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Are Money, Interest Rates, Output and the Exchange Rate Cointegrated? Implications for Monetary Targeting

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This study examines the relationship between various monetary aggregates and real income, the 91-day Treasury bill rate, and the nominal exchange rate using the Engle and Granger cointegration method. The idea is that the choice for a monetary target should be controllable by the Central Bank and must have a stable and predictable relationship with variables of interest to policymakers. The results show that only M1 is cointegrated with real income, the 91-day Treasury bill rate, and the nominal exchange rate taken together. Overall, the results imply that M1 is the best choice for a target variable.

1. Introduction

Monetary theory proposes several criteria in the choice of a monetary target. These are: (1) The monetary aggregate must be controllable by the Central Bank given the available instruments: and (2) The aggregate must have a stable and predictable relationship with variables of interest to policymakers such as GNP, inflation, the exchange rate, interest rates.

Previous studies of money demand such as Goldfeld (1973) use different monetary aggregates and dynamic simulation techniques to determine the ability of different model specifications to predict money demand. Chow tests are employed to test for structural stability. The usefulness of these types of studies for policy purposes in the U.S. became questionable in the mid-80s when the estimated equations started to underpredict money demand. This has, in turn, been attributed to financial innovations which obscured the distinctions among different types of money balances held.

This study uses the simplest version of cointegration due to Engle and Granger (1987) to estimate money demand functions and

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closely follows the procedure outlined in Trehan (1988). The method of cointegration estimates a long-run equilibrium relationship among the variables and allows for adjustment towards this equilibrium. It also allows for the effects of short-run changes in the independent variables via an error-correction mechanism. The properties of the money demand function are important in determining the usefulness of different aggregates as target variables. The stability of the money demand function ensures that policy-induced variations in the target variable would have predictable effects on the economy.

Quarterly data from 1982.3-1991.2 are used. The study is divided into the following sections: Section 2 discusses the relevance of the cointegration method and its implementation; Section 3 presents the empirical results on cointegration; Section 4 presents the error-correction specification for money demand; Section 5 summarizes and concludes the study.

2. Empirical Methodology

Many macroeconomic time series are not stationary in their levels. This means that a random disturbance will lead such a series to drift away from its mean level or trend. Such a series is said to contain a unit root.

Non-stationarity poses many econometric problems as conventional econometric techniques require stationarity. Money demand functions, for example, could be estimated directly if the time series for monetary aggregates, interest rates, and output were each stationary.

At the same time, however, it is possible that while individual time series are not stationary in their levels, they are stationary in their first differences, or integrated of order one, I(1). If individual time series are integrated of order one, they may be "cointegrated." The latter means that one or more linear combinations of these time series may be stationary even if they are not individually stationary. If these time series are cointegrated, there exists a stable long-run relationship among levels of the variables. Thus, a random shock will not cause these variables to drift away from each other.

The first step, therefore, is to determine whether the individual time series are stationary. The formal way of doing this is to use a Dickey-Fuller test for the presence of a unit root. The null hypothesis is that the series contains a unit root, i.e., the series is not stationary or has no tendency to return to its original level following a random disturbance. To implement the test, the log of each variable is regressed on a constant, a time trend, and the variable's level, or alternatively, the first difference of the logs of each variable is regressed on a constant and one lagged first difference of the log of the variable in question. Both methods are ways of inducing stationarity in time series. The test statistic is equal to the coefficient on the lagged dependent variable minus one divided by its standard error. The null hypothesis is that the series has a unit root and the critical values for this statistic are given in Fuller (1976) as the statistic does not have the usual t-distribution. Intuitively, the test for the presence of a unit root is akin to the following: In a regression of the form

$$Y_t = \alpha_0 + \rho Y_{t-1} + \epsilon_t$$

the test for the presence of a unit root is simply a test of whether $|\rho|$ is significantly different from one or not. Under the null hypothesis, ρ is not significantly different from one. If so, then Y_t is characterized as a random walk process, i.e., it drifts over time permanently following a random disturbance, ϵ_t.

3. Empirical Results

Table 1 presents the results of unit root tests for the levels and differences of the logs of real total liquidity (*TL*), real *M1*, real *M2*, real reserve money (*RM*), real GNP (*Y*), the nominal exchange rate (*E*), and the 91-day Treasury Bill rate (*TB*).

