Cointegration, Error Correction
And the Demand for Money in Saudi Arabia

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Abstract:

This study investigates the determinants of the money demand function in Saudi Arabia. Saudi economy was instable during the period 1977-1997 because of its dependence of the production of oil. This depending affects sharply the rates of growth and the rates of inflation. The integration and cointegration proprieties of the data are analyzed and the model of error correction is used to estimate the demand for money. This paper concludes that even the period of high instability in the economy, there exists a stationarity long run demand for narrow money (M1) in Saudi Arabia.

JEL Classification Codes:
E41: Demand for Money
C22:Time Series Models

Cointegration, Error Correction And the Demand for Money in Saudi Arabia

This paper presents a study of the money demand function in Saudi Arabia. Saudi economy is heavily dependence on the production of single primary good, which mad the economy suffer from sever changes with the fluctuation in the oil markets. The period 1977:1-1997:3 includes three periods, which are characterized by large over-all changes in the economy of Saudi Arabia. The period of 1977-1981 is when the first Gulf war started which caused a jump in oil prices, which significantly increased the government revenues. The economy had had high rates of growth and high rate of inflation during that time. But during the period 1982-1987, as a result of the sharp decline in oil prices, Saudi Arabia economy had had negative rates of growth accompanied by negative rates of inflation. However, with the improvement in oil prices since the early 1988, the economy has experienced positive rates of both growth and inflation. Applying the technique of cointegration to estimate the demand for money, this paper concludes that even in the period of high changes in the economy of Saudi Arabia, there exists a stationary long-run demand for narrow money (M1).

Introduction:

Even though the demand for money is a controversial area of study for both theory and policy, the simple model for the demand for real money balances is established as following:

$$(\frac{M}{P})^d = f(y,r) \qquad \{1\}$$

Where M is the nominal money demand, P is the price index, y is real income which reflects the level of transactions in the economy, and (r) is the rate of interest which represents the opportunity cost of holding money. It is also argued that individuals want to hold a real quantity of money balances, so that the demand for real money holdings should be proportional to the inflation rate and exchange rate. (W.Enders, p. 356) .In logarithms, an econometric specification for such an equation can be written as:

$$m_t = \beta_0 + \beta_1 y_t + \beta_2 r_t + \beta_3 \pi_t + \beta_4 Ex_t + e_t \qquad \{2\}$$

where $m_t = \ln(M/P)_t$ = the natural logarithm of the real money demand

P_t = price level (consumer price index)

y_t = the natural logarithm of the real income

r_t = interest rate

π_t = expected inflation rate

Ex_t =real exchange rate

e_t = stationary disturbance term

β_i= parameters to be estimated

Money demand and income are only expressed in logarithms.

The hypothesis that the money market clears allows to collect time-series data of the money supply as a measure of the money demand if the money market always clears, the price level, real income (GDP), an appropriate short-term interest rate (r), and the exchange rate (Ex). The behavioral assumptions require that $\beta_1 > 0$, and $\beta_{2,}\beta_3, \beta_4 < 0$. The properties of the unexplained portion of the money demand {i.e. the e_t sequence} are an integral part of the theory. If the theory is to make any sense at all, any deviation in the demand for money must necessarily be temporary in nature. Clearly, if e_t has a stochastic trend, the error in the model will be cumulative so that the deviations from money market equilibrium will not be eliminated. Hence, a key assumption of the theory is that the error term is stationary.

The problem confronting the estimation of the demand function for money is that the real income, money demand, price level, interest rate and exchange rate can all be characterized as nonstationary I (1) variables. As such, each variable can meander without any tendency to return to a long-run level. However, the theory expressed in equation (2) asserts that there exists a linear combination of these nonstationary variables that is stationary.

Solving for the error term, we can rewrite the relation (2) as:

$$e_t = m_t - \beta_0 - \beta_1 y_t - \beta_2 r_t - \beta_3 \pi_t - \beta_4 \mathrm{Ex}_t \qquad \{3\}$$

Since $\{e_t\}$ must be stationary, it follows that the linear combination of integrated variables given by the right-hand side of (3) must also be stationary. Thus, the theory necessitates that the time paths of the five nonstationary variables $\{m_t\}$, $\{y_t\}$, $\{r_t\}$ $\{\pi_t\}$ and (Ex_t) be linked.

So equilibrium theory of the demand for money involving nonstationary variables requires the existence of a combination of the variables that is stationary. And within an equilibrium demand for money, the deviations from equilibrium must be temporary.

The concept of cointegration is that non-stationary time series are cointegrated if a linear combination of these variables is stationary. In other word, there is a long-run deviation from the equilibrium (Engle and Granger, 1987). The cointegration requires the error term in the long-run relation to be stationary. If so, the variables are cointegrated in the long run. Furthermore, applying constrained error correction model captures the short-run dynamic adjustment of cointegrated variables.

