that y, m, and R are likely to be integrated of order one {I(1)}. The ADF test suggests that p may be integrated of order two for the period under consideration. Therefore, the Phillips-Perron test using the Bartlett Kernel with automatic Newey-West bandwidth selection is also used to test each of the series for unit roots. The Phillips-Perron tests suggest that all of the series can be treated as I(1) series. For this sub-sample nine lags are included in the model (based on LR test). The trace statistic (45.60) suggests one cointegration relationship at the 10% significance level (none at the 5% level). The LR test of the quantity theory of money restrictions gives: $\chi^2(2) = 10.73$; p-value = 0.005, thus the restrictions are rejected. This suggests that the restrictions imposed by the quantity theory of money do not hold for this sub-period. Even though the restrictions do not hold in an absolute sense, the coefficients on m and y are very close to those values predicted by the quantity theory of money.

The results for the Whitesell (1997) sub-periods are summarized in tables 5 and 5A. Augmented Dickey-Fuller unit root tests suggest that p, y, m, and R are likely to be integrated of order one {I(1)} for the sub-period 1959:1 – 1979:4. For this sub-sample five lags are included in the model (based on LR test). The trace statistic (68.62) suggests one cointegration relationship at the 1% significance level (two at the 5% level). One cointegration relationship is considered here so that the results can be easily compared to the previous results. Next, we test the restrictions imposed by the quantity theory of money. The LR test of the restrictions gives: $\chi^2(2) = 11.91$; p-value = 0.003, thus the restrictions are rejected. This suggests that the restrictions imposed by the quantity theory of money do not hold for this sub-period. Even though the restrictions do not hold in an absolute sense, the coefficients on m and y are very close to those values predicted by the quantity theory of money.

For the sub-period 1980:1 – 2004:1, Augmented Dickey-Fuller unit root tests suggest that y, m, and R are likely to be integrated of order one {I(1)}. However, for this sub-period, it appears that p should be treated as trend stationary. Therefore, a deterministic trend will be included in the cointegration space. For this sub-sample six lags are included in the model (based on LR test). The trace statistics suggest that the cointegration space is of full rank. This apparent contradiction is likely a result of the low power of cointegration tests. Thus, this sub-period will not be used to consider the quantity theory of money issues.

The final sub-periods considered are 1959:1 – 1984:2 and 1984.3 – 2004:1, which seem to be suggested by figure 1. Augmented Dickey-Fuller unit root tests suggest that y, m, and R are likely to be integrated of order one {I(1)} for the sub-period 1959:1 – 1984:4. Again, it appears that p may be I(2) (p-value = .11), but we will treat p as an I(1) series here. For this sub-sample nine lags are included in the model (based on LR test). The trace statistic (53.17) suggests one cointegration relationship at the 5% significance level. Next, we test the restrictions imposed by the quantity theory of money. The LR test of the restrictions gives: $\chi^2(2) = 15.80$; p-value = 0.0004, thus the restrictions are rejected. This suggests that the restrictions imposed by the quantity theory of money do not hold for this sub-period. Even though the restrictions do not hold in an absolute sense, the coefficients on m and y are very close to those values predicted by the quantity theory of money.

For the sub-period 1984.3 – 2004:1, Augmented Dickey-Fuller unit root tests suggest that y, m, and R are likely to be integrated of order one {I(1)}. The ADF test suggests that p may be integrated of order two for the period under consideration. Therefore, the Phillips-Perron test using the Bartlett Kernel with automatic Newey-West bandwidth selection is also used to test each of the series for unit roots. The Phillips-Perron tests suggest that all of the series can be treated as I(1) series. For this sub-sample nine lags are included in the model (based on LR test). The trace statistics suggest that the cointegration space is of full rank. This apparent contradiction is likely a result of the low power of cointegration tests. Thus, this sub-period will not be used to consider the quantity theory of money issues.

6. Conclusion

This paper finds convincing evidence in support of the quantity theory of money using time series data from the United States for the period 1959-2004. By including an additional decade of information, this paper improves upon previous studies that could not find a long-run relationship between money, prices, interest rates, and output for the United States (for example, Miyao (1997)).

This paper uses the Johansen procedure to estimate the long-run relationship between prices, money, output, and nominal interest rates. Likelihood ratio tests show that, within the framework of this paper, the restrictions implied by the quantity theory of money cannot easily be rejected for the entire sample period.

However, when considering different sub-periods of the data, there is mixed evidence concerning the quantity theory of money, particularly in recent decades. It appears that more research, incorporating different methodologies is required in this area.

