The Demand for Money in UAE: Cointegration and Error Correction Tests

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I. Introduction

Standard times series regressions pay little attention to whether the relationships between economic variables are real or spurious. Spurious relationships arise because most economic time series exhibit non-stationary tendencies, and can be identified when the regression's adjusted coefficient of determination (R2) exceeds the Durbin Watson (DW) statistic (Granger 1974). However, the high R2's may reflect correlated trends rather than underlying economic relationships while the low DW statistics may indicate non-stationarity. One method of checking for spurious relationships involves first-difference regressions, where first differencing is expected to restore stationarity. Whether the relationships found in level regressions appear in first-difference specifications remain an empirical question.

Cointegration, on the other hand, attempts to identify conditions for which relationships are not spurious (Engle and Granger 1987; Granger 1986; Hendry 1986). The idea underlying cointegration is to allow for modeling the belief that certain economic variables may drift apart in the short-run, but not diverge too far apart in equilibrium. If the time series variables are cointegrated, their long-run trends adjust according to an

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equilibrium constraint. The deviation between the series and its equilibrium trend is known as the equilibrium error. Modeling this error is called error-correcting form, and the data generated by error-correction model should be co-integrated. A typical error-correction model would relate the changes in one variable to past equilibrium errors, as well as to past changes in the other variables (see Engle and Granger, 1987). The relationship between cointegration and error-correction is that co-integrated series can be represented by error-correction models. Furthermore, cointegration implies that deviations from equilibrium are stationary, even though the series themselves are non-stationary. Following the definition of Miller (1991), if two time series Xt and Yt are non-stationary in their levels but stationary in their first differences, the series are said to be co-integrated with a co-integration factor ß, where ß is such that the error term zt = yt - ßxt is stationary. If such a factor exists, it must be unique. Any other factor (ß + ?) generates an additional term (?Xt) which is non-stationary by definition. In this case, an error-correction model should be estimated.

Cointegration and error-correction modeling is thus a two-step procedure. In the first step, a level regression is performed to test the hypothesis of cointegration (long-run relationships). To test for cointegration, only the series exhibiting first-order unit root are employed in the cointegration regression. In this regression, one of the system-variables is regressed on a constant and the remaining variables; second, the residuals from the first regression are regressed upon the lagged residuals and up to eight lags of the first differences of the residuals. The lag structure is determined using Akaike's final predication error (FPE). This error-correction representation is expected to capture the short-run relationships among the variables. A test statistic less than the critical value is sufficient to reject cointegration.

The primary purpose of this paper is to examine monetary dynamics in the United Arab Emirates (hereafter, UAE) using this two-step procedure over the period 1975:i - 193:iv. The rest of the paper is organized as follows: Section II specifies the empirical model designed to capture the behavior of the demand for money in UAE. Section III describes the data and the data sources. The empirical findings are presented in Section IV.

The results reported in this section include testing for the stationarity of the time series used in estimating the money demand, namely: the logarithms of money stock M1, M2, real non-oil GDP, nominal interest rate, and price level. Cointegration between these series was also tested. Finally, Section VI concludes our study.

II. The Model

Monetary economists generally debate the variables that are expected to influence the demand for money. Following Miller (1991), we expect the long-run money demand in UAE to behave in the following way:

$$\mathrm{In}\ \mathrm{M}_t^d = \beta_0 + \beta_1 \mathrm{InY}_t + \beta_2 \mathrm{InR}_t + \beta_3 \mathrm{InP}_t + u_t \ (1)$$

where Mtd is the quantity of nominal money balances demands, Yt is the real non-oil GDP, Rt is the nominal interest rate. Pt is the price level and ut is the error term. The long-run money demand becomes a demand for real balances if, and only if, ß3 equals one.

Researchers debate the choice of variables for money demand regressions. Questions arise about the appropriate monetary-aggregate, interest rate and scale variable measures. We consider two alternatives measures for the monetary aggregate, namely M1, and M2. For the interest rate, we use one alternative, the market rate of interest (R) and one alternative for scale variable-nominal non-oil gross domestic product decomposed into real non-oil gross domestic product (Y) and the implicit price deflator (P).

