

MONETARY DYNAMICS: AN APPLICATION OF CO-INTEGRATION AND ERROR -CORRECTION MODELING.

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Abstract

Early studies that have been conducted on the estimation of money demand in the United States faced some dynamic problems such as, difficulties with the autocorrelation , the distinction between the long- run and short-run demands for money.

In seeking to construct an improved model, many economists took another approach of formulating an equation that integrates long-run properties with short-run dynamics, based on the recent merging of the theories of error-correction and Co-integration.

This paper will use the same approach that Miller (1991) had used in his paper, but the time period will be from (1959:i to 1999:i). with new econometric methodology that marries long-run trend relationships between economic variables to a system of short-run dynamic adjustment equations.

Key words: Money Demand, Error-Correction, Co-integration, Monetary Dynamics

Introduction:

Early studies that have been conducted on the estimation of money demand in the United States faced some dynamic problems. Courchance and Shapiro (1964) identified some of those problems such as, difficulties with the autocorrelation , the distinction between the long- run and short-run demands for money. Further studies, by Fiege (1967), Walters(1966), Starleaf (1970) indicated that there was no distinction exists between long-run and short run demands for money.

The study of Monetary dynamics continued to interest more scholars, Milton Friedman and Anna J. Schwartz (1982) develop an empirical model of money demand in the United States and United Kingdom. In their model, they specified monetary aggregates determined by Income, Prices, and Interest Rates.

The outcome of Friedman and Schwartz study indicates the potential for an improved equation but does not entail the form of specification required. In seeking to construct an improved model, many economists took another approach of formulating an equation that integrate long-run properties with short-run dynamics, based on the recent merging of the theories of error-correction and Co-integration.

One of those studies, that I am interested to focus on, is the paper that was written by Miller (1991). In his paper, Miller examined monetary dynamics for the period (1959:i to 1987:iv) with new econometric methodology that marries long-run

trend relationships between economic variables to a system of short-run dynamic adjustment equations.

In this paper I will try to use the same approach that Miller had used in his paper, but the time-period will be from (1959:i to 1999:i). Several initial comments about the paper are worth making.

First, it starts by establishing the time-series properties of the individual variables in the money demand function. The aim here is simply to show that the variables are integrated of the same order. The sampling distribution of the OLS estimator is not well behaved if the disturbance is non-stationary: The distribution of OLS estimator does not have finite moments, and furthermore, OLS is inconsistent in general.

If a unit root is present, it is essential to first difference the variables, thereby eliminating the unit root and achieving stationarity before attempting to estimate the money demand model. For this purpose, I use the Augmented Dicky-Fuller (ADF) test as recommended by Engle and Granger (1987) in addition to the Durbin-Watson statistic suggested by Sargan and Bhargava (1983) to determine whether the time series are stationary in first differences or levels.

Second, Co-integration test is used to establish a long-run equilibrium relationship among money demand, real income, price level, and interest rate.

Third, modeling the dynamic adjustment of the model I use the error-correction procedure. The error correction methodology follows that in Engle and Granger (1987). Finally, the paper examines whether the US money demand relationship has shifted during the period of estimation (structural change).

Research Questions:

The main questions to be addressed in this paper are:

- I. How do changes in the money stock respond to changes in the determinants of long-run money demand?
- II. How do the determinants of long-run money demand adjust to one another and to adjustments in the money supply?

Methodology:

In order to attempt to answer the above questions, a multiple regression model will be specified and estimated. This model will draw upon the model that was used by monetary economists taking into account the modifications that were proposed by Miller (1991).

The empirical analysis will be carried in the following steps:-

1. Model Specification.
2. Testing for Stationary Series.
3. Co-integration Equations.
4. Error-Correction Model.

Data Sources:

Throughout the Federal Reserve Board Statistical Data, and from St. Louis Federal Reserve Bank I was able to obtain a historical Quarterly data covering the period (1959:i to 1999:i).

Model Specification

This paper tries to apply the Unit Root test, Co-integration and Error-Correction modeling method to the initial model of the monetary theory, with the following modification;

1. Considering four alternatives for the monetary aggregate-B, M1, M2 and M3.
2. Considering one alternative for the scale variable—nominal gross national product(Y), decomposed into real gross national product(y).
3. Considering two alternatives for the interest rate—the four to six-month commercial-paper rate (r_c) and the dividend-price ratio (r_d).

The Initial Model:

$$M^d = \beta_0 + \beta_1 \text{Ln}Y_t + \beta_2 \text{Ln}P_t + \beta_3 \text{Ln}r_t + \varepsilon_t$$

where M^d is the quantity of nominal money balances demanded, Y is GNP, r is the nominal interest rate, P is the price level, t is the time period, and Ln is the natural logarithm.