The main purpose of this paper is to empirically investigate the long-run money demand in Saudi Arabia to test for the stationary of the long-run equilibrium relationship between real money balance and both real income and the rate of interest, which according to Friedman (1956) is stationary. This paper utilizes the techniques of cointegration and error correction in evaluating such relation.

Data and the Unit Root Test

The data used are quarterly during the period 1977-1997, which includes 81 observations of the money demand relation. M1 narrow money demand and GDP are extracted from SAMA publications. The nonoil GDP annual data are transformed by linear interpolation to quarterly data. The price variable representing quarterly consumer index is extracted from IMF publication. Inflation rate is calculated from the consumer price index. Interest rates on eurodollar are also from IMF publications. The real exchange rate is calculated by deflating the nominal exchange rate by the consumer price index. Money demand (M1) and nominal income are used in real term; on the other hand, nominal interest rate is used in the estimation.

Before testing for cointegration is performed, we should test for the stationary of the variables of the money demand relation. The Augmented Dickey-Fuller (ADF) test is conducted to check for a unit root for all variables in both levels and first differences. These tests are presented in Table (1), which reveals that the hypothesis of a unit root can not be rejected in all variables in levels. However, the hypothesis of a unit root is rejected in first differences which indicates that all variables are integrated of degree one, I (1).

Table (1): Test for Unit Roots

Variables	Unit Root in levels	Unit Root in differences
	ADF	ADF
m	-2.060(4)	-4.405(4)*
y	-2.958(4)	-2.215(0)**
r	-2.808(4)	-8.747(0)*
π	-1.388(2)	-5.608(2)*
Ex	-1.286(1)	-5.770(4)*

** Rejection the null hypothesis at 1%, * Rejection of the null hypothesis at 5%.
Numbers in parenthesis are the numbers of lags.

The ADF test reveals that the four variables have at 5% of significance, a unit root in levels and stationary in differences. So these variables are I (1), and have the same degree of integration.

The estimation of the relation (1) by direct OLS gives the following integration equation:

$$\hat{m}_t = -7.145 + 1.7574 y_t \; - 0.0131 r_t - 0.0194 \pi_t + 0.0713 Ex_t$$

(-19.409) (53.118) (-6.878) (-2.992) (2.505) {4}

$\overline{R}^2 = 0.9786$ F = 938.33 DW = 0.601

The estimated parameters of (4) are in accordance with the economic theory. Inflation and interest rates have negative parameters while real income has a positive elasticity. All coefficients are statistically significant at 1% level while the dummy variable is significant at 5% level. The estimated short-run static elasticity is 1.76 for real income. The interest rate and the inflation rate have a negative effect on real money demand while real exchange has a positive effect. The nonstationarity of the variables biased the previous estimation, and the low value of DW can be interpreted as sign of spurious correlation.

The dynamic Short-Run Relationship (ECM):

Conducting ADF tests reveals that the variables of the money demand relation (2) are I (1) at 1% level of significance. Furthermore, cointegration involves examining the stationarity of the residuals from the long-run relationship. If the residuals are integrated of degree zero, then we can assure that the linear combination of the variables in the demand for money relation are cointegrated.

Table (2) shows the ADF stationarity tests of the residuals, it is shown that these residuals are stationary of degree zero at 5% level of significance (i.e. I (0)). In other words, the linear combination of the five variables of the model (1) is stationary and they are cointegreted.

Table (2): ADF test for residuals

n	ADF
0	-4.642
1	-4.710
2	-3.816
3	-3.188
4	-4.147

The critical ADF values are –2.591 at 1%, -1.944 at 5%, and –1.618 at 10%.

ADF test for residuals of the cointegrating regression reveals that the null hypothesis can be rejected at 1% level of significance, and the variable (e) is stationary of degree zero I (0).

The dynamic relationship includes the lagged value of the residual from the cointegrating regression (e_{t-1}) in addition to the first difference of variables, which appear in the right hand side of the long-run relationship (real income, inflation rate, interest rate and real exchange rate). The inclusion of the variables from the long-run relationship would capture short run dynamics. Therefore, the dynamic relationship is stated as following:

$$\Delta m_t = b_0 + b_1 \Delta y_t + b_2 \Delta r_t + b_3 \Delta \pi_t + b_4 \Delta Ex_t + \beta_5 e_{t-1} + \mu_t \quad \{5\}$$

The results from estimating equation (5) is:

$$\Delta m_t = 0.0024 - 0.3537 e_{t-1} + 1.678 \Delta y_t - 0.0033 \Delta r_t - 0.0077 \Delta \pi_{t-1} + 0.0669 \Delta Ex_{t-1}$$

(0.5156) (-5.245) (4.9648) (-1.260) (-2.4348) (2.2035) {6}

$\overline{R}^2 = 0.415$ $F = 12.478$ $DW = 1.814$

The error correction model proves that the short run dynamic elasticity of money demand relative to income is 1.68. The error term means that 35% of the money demand fluctuations are corrected each period. The estimated coefficients of inflation rate and real exchange rate are significant at 5% level while the estimated coefficient of the interest rate is not significantly different from zero. This result means that the interest rate does not have a significant effect on the short run real money demand in Saudi economy.