The results in Table 1 show that the null hypothesis of non-stationarity can be rejected at the 1 percent level for reserve money, the exchange rate, and the 91-day Treasury bill rate, all in difference form. For all the other series, the null hypothesis of non-stationarity cannot be rejected at even the 10 percent level of significance. The results suggest that the levels of all the variables as well as total liquidity, *M1*, and income in difference form contain unit roots.

Table 1 - Tests for Non-Stationarity (1982.3 - 1991.2)

	TL	M1	M2	RM	Y	E	TB
A. Tests for Levels of Variables							
Constant	- 0.011	0.139	0.040	0.327	0.108	0.247	0.487
	(0.177)	(0.138)	(0.186)	(0.180)	(0.219)	(0.120)	(0.267)
Trend	0.001	0.001	0.001	0.003	0.0006	0.0009	0.00006
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.003)
Coefficient on lagged level	0.996	0.953	0.988	0.899	0.981	0.917	0.833
	(0.034)	(0.037)	(0.038)	(0.054)	(0.034)	(0.052)	(0.093)
B. Tests for Differences of Variables							
	TL	*M1*	*M2*	*RM*	*Y*	*E*	*TB*
Constant	- 0.0001	0.0006	0.0006	0.009	0.0004	0.021	0.008
	(0.002)	(0.002)	(0.002)	(0.005)	(0.001)	(0.010)	(0.034)
Lagged level	0.879	0.855	0.855	0.495[1]	0.808	0.333	0.027
	(0.080)	(0.087)	(0.087)	(0.147)	(0.101)	(0.162)	(0.176)

Notes: Significant at 1 percent.
Each regression uses logs of all the series and one lag of the dependent variable.

Despite this latter finding, however, cointegration allows a means of determining whether a long-run relationship exists between variables with unit roots. This is possible if the sources of non-stationarity are other sets of variables. Hence, these variables will not tend to drift away from each other. This can be ascertained by examining if the residuals from an OLS regression of these variables are stationary using the Dickey-Fuller test again. The null hypothesis is one of no cointegration, or equivalently, that the residuals are non-stationary.

Table 2.1 presents the results of regressing *M1*, *M2*, or reserve money on real income, the 91-day Treasury bill rate, and the nominal exchange rate.[1] Including the exchange rate in the money demand

[1] The results for total liquidity are not reported here because the coefficient on the interest rate is positive although insignificant.

equation is important because as McKinnon (1982) argues and McNown and Wallace (1992) have shown, international currency substitution may destabilize the demand for money. The latter's

Table 2.1
Tests for Cointegration

	M1	*M2*	*RM*
A. Estimated Equations			
Constant	- 7.526[1] (0.530)	- 6.645[1] (0.332)	- 8.871[1] (0.829)
Real Y	1.797[1] (0.082)	1.806[1] (0.051)	1.809[1] (0.129)
Interest Rate	- 0.037 (0.019)	- 0.035[1] (0.012)	- 0.163[1] (0.031)
Exchange Rate	- 0.077[1] (0.019)	0.017[1] (0.012)	0.492[1] (0.031)
B. Test Statistics			
Dickey-Fuller Test	- 29.27[1]	- 2.188	- 2.686

Note: [1] Significant at 1 percent.

results, in particular, show that the variables explaining the demand for *M2* do not form a cointegrated system unless the exchange rate is included.

The results in Table 2.1 show that the hypothesis of no cointegration between the monetary aggregate *M1, M2*, or *RM* and real income, the 91-day Treasury bill rate, and the nominal exchange rate can be rejected at the 1 percent level in the case of *M1* based on the results of the Dickey-Fuller test. The Dickey-Fuller test does not allow us to reject the hypothesis of no cointegration between *M2* or *RM* and the explanatory variables even at the 10 percent level. In addition, the finding of a significantly negative coefficient of the nominal exchange (P/$) rate in the *M1* cointegrating regression may indicate the following: As the peso depreciates, the demand for *M1* decreases as portfolio holders switch to dollars and/or to interest-bearing peso assets.