Hence, recent studies, such as the one that was conducted by Miller, reclassified M^d into five monetary aggregates; $M1$, $M2$, $M3$, $M1A$, and B .

where:

M1: Contains currency, traveler’s checks, demand deposits, and other checkable deposits.

M2: Contains M1, money market deposit accounts and ordinary savings deposits, money market mutual fund shares (general purpose and broker-dealer), small time deposits, overnight RPs, overnight Eurodollars, and M2 consolidation component.

M3: contains M2, money market mutual funds (institution only), large time deposits, Term RPs, Term Eurodollars, and M3 consolidation component.

M1A: Subtracts other checkable deposits from M1.

B: Is the adjusted monetary base of the Federal Reserve Bank of St. Louis.

In addition to the above model specification, Miller considered in his paper two alternatives for the interest rate—the four to six-month commercial-paper rate(r_c) and the dividend-price ratio (r_d), and one alternative for the scale variable—nominal gross national product(Y), decomposed into real gross national product(y) and the implicit price deflator (P).

When constructing a model where all variables are integrated of order one and no lags of the dependent variable are included, one should be concerned about the possibility of a spurious regression. The classical approach to dealing with the spurious regression is to difference the non-stationary variables before estimating regression.

Table 1 reports a high R-Squ., and low D-W. statistic, which indicates that the initial model experience a spurious regression in all four equations related to $\text{Ln}B$, $\text{Ln}M1$, $\text{Ln}M2$, and $\text{Ln}M3$.

So, the modified model will become:

$$\text{Ln}M^d = \beta_0 + \beta_1 \text{Ln}Y_t + \beta_2 \text{Ln}P_t + \beta_3 \text{Ln}r_t + \varepsilon_t$$

Where : LnM^d : (money demand) will represent the four monetary aggregates; LnB, LnM1, LnM2, and LnM3, respectively.

$Ln r$: (interest rate) will represent the four to six-month commercial-paper rate (r_c) and the dividend-price ratio (r_d).

$Ln p$: implicit price deflator.

$Ln Y$: real gross national product (GNP).

Note, Equations 1-3 shows the components of regressing the monetary aggregates with and without r_c and r_d respectively (reported in table 1).

$$Ln M^d = \beta_0 + \beta_1 Ln Y_t + \beta_2 Ln P_t + \varepsilon_t \quad (1)$$

$$Ln M^d = \beta_0 + \beta_1 Ln Y_t + \beta_2 Ln P_t + \beta_3 Ln r_c + \varepsilon_t \quad (2)$$

$$Ln M^d = \beta_0 + \beta_1 Ln Y_t + \beta_2 Ln P_t + \beta_3 Ln r_d + \varepsilon_t \quad (3)$$

(Table 1 go about here)

So, this *spurious regression* gives a lead to investigate whether this spuriousity was caused by non-stationary time series, trends, or due to model misspecification.

Testing for Stationary Series:

Unit Root Tests

Unit root tests should be performed before applying Co-integration tests because statistical inference from time series is usually based upon the assumption of stationarity. If the time series data are non-stationary, some extra care is needed to form a time series model. This study employs the augmented Dicky-Fuller test.

The null hypothesis of non-stationarity is tested against the alternative of stationarity and is investigated for real money balances, nominal gross national product (GNP), price level, and the interest rate (Dividend price ratio and the three month commercial paper rate).

Table 2 reports Augmented Dickey-Fuller (ADF) test for the stationary of the natural logarithm of each variable over the 1959:i to 1999:i time period. For the levels, of the series, only LnB, and LnM1 reject the null hypothesis of non-stationary series at 1 and 5 & 10 percent critical values respectively.

(Table 2 go about here)

After first differencing, all the series reject the null hypothesis at all levels (10, 5, and 1 percent) except LnM2 rejects the null at the 10 and 5 percent level only, and LnM3 reject the null only at 5 and 10 percent, but does not reject the null at the 1 percent critical value. At the meantime, LnP does not reject the null at all 1, 5, and 10 percent.

In addition, taking the second differencing for all series induce stationarity for LnP, LnM2, and LnM3. However, it indicates over-differencing for the rest of the series, since the coefficients of the lagged level (that is, the second-difference of the series) significantly exceed minus one in absolute value.

Testing for Co-integration:

Phillips and Ouliaris (1988) classified the test of co-integration into two categories. First are the residual based tests which rely on the residuals calculated from regressions among level of economic time series. The second category is composed of the Stock and Watson (1988) of the common trend idea, and the state space approach suggested by Aoki (1988a,b). For the purpose of this paper, *the Residual Based Tests will be used.* Hence, tests are based on the unit roots test.