The procedure followed in estimating the above equation involves four steps. First, the times-series properties (i.e., stationarity) of the data should be investigated. Estimting equation (1) with non-stationary data will lead to unreliable t-ratios, as the series would have infinitely large variable (see Arize and Shwiff, 1993). Second, we estimate cointegration regressions with ordinary least squares using variables with the same order of integration. Third, test the residuals of the cointegration regressions for stationary. Finally, we construct the error-correction models.

Test for Stationarity

Standard statistical time-series analyses are based on the assumption of stationarity. Prior to specification and estimation, diagnostic checks have to be performed on the data to test for unit-roots. Existence of unit roots indicate non-stationarity of the series. Dickey-Fuller (DF), and Augmented Dickey-Fuller (ADF) tests are performed to test for stationarity. These tests are the familiar t-tests, with the critical values coming from Fuller (1976), and Dickey and Fuller (1979). The Augmented Dickey-Fuller test requires the estimation of the regression equation

where d is the first difference operator, X is the logarithm of the variable being tested, pi, a and d are parameters to be estimated and et is an error term. In estimating equation (2), the t-ratio of the coefficient associated with the lagged level term is important in determining the stationarity of the economic time series. If the t-ratio is less than the critical value, the null hypothesis of a unit root (non-stationarity) is less than the critical value, the null hypothesis of a unit root (non-stationarity) is rejected. On the other hand, if the calculated t-ratio is larger than the critical value, and the null hypothesis is not rejected, a common practice in time-series analysis is to difference the time series before the assumption of stationarity can be presumed to hold (Jansen and Hafer 1991). A first difference version of equation (1) is estimated to determine if the data are stationary in changes. If the t-ratio on the coefficient of the lagged change variable is less than the critical value, the hypothesis of a unit root is rejected and the level series is characterized as integrated of order one. Otherwise, a second difference is performed and a new test is conducted.

Co-integration

To determine the order of integration, we use the procedures suggested by Dickey and Fuller (1979). We difference each series successively until stationary series emerge. The cointegration test requires that the economic series used in the regression equation (1) above, pass the unit root test, and the residuals from the regression must be stationary (i.e., integrated of order one). In this regression, one of the system-variables is regressed on a constant and the remaining variables. Second, the residuals from the first regression are regressed upon the lagged residuals and some lag structure of the residuals. A test statistic less than the critical value is sufficient to reject cointegration.

III. Data Description

The data used in estimating the above model consist of quarterly observations of the monetary aggregates (M1 & M2), non-oil GDP, interest rate, and price level. All data are expressed in nominal terms except non-oil GDP. The period under investigation is 1975: i - 1993: iv. The monetary aggregates and the interest rate data are compiled from various issues of the UAE Central Bank Bulletins. The data GDP are published annually by the UAE Ministry of Planning. To generate the quarterly figures, we used SAS interpolation procedure.1

IV. Empirical Results

Table 1 reports Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests for stationarity of the log of monetary aggregate (In M1), the log or real GDP (In Y), the log of interest rate (In R), and the log of price level (In P). As can be seen from the table, none of the levels of the series save two rejects the null hypothesis of non-stationarity at the 1 percent and the 5 percent levels (see Engle and Yoo 1987 for critical values). The test of the natural logarithm of the M1 and Y (that is, In M1, In Y) the exception, rejects the null hypothesis. Further analysis of M1 and Y suggests that first differencing induces stationarity. The autocorrelation and partial autocorrelation charts show that first differencing leaves a highly autocorrelated series with a slowly declining autocorrelation function. This result confirms findings by other researchers, e.g., Arize and Shwiff (1993), that the variables commonly used in many demand studies are non-stationary. However, after taking the first difference, each series rejects the null hypothesis of non-stationarity at 1 percent level or 5 percent. The only exception is the natural logarithm of price level which rejects the null hupothesis by the ADF test but not by the DF test.

Table 1: Tests for stationarity 1975:i to 1993:iv

	DF Test		ADF Test	
	levels	1st Differences	level	1st Differences
variables:				
ln M1	-4.572**	-8.571**	-5.494**	-5.164**
ln M2	-2.779	-9.701**	-2.751	-4.881**
ln Y	-5.908**	-4.428**	-1.927	-4.247**
ln P	-2.449	-2.607	-2.619	-3.768*
ln R	-0.389	-9.367**	-0.442	-5.588*

Note: The Augmented Dickey-Fuller (ADF) test is based on the following regression:

$$\Delta X_t = \mu + \delta T + \alpha X_{t=1} + \sum_{i=1}^{m} Y_i \, \Delta X_{t-i} \;\; \epsilon_t$$

where d is the first difference operator and ϵ_t is a stationary random error. The null hypothesis is that X_t is a nonstationary series and it is rejected when α is significantly negative. The Dickey-Fuller (DF) test deletes the summation from the equation.