Table 2.2 - Tests for Cointegration

A. Estimated Equations			
	M1		
Constant	-7.521[1] (0.472)	3.740[1] (0.215)	3.589[1] (0.265)
Real Y	1.743[1] (0.073)		
Interest Rate		- 0.004 (0.073)	
Exchange Rate			0.047 (0.089)
	M2		
Constant	- 6.778[1] (0.362)	4.938[1] (0.221)	
Real Y	1.818[1] (0.056)		
Interest Rate			0.006 (0.075)
Exchange Rate			
	RM		
Constant	- 8.808[1] (2.266)	3.761[1] (0.332)	1.999[1] (0.286)
Real Y	1.948[1] (0.351)		
Interest Rate		- 0.0009 (0.113)	
Exchange Rate			0.599[1] (0.097)
B. Test Statistics			
	M1	**M2**	**RM**
Dickey-Fuller Test			
Real Y	- 21.59[2]	- 1.93[3]	- 1.37
Interest Rate	- 0.26	0.57	1.28
Exchange Rate	- 0.53	- 0.01	- 0.88

[1] Significant at 1 percent.
[2] Significant at 5 percent.
[3] Significant at 10 percent.

Table 3.1 - Error-Correction Specifications for Money Demand (1982.4 - 1991.2)

Dependent Variable	$\Delta M1$	$\Delta M2$	ΔRM
Constant	0.01[1] (0.003)	0.008[1] (0.003)	0.019[1] (0.005)
ΔY	0.729[1] (0.262)	0.792[1] (0.279)	
ΔY_{-1}	0.501[1] (0.230)	0.471 (0.256)	0.766 (0.303)
ΔTB	- 0.018 (0.012)	- 0.046[1] (0.011)	- 0.029 (0.023)
ΔTB_{-1}		- 0.31[1] (0.011)	- 0.036 (0.022)
ΔE	- 0.136[1] (0.051)		
ΔE_{-2}		- 0.160 (0.051)[1]	- 0.105 (0.098)
Error Correction Term	- 0.291[1] (0.065)	- 0.188 (0.102)	- 0.158 (0.097)

[1] Significant at 1 percent.

The regressions in Table 2.1 were re-run to test for pairwise cointegration between each monetary aggregate and each explanatory variable. This is useful since the results in Table 2.1 imply that *M2* and *RM* are not cointegrated with real income, the interest rate, and the exchange rate taken together. Nevertheless, it is possible for them to be cointegrated with each explanatory variable alone.

The results in Table 2.2 indicate that the null hypothesis of no cointegration between *M1* and *GNP* and *M2* and *GNP* can be rejected at the 5 percent and 10 percent level, respectively. The null hypothesis of no cointegration between each of the monetary aggregates and either the interest rate or the exchange rate cannot be rejected at the usual levels of significance.

The results in Tables 2.1 and 2.2 suggest that *M1* is the best choice for a target variable as it consistently exhibits a tendency towards a stable relationship with key macro variables. The fact that *M1* is cointegrated with real income, the interest rate, and the exchange rate means that in a money demand function estimated using *M1*, disturbances in real income, the interest rate, and the exchange rate would not lead to permanent shifts in the estimated function.

4. Error-Correction Specifications for Money Demand

While cointegration tells us about long-run relationships, the behavior of monetary aggregates over the short run is equally important. An error-correction model allows for the gradual adjustment of the dependent variable towards long-run equilibrium while allowing for short-run adjustment.

The error-correction models estimated consisted of the first difference of the monetary aggregate as the dependent variable, a constant, first differences of the logs of real income, the 91-day Treasury bill rate, the nominal exchange rate, and an error-correction term where the latter uses the coefficient from the cointegrating regressions. The first differences of the explanatory variables and their lags capture the short-run effects of disturbances to real income, the interest rate, and the nominal exchange rate while the error - correction term captures the adjustment towards long-run equilibrium. The error-correction model was estimated with 4 lags of the explanatory variables.[2] Lags which had insignificant coefficients were eliminated. The demand functions estimated for each monetary aggregate are shown in Table 3.1. The coefficient on the error-correction term in the *M1* equation reveals that approximately 29 percent of the previous quarter's discrepancy between the actual and equilibrium value of *M1* is corrected each quarter while those for *M2* and *RM* are 18 percent and 15 percent, respectively. Of the explanatory variables, income and the nominal exchange rate are significant when *M*1 or *M2* is used. The 91-day Treasury bill rate is also significant in the *M2* regression reflecting perhaps the holding of money primarily as an asset.