Engel and Granger(1987) examined alternative monetary aggregates and nominal gross national product for Co integration. They consider four measures for the money stock- M1, M2, M3, and liquid assets (L)--from 1959:i to 1981:ii. They conclude that the money stock and nominal gross national product (GNP) are not co-integrated with the possible exception of M2, which passes the ADF test when the natural logarithm of M2 is regressed on the natural logarithm of GNP.

According to Miller (1991), "The use of different variables as the left-hand-side conditioning variable may yield a different vector of Co-integration parameters." However, In Miller's paper, he examined all possible Co-integration regressions and report the one with the highest adjusted coefficient of determination. Such a procedure has been used by Hall (1986), since a high adjusted coefficient of determination minimizes the potential bias in the estimate of the Co-integration parameter (Banerjee et al. 1986).

(Table 3 goes about here)

First, considering trivariate Co-integration regressions of the natural logarithm of the monetary aggregates onto the natural logarithms of real Gross National Product, which denoted by the letter (Y) and the implicit price deflator (P).

$$Ln M^d = \beta_0 + \beta_1 Ln Y_t + \beta_2 Ln P_t + \epsilon_t \tag{1}$$

Table 2 reports the results for the full sample of 1959:i to 1999:i. The high Adj.R-Sq., and low D-W statistics suggest possible spurious regression and make Co-integration, error-correction modeling a potentially fruitful exercise (Hendry 1989). The D-W cannot be too low, since this signals non co-integration.

Second, introducing the interest rate for the three months commercial papers to produce three-variable co-integration regressions.

$$Ln M^d = \beta_0 + \beta_1 Ln Y_t + \beta_2 Ln P_t + \beta_3 Ln r_{ca} + \epsilon_t \tag{2}$$

Now, at the level, non of the monetary aggregates show co-integration with the explanatory variables.

Third, introduce the dividend price-ratio to the model and exclude the three months commercial papers.

$$\ln M^d = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln P_t + \beta_3 \ln r_{dt} + \varepsilon_t \quad (3)$$

The ADF test, (at the level), does not reject the null hypothesis of non-stationary errors in any case, which indicates a weak co-integration between the monetary aggregates and the explanatory variables at the level.

Since the M2 and M3 regressions that excluded the dividend price-ratio are not co-integrated, the Co-integration vectors identified for the M2 and M3 Co-integration regressions with the dividend price-ratio are probably unique. That is, when a number of variables are uniquely co-integrated, the elimination of any of the variables produces a non co-integration finding (Granger 1983 and Engle and Granger 1987).

Co-integration regressions suggest that only two monetary aggregates, M2 and M3 have a long-run trend relationship with real GNP, the implicit price deflator, and the dividend price-ratio; but M1, the other monetary aggregate, appears to be non-co-integrated with the determinants of money demand examined.

I conclude that the natural logarithms of M2 and M3 are co-integrated with real GNP, the implicit price deflator, and the dividend price-ratio. The Co-integration regression measures the long-run equilibrium relationship between these variables and the residuals measure short-run disequilibria. Table 2 also reports these results.

However, in Millers' paper (1991), he found that M2 has a long-run trend relationship with real GNP, the implicit price deflator, and the four to six-month commercial paper rate. In the meantime, Trehan (1988) finds that real central bank money and real M3 are co-integrated with the determinants of money demand-real GNP and three-month bank loan rates-in West Germany; real M1 and real M2 are not co-integrated with determinants of money demand.

Error-Correction Models:

In an error-correction model, the short-term dynamics of the variables in the system are influenced by the deviation from equilibrium.

This involves regressing the first difference of each variable in the co-integration equation onto lagged values of the first-differences of all of the variables plus the lagged value of the error-correction terms (that is, the error term from the co-integration regression).

In this study, I report the Akaike's FPE criteria (see Akaike 1973) for determining the lag structure of the error-correction model. Choosing the lag lengths that minimize Akaike's FTP criteria. The procedure for constructing the ECM are:

1. I consider for each of the error-correction models examined all possible combinations of lags from one to four.
2. Calculate Akaike's FPE, and choose the lag structure that minimizes the PFE.

These results are reported in Table 4.

The following are the equations that should be applied for the ECM, though, only equations a1-a4 were used due to the length constrained of this paper.

$$\text{Ln } M^d = \beta_0 + \beta_1 \text{Ln } Y_t + \beta_2 \text{Ln } P_t + \beta_3 \text{Ln } r_{dt} + \varepsilon_t$$

Where $\text{Ln } M^d$ will represent LnM2 and LnM3 (the co-integrated monetary aggregates).