**** means significant at the 1 percent level.**

*** means significant at the 5 percent level.**

The possibility of cointegration between money stock and the determinants of the money demand namely: the non-oil GDP, the interest rate, and the price level were also examined. Only the regression equation with the highest adjusted coefficient of determination is reported. Such a procedure is recommended by many researchers, including Hendry (1986) and Miller (1991). The high adjusted coefficient of determination indicates a minimum bias in the estimate of the cointegration parameter. Table 2 reports the results of testing for cointegration between the money stock and the remaining explanatory variables.[2] First, we considered cointegration between the money stock (M1 and/or M2) and both the real non-oil GDP and the price level.3 The coefficient of the real non-oil GDP is in the neighborhood of one for M1, but much more than one in the case of M2. The coefficient of one is interesting in the demand for money since it indicates a stationary velocity. When the interest variable is introduced in the cointegration equation, the coefficient of the real non-oil GDP remains in the neighborhood of one for M1, and the coefficient of price-level (P) becomes close to one. DF test does not reject the null hypothesis of non-stationarity in the case of M1 and M2 at the 1 percent level. However, the

ADF test rejects the null hypothesis of non-stationarity for the M1 regression at the 1 percent level.[4]

Table 2: Cointegration Regression 1975:i to 1993:iv

	Coefficient of							
	const.	**ln Y**	**ln P**	**ln R**	**ln E**	**D-W**	**DF**	**ADF**
variables:								
ln M1	0.725	0.767	1.66		0.96	0.45	-2.96	-2.82
	(1.1)	(12.2)	(8.1)					
ln M2	-5.846	1.513	0.44		0.90	0.10	-2.22	-1.66
	(-4.1)	(11.2)	(1.01)					
ln M1	0.411	0.900	1.003	-0.472	0.97	0.66	-4.14**	-5.29**
	(0.76)	(16.7)	(5.2)	(-6.6)				
ln M2	-6.726	1.885	-1.397	-1.317	0.97	0.34	-2.62	-2.99
	(-7.7)	(21.6)	(-4.5)	(-11.5)				

Note: The errors from the cointegration equations are recovered to perform the Augmented Dickey-Fuller nonstationarity tests on the following regression:

$$\Delta\mu_t = \mu + \delta \mathbf{T} + \alpha \mathbf{X_{t-1}} + \sum_{i=1}^{m} \sigma_{1+i}\, \mu_{t-1} + \epsilon_t$$

where is the error from cointegration equation, Et is the stationary random error and the null hypothesis of nonstationarity is rejected when σ_1 is significantly negative. The Dickey-Fuller (DF) tests for nonstationarity delete the summation. R^2 is the adjusted coefficient of determination and D-W is the Durbin-Watson statistic.

****means significant at 1 percent level.**

*** means significant at 5 percent level.**

To conclude this section, we can say that the cointegration regressions suggest that only one monetary aggregate, M1, has a long-run trend relationship with real non-oil GDP, the interest rate and price level. Stated differently, the logarithms of M1, Y, R, P are co-integrated. The other monetary aggregate, M2, appears to be not cointegrated with the determinants of money demand examined.

Error-Correction Models

The final stage in estimating the demand for money is the construction of an error-correction model. This involves regressing the first difference of each variable in the cointegration equation onto lagged values of the first differences of all the variables plus the lagged values of the error-correction terms. The lag lengths used in the error-correction model is determined such that it minimizes Akaike's final prediction error (Akaike, 1969). For each of the error-correction models examined, all possible combinations of lags, from one to eight, are considered, Akaike's FPE was calculated and the lag structure that minimizes the FPE was chosen. These results are reported in Table 3. The sums of the coefficients are shown on the first line. The numbers in parentheses under the sum of the coefficients are the values of the F statistics, needed for testing whether the sum of the coefficients is significantly different from zero. The numbers in brackets are the number of lags needed to minimize the FPE.