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[2] Uniform lags of 8 on the explanatory variables yielded inferior results. The coefficient on the error correction term was insignificant.

Table 3.2 - Error Correction Specifications for Money Demand Using a Single Explanatory Variable (1983.1 - 1991.3)

Dependent Variable		ΔM1	
Constant	0.0008	0.006	0.016[1]
	(0.0029)	(0.005)	(0.005)
ΔY	1.515[1]		
	(0.182)		
ΔInterest Rate		-0.048	
		(0.027)	
ΔExchange Rate			-0.302[1]
			(0.091)
Error Correction Term	-0.361[1]	0.013	0.021
	(0.080)	(0.365)	(0.033)
Dependent Variable		**ΔM2**	
Constant	0.0007	0.006	0.016[1]
	(0.003)	(0.005)	(0.005)
ΔY	1.4871		
	(0.235)		
ΔInterest Rate		-0.048	
		(0.026)	
Exchange Rate			-0.313[1]
			(0.089)
Error Correction Term	-0.072	0.026	0.037
	(0.138)	(0.035)	(0.032)
Dependent Variable		**ΔRM**	
Constant	0.017[1]	0.021[1]	0.026[1]
	(0.004)	(0.004)	(0.005)
ΔY	0.757[1]		
	(0.311)		
ΔInterest Rate		-0.059[1]	
		(0.023)	
ΔExchange Rate			-0.186[1]
			(0.090)
Error Correction Term	0.024	0.036	0.016
	(0.030)	(0.021)	(0.031)

[1] Significant at 1 percent.

When the error-correction specification for money demand is done using only a single explanatory variable, the results for *M1* and *M2* do not change much. These results are shown in Table 3.2. However, income, the interest rate, and the exchange rate are now significant in the *RM* equation. Despite these, however, *M1* is still superior to either *M2* or *RM*. First, the coefficient on the error-correction term in the *M1* regression is statistically significant; secondly, it says that 36 percent of the discrepancy between the actual and equilibrium value of *M1* is corrected every quarter, at least in the regression with income as the explanatory variable. All the other specifications are inferior as they imply an unreasonably slow adjustment.[3]

5. Summary and Conclusions

This study examines the relationship between various monetary aggregates and real income, the 91-day Treasury bill rate, and the nominal exchange rate using the Engle and Granger cointegration method. The idea is that in selecting a particular monetary aggregate to target, the choice should ideally satisfy the theoretical requirements for such, namely, the aggregate must be controllable by the Central Bank given the available instruments, and the aggregate must have a stable and predictable relationship with variables of interest to policymakers. Cointegration tests allow for the specification of a long-run equilibrium relationship among the variables of interest. It also allows for short-run adjustment towards this long-run relationship via an error-correction mechanism. The results of the Dickey-Fuller tests suggest that the levels of all the variables as well as total liquidity, *M1* and income in difference form contain unit roots, i.e., are not stationary. Furthermore, only narrow money, *M1*, is cointegrated with real income, the 91-day Treasury bill rate, and the nominal exchange rate taken together. None of the other monetary aggregates were significantly cointegrated with these variables taken together. These results are in contrast with other studies which suggest that narrow money tends to be unstable because of portfolio shifts. Our results suggest that portfolio shifts to dollars and/or to interest-bearing peso assets occur as the peso depreciates but that

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[3] Trehan (1988), for example, estimates that about one-fourth of the previous quater's discrepancy between the actual and equilibrium value of the monetary aggregate is corrected each quarter in the German case.

this does not make the demand for *M1* unstable. Of the various variables of interest, only real income is cointegrated with either *M1* or *M2* in pairwise regressions.

Error-correction specifications suggest that approximately 29 percent of the previous quarter's discrepancy between the actual and equilibrium value of *M1* is corrected in each quarter. This result is similar to Trehan's (1988) for Germany. When either *M2* or reserve money is used, the speeds of adjustment are much slower. In the error-correction models using pairwise cointegrating regressions, the results using *M2* or reserve money imply implausibly slow speeds of adjustment.

Overall, the results imply that *M1* is the best choice for a target variable.

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