After taking the first difference for each variable, the error-correction model will look like:

$$d\text{Ln}M_{2t} = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{a1})$$

$$d\text{Ln}Y_t = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{a2})$$

$$d\text{Ln}P_t = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{a3})$$

$$d\text{Ln}r_{dt} = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{a4})$$

$$d\text{Ln}M_{3t} = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{b1})$$

$$d\text{Ln}Y_t = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{b2})$$

$$d\text{Ln}P_t = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{b3})$$

$$d\text{Ln}r_{dt} = \beta_1 d\text{Ln}M_{2t-i} + \beta_2 d\text{Ln}Y_{t-i} + \beta_3 d \ln P_{t-i} + \beta_4 d\text{Ln}r_{dt-i} + \beta_5 \varepsilon_{t-i} \quad (\text{b4})$$

(Table 4 goes about here)

In table 4, the sum of the coefficients is reported on the first line. The number in parentheses under the sum of the coefficients is a chi-squared statistic testing whether the sum of the coefficients is significantly different from zero. In addition, the numbers in brackets tell specifically which lagged terms are included. For example, for the dlnM2 equations in the full sample, the Akaike method includes three lags each of dlnM2, dlnY, dlnP, and dlnrd.

Several interesting observations emerge from the findings. First, the expected sign of the coefficient of the error-correction term is positive for dlny and are negative for dlnM2, dlnP, and dlnrd. That is, when the money supply exceeds the long-run money demand, real output should rise, the price level and dividend price-ratio should fall, and if monetary policy is stabilizing, then the money stock growth rate should fall.

While in the full sample regressions suggest that the error-correction term affects only the growth rate of real GNP, the sub-sample results imply different relations. The early sample (1959:1-1987:4) suggest that the error-correction term affects the growth rate, price level, and dividend price-ratio, but the late sample (1988:1-1999:1) suggests that the error-correction term does not affect any variable in the equation.

The error-correction modeling technique allows the consideration of issues of temporal causality. Table 4 suggest that LnY, LnP, and Lnrd in the early period are econometrically exogenous. Other variables do not provide additional

explanatory power over and above the lagged changes in LnY , LnP , Lnrd in the early sample. Hence, non of the variables in the late sample are econometrically exogenous.

More specifically, strong evidence exists of a two-way temporal linkage between the money stock and the growth rate of real GNP, price level, dividend price-ratio, except for the late sample in table 4.

Conclusion:

Using co-integration analysis to identify the long-run money demand suggests only M2 and M3, have a long-run trend relationship with real GNP, the implicit price deflator, and the dividend price-ratio; none of the other monetary aggregates is co-integrated with the determinants of money demand examined.

The money-stock equations in the error-correction systems can be given the following interpretation. The observed money stock must lie on money supply and not money demand at all times; the money-stock equals money demand only in long-run equilibrium.

I conclude that the natural logarithms of M2 and M3 are co-integrated with real GNP, the implicit price deflator, and the dividend price-ratio. The Co-integration regression measures the long-run equilibrium relationship between these variables and the residuals measure short-run disequilibria.

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Table (1)

Coefficients of							
	CONST	LnY	LnP	Ln γ_c	Ln γ_d	Adj. R-Sq.	D-W
LnB	3.691	0.062	0.267	-0.060		0.96	0.085
LnM1	4.916	0.055	0.208	-0.047		0.94	0.012
LnM2	3.462	0.350	-0.053	-0.073		0.99	0.043
LnM3	3.611	0.348	0.006	-0.106		0.99	0.055
LnB	3.889	-0.085	0.155		0.197	0.98	0.254
LnM1	5.355	-0.128	0.130		0.216	0.98	0.096
LnM2	3.141	0.303	-0.206		0.120	0.99	0.060
LnM3	3.922	0.332	-0.226		0.126	0.99	0.046

Table (2): Testing for Stationarity: 1959:i to 1999:i

	ADF Test		
	Level	1 st .Difference	2 nd .Difference
LnB	2.591340*	-6.85259***	-11.34226 ov
LnM1	2.900617**	-3.709622***	-8.902860 ov
LnM2	1.201199	-3.214800**	-7.444619***
LnM3	1.049122	-2.848648*	-7.188328***
LnY	-1.20324	-4.197202***	-8.587516 ov
LnP	-1709497	-1.554235	-5.249756 ***
Lnrc	-1.731566	-5.4050525***	-7.579993 ov
Lnrd	0.560743	-4.544330***	-7.923305 ov

***means significant at the 1, 5, and 10 percent level.

**means significant at the 5, and 10 percent level.

*means significant at the 10 percent level.