Table 3: Temporal causality tests from error-correction models: Akaike FPE lag-length selection criteria.

	Coefficients of				
	Ext	$\sum \Delta$ ln M1	$\sum \Delta$ ln Y	$\sum \Delta$ ln P	$\sum \Delta$ ln R
equations:					
Δ ln M1	-0.227	0.102*	-0.359	1.246*	0.216
	(-1.42)	(4.81)	(0.89)	(4.71)	(0.59)
		[4]	[3]	[2]	[6]
Δ ln Y	0.098*	0.051*	0.675**	0.181	0.141
	(3.64)	(3.32)	(48.79)	(1.54)	(0.99)
		[1]	[2]	[2]	[2]
Δ ln P	0.032	0.014	-0.02	0.721**	0.001
	(1.24)	(0.91)	(0.42)	(47.8)	(1.14)
		[2]	[3]	[2]	[3]
Δ ln R	0.154	-0.244	0.563*	-0.128	0.029
	(1.62)	(0.66)	(6.06)	(0.56)	(1.150
		[6]	[1]	[8]	[2]

Note: Ect is the error-correction term determined from the corresponding cointegration reported in Table 2. The numbers in parentheses under the coefficients are values of F statistics. The numbers in parentheses under the error-correction terms are t-statistics. Numbers in brackets indicate the number of lags.
****means significant at 1 percent level.**
*** means significant at 5 percent level.**

Several things are worth noting here. First, all the coefficients that are significantly different from zero have the expected sign. Second, the expected signs of the coefficients of error-correction term are positive for ln Y and ln P and negative for ln R and ln M1. This result has important implications for policy makers who want to know whether changes in the interest rate can stabilize the system in the long-run. When the money supply exceeds the long-run money demand, output and price level should rise and the interest rate should fall to keep the system in equilibrium. If monetary policy is stabilizing, then the money growth rate should fall. From a statistical perspective, the long-run relationship means that the three variables move together over time so that short-term disturbances from the long-run trend will be corrected. The sample regressions suggest that the error-correction term affects only the real non-oil GDP.

V. Conclusion

We use cointegration, error-correction modeling to examine the long-run and short-run money demands. The cointegration equation measures long-run money demand. The error-correction equations model the short-run dynamics of the determinants of long-run money demand.

The money-stock equations in the error-corrections 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. Thus, the path of money-stock growth rate reflects monetary policy decisions, to the extent that central bank has some exogenous control, and/or endogenous movements in response to the adjustments of other economic variables (that is, the long-run determinants of money demand). If the Central Bank has exogenous control of the money stock and exercises such control, then the error-correction regression can be interpreted as a monetary policy reaction function. If, on the other hand, the money stock is endogenous, then the error correction regression must be interpreted as the endogenous response of the money-stock growth rate to adjustments in the macroeconomy.

Using cointegration analysis to identify the long-run money demand suggests that only one monetary aggregate, M1, has a long-run trend relationship with real non-oil GDP, the interest rate and the price level. This finding offers a new piece of evidence supporting the use of M1 as a guide to monetary policy implementation.

The error-correction model results provide evidence that monetary disequilibria were allowed to have more effect on the goods and services markets rather than financial markets; the error-correction term significantly affected the growth rate of the real non-oil GDP but not the interest rate. The absence of a significant effect on the interest rate may only reflect a central bank policy of stabilizing interest rates since, when interest rates are stabilized, they are unable to adjust in response to money market disequilibria.

Footnotes

1 The data used in testing this model are available with the authors upon request.

2 Table 2 reports standard t-statistics but the standard errors are misleading in the cointegration equations (Engle and Granger 1987).

3 This cointegration regression captures the long-run relationship between the measure of monetary aggregate and the two explanatory variables if two conditions hold. First, the logarithm of the monetary aggregate and logarithms of the explanatory variables are integrated of the same order. Second the error term is stationary.

4 The high and low D-W statistics suggest possible spurious regression (for more details see Hendry 1986).

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This paper focusses on monetary dynamics in the United Arab Emirates using cointegration and error correction modeling. This approach examines the long-run trend relationships between economic variables in a system of short-run dynamic adjustment equations. The empirical results show how the money stock respond to changes in the determinants of long-run money demand. Furthermore, the results indicate how the determinants of long-run money demand adjust to each other and to changes in the money supply.