5. **References**

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Table 1: No restrictions imposed

Variable	CR	EC
p	1	0.004 [1.18]
R	-0.01 [-0.82]	0.72 [1.34]
m	-1.17 [-5.52]	0.02 [3.09]
y	1.11 [2.59]	0.02 [2.18]
Constant	-4.80	

Notes: CR is cointegration relationship. EC is error-correction term. Trace statistic (51.90) indicates one CR at the 5% significance level. The long-run relationship is given by p = 4.80 + 0.01 R + 1.17 m – 1.11 y. *The adjusted sample spans 1962:1 – 2004:1. The number of observations in the adjusted sample is 169.*

Table 2: Test of the restrictions implied by the quantity theory of money

Variable	CR	EC
p	1	0.0003 [2.46]
R	-1.29 [-3.95]	0.03 [1.75]
m	-1	0.0003 [1.23]
y	1	0.0007 [2.17]
Constant	5.24	

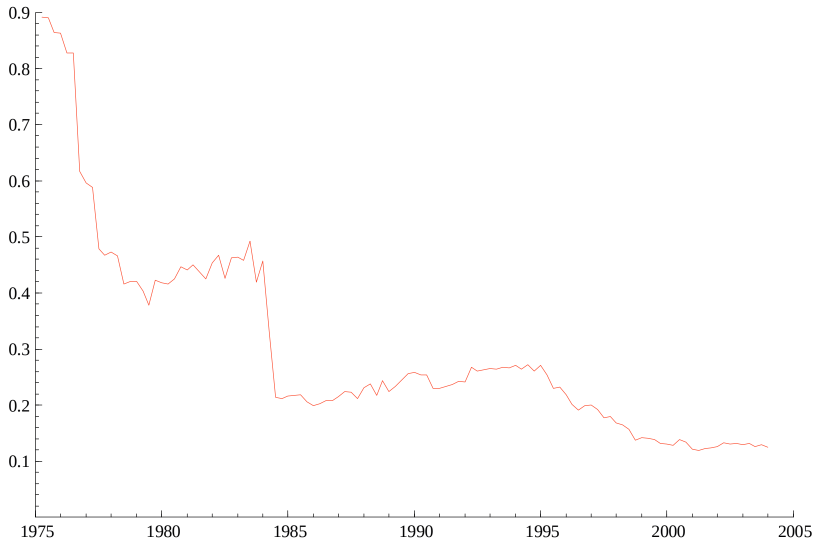
Notes: Restrictions implied by the quantity theory of money are imposed on the long-run cointegration relationship. LR test: $\chi^2(2) = 2.93$*; p-value = 0.23. Thus, we do not reject the restrictions. The long-run relationship is now given by* p = -5.24 + 1.29 R + m – y.

Table 3: A further test on the nominal interest rate

Variable	CR	EC
p	1	0.0003 [2.46]
R	-1	0.04 [1.76]
m	-1	0.0004 [1.23]
y	1	0.0009 [2.16]
Constant	2.91	

Notes: An additional restriction is placed on the coefficient of R. LR test: $\chi^2(3) = 2.95$*; p-value = 0.40. Therefore, we do not reject the restrictions. The long-run relationship is now given by* p = -2.91 + R + m – y.

Figure 1: Recursive Eigenvalues



Notes: Recursive eigenvalues – complete re-estimation at each sample size. 53 observations are included in the base period.

Table 4: Sub-periods following Miyao (1996)

Variable	1959:1-1988:4	1959:1-1990:4	1959:1-1993:4
p	1	1	1
R	-0.01 [-3.48]	-0.01 [-2.34]	-0.03 [-2.41]
m	-1.06 [-28.48]	-1.10 [-34.15]	-1.09 [-6.40]
y	1.14 [13.56]	1.19 [16.28]	1.57 [4.06]
Constant	-5.81	-6.02	-9.10

Notes: Cointegration relationship is reported for each sub-sample considered by Miyao (1996).

Table 4A: Test of the restrictions implied by the quantity theory of money for Miyao sub-periods

Variable	1959:1-1988:4	1959:1-1990:4	1959:1-1993:4
p	1	1	1
R	-0.01 [-8.02]	-0.01 [-9.01]	0.01 [1.16]
m	-1	-1	-1
y	1	1	1
Constant	-5.04	-5.02	-5.24

Notes: The quantity theory of money restrictions are rejected for all sub-periods except 1959:1-1988:4.

Table 5: Sub-periods following Whitesell (1997)

Variable	1959:1-1979:4
p	1
R	-0.02 [-3.16]
m	-1.14 [-32.16]
y	1.22 [16.07]
Constant	-5.88

Notes: Cointegration relationship is reported.

Table 5A: Test of the restrictions implied by the quantity theory of money for Whitesell sub-periods

Variable	1959:1-1979:4
p	1
R	-0.03 [-5.12]
m	-1
y	1
Constant	-4.91

Notes: The quantity theory of money restrictions are rejected..

Table 6: Sub-periods 1959:1 – 1984:2

Variable	1959:1-1984:2
p	1
R	0.03 [3.24]
m	-1.20 [-15.76]
y	0.91 [6.02]
Constant	-3.26

Notes: Cointegration relationship is reported.

Table 6A: Test of the restrictions implied by the quantity theory of money for Sub-periods 1959:1 – 1984:2

Variable	1959:1-1984:2
p	1
R	-0.01 [-4.40]
m	-1
y	1
Constant	-5.06

Notes: The quantity theory of money restrictions are rejected.