Table 3: Co-integration Regressions (1959:i to 1999:i)

Coefficients of									
	CONST	LnY	LnP	Ln r_c	Ln r_d	Ad.R.Squ.	D-W	ADF Level	ADF 1 st . Differ
LnB	2.968	0.132	0.127			0.96	0.067	0.289	-6.54
LnM1	4.349	0.110	0.098			0.94	0.008	-0.149	-3.526
LnM2	2.579	0.436	-0.223			0.98	0.026	-0.277	-4.626
LnM3	2.333	0.472	-0.240			0.98	0.025	-0.449	-3.825
LnB	3.691	0.062	0.267	-0.060		0.96	0.085	-0.371	-6.549
LnM1	4.916	0.055	0.208	-0.047		0.94	0.012	-0.382	-4.528
LnM2	3.462	0.350	-0.053	-0.073		0.99	0.043	-1.042	-5.48
LnM3	3.611	0.348	0.006	-0.106		0.99	0.055	-1.154	-5.273
LnB	3.889	-0.085	0.155		0.197	0.98	0.254	-2.400	-6.461
LnM1	5.355	-0.128	0.130		0.216	0.98	0.096	-2.330	-4.478
LnM2	3.141	0.303	-0.206		0.120	0.99	0.060	-1.502	-5.035
LnM3	3.922	0.332	-0.226		0.126	0.99	0.046	-1.448	-4.369

NOTE: the errors from the cointegration equations are recovered to perform the Augmented Dicky-Fuller test (ADF).

Table (4):

Temporal Causality Tests from Error-Correction Models:
Akaike FPE Lag-Length Selection Criteria.

Equations	EC(-1)	Coefficients of			
		Sum(dlnM2)	Sum(dlnY)	Sum(dlnP)	Sum(dlnrd)
<u>1959:1-1999:1</u>					
dlnM2 (141)	-0.012 (1.34)	0.830 (217.26)	0.031 (2.04)	0.022 (0.42)	0.001 (0.003)
		[3]	[3]	[3]	[3]
dlnY (143)	0.017 (0.17)	1.086 (22.27)	0.200 (4.88)	0.649 (23.81)	0.028 (0.72)
		[2]	[3]	[3]	[2]
dlnP (142)	-0.019 (1.53)	0.097 (1.34)	0.094 (8.94)	0.769 (269.61)	0.001 (0.00)
		[2]	[2]	[4]	[2]
dlnrd (140)	-0.037 (0.12)	2.731 (22.27)	0.070 (0.09)	-0.715 (4.75)	-0.142 (2.75)
		[2]	[3]	[4]	[3]
<u>1988:1-1999:1</u>					
dlnM2 (30)	-0.006 (0.02)	0.755 (17.64)	0.116 (1.12)	-0.048 (0.05)	0.007 (0.10)
		[3]	[3]	[3]	[2]
dlnY (33)	-0.014 (0.05)	0.611 (5.71)	0.373 (4.41)	0.495 (2.49)	0.001 (0.00)
		[2]	[2]	[2]	[2]
dlnP (34)	-0.047 (3.38)	0.090 (0.57)	0.048 (0.38)	0.714 (27.14)	0.008 (0.26)
		[2]	[2]	[2]	[1]
dlnrd (33)	-0.370 (1.79)	3.437 (7.95)	-0.169 (0.04)	-0.448 (0.08)	0.010 (0.00)
		[2]	[2]	[2]	[2]
<u>1959:1-1987:4</u>					
dlnM2 (98)	-0.014 (1.90)	0.798 (116.42)(0.47)	0.145 (3.34)	0.054 (0.19)	-0.003
		[2]	[3]	[2]	[3]
dlnY (97)	0.063 (1.25)	1.809 (23.52)	0.147 (1.87)	0.468 (7.61)	0.050 (1.12)
		[3]	[3]	[3]	[2]
dlnP (96)	0.005 (0.07)	0.298 (5.61)	0.020 (0.28)	0.804 (194.88)(7.56)	0.045
		[3]	[3]	[3]	[3]
dlnrd (98)	0.166 (1.82)	1.871 (4.92)	-0.045 (0.02)	-0.415 (1.36)	0.166 (2.62)
		[2]	[3]	[3]	[2]

NOTE: EC is the error-correction term determined from the corresponding co-integration reported in table 3. The numbers in parentheses are chi-squared statistics. Numbers in brackets indicate the number of lags.