Johansen Cointegration and Long-Run Elasticities:

It is widely recognizable that Engle and Granger test for cointegration is enough if our concern is only to examine the effect of error correction mechanism of money demand for two sequences periods such as t and t-1. However, since our objective is to focus on the whole structure of the money demand, it is more useful to apply multivariate cointegration analysis of Johansen.

Following Johansen and Jueselius (1990), a cointegrating test is conducted. In this method, the time series X_t is modeled as a vector autoregressive (VAR):

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \dots\dots\dots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \mu + \varepsilon_t \qquad \{7\}$$

Where X_t is a vector of non-stationary (in levels) variables. And Π is a $P \times P$ matrix, which is called a long run impact matrix, and μ_i is the constant or drift term.

In this regard, if $0 \le rank(\Pi) \le P$, then the components of X_t are cointegrated. If $rank(\Pi) = r$, where $0 \le r \le P$, then there are r cointegrating vectors or stationary long-run relationships among the P variables. In this case, Π is decomposed as $\Pi = \alpha\beta'$ where β is a matrix contains the cointegrating vectors and α is interpreted as measuring the average of the speed of adjustment.

Table (٣) presents the cointegration test which indicates a long run equilibrium relationship between real money balance (M1), real income, and interest rate.

Table (٣): Johansen Cointegration

$Eigenvalue\ \hat{\lambda}_i$	$\lambda_{\max} = -T\ln(1-\hat{\lambda}_i)$	$\lambda_{trace} = -T\sum \ln(1-\hat{\lambda}_i)$	Critical values for $\lambda_{\max}$ at 5%	Critical values for λ_{trace} at 5%	Hypo. No. of CE
0.658995	87.14451	144.36819	٣٣.٤٦	68.52	$r \le 0$
0.260936	24.49236	57.223681	٢٧.٠٧	47.21	$r \le 1$
0. 179751	16.04993	32.731321	٢٠.٩٧	29.68	$r \le 2$
0.163432	14.45425	16.681391	١٤.٠٧	15.41	$r \le 3$
0.027121	2.227141	2.227141	3.76	3.76	$r \le 4$

Critical values are extracted from Osterwald-Lenum

The results of the trace and maximal value tests summarized in Table (3) indicate the possibility of rejecting the null hypothesis that says of no cointegrating at 5% significance level. This means that the whole structure of the demand for money is cointegrated with real non-oil income, inflation rate, real exchange rate and interest rate. Also, it means that there is a static linear combination between money demand, real non-oil income, inflation rate, exchange rate and interest rate, despite that every variable is nonstationary in levels. Finally, this result confirmed the presence of a long run equilibrium relationship between these variables, which means that they do not diverge away from each other where it shows similar behavior.

Since the calculated value of the trace test (144.37) exceeds the critical value (68.52) at 5% significance level, it is possible to reject the null hypothesis that there is any cointegrating vector. For more than one cointegrating vector, we compare the trace value with the critical value at 5% significance level. The likelihood ratio test indicates four cointegrating equations at 5% significance level. Comparison fails to reject the null hypothesis of at least there is one coinegrating vector. The normalized cointegrating regression resulting from this vector is:

$$m_t = 6.816 + 1.722 y_t - 0.0181 r_t - 0.1555 \pi_t + 0.1166 Ex_t$$

$$(0.069) \quad (0.0027) \quad (0.0245) \quad (0.0379) \qquad \{8\}$$

Log Likelihood 655.95

This means that the long-run real money demand elasticity with respect to real non-oil income is equal 1.722, with respect to interest rate is equal -0.018, with respect to inflation rate is -0.155 and with respect to real exchange rate is 0.1166.

Conclusion:

This paper provides a study of the long-run real demand for money in Saudi Arabia during 1977:1-1997:3 this period of time involves large economic changes in the rates of growth and inflation. The techniques of cointegration and error correction models are employed in order to test for stability of the demand for money. The results assure the existence of a stationary long-run demand for money in Saudi Arabia. The relationship between real money M1, the real income, the interest rate, the inflation rate and the exchange rate is significantly different from zero. However, the effect of interest rate on the demand for money is still very low comparing to the average in other countries which is explained by social and religion rationales of the people of Saudi Arabia.

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December 26, 1998

Dear Professor Amato,

In reference to your letter of November 3, 1998, I send including this correspondence a WordPerfect copy of our paper entitled "Cointegration, Error-Correction and Demand for Money in Saudi Arabia". I include also a hard copy, an abstract and the JEL Classification codes.

Thank you for your co-operation.

Yours sincerely,

Mamdouh ALKHATIB ALKSWANI