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MONETARY POLICY AND THE VELOCITY OF MONEY IN GREECE: A COINTEGRATION APPROACH

by

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ABSTRACT

Long run real money demand and velocity functions for the narrow monetary aggregate M1 are tested by means of the cointegration approach developed by Johansen and Juselius (1990). The results support the existence of a systematic relationship between M1-velocity, the rate of interest and the exchange rate. An interesting aspect of the trivariate error correction vector autoregressive analysis is the evidence of bidirectional causality between the exchange rate and velocity. Furthermore, changes in rate of interest provide information that helps predict future movements of M1-velocity. Finally, the results derived from Engle and Granger (1987) two-step procedure suggest that M1-velocity is subject to control through policy-induced interest rate and exchange rate movements, thus justifying the adoption of M1 as a useful monetary target.

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I. INTRODUCTION

Since the mid-1970s, when the drachma was unpegged from the US dollar, the Greek monetary authorities have framed the management of monetary policy in terms of target growth rates for various financial aggregates (for a survey see, Karfakis, 1988). The targetry of the narrow money aggregate M1 (currency in circulation plus private sight deposits) has played an important role in the making of monetary policy.

For a monetary aggregate to be useful as an intermediate target, there should exist some sort of equilibrium relationship between it and other macroeconomic variables, such as prices, output and interest rates. One implication of this long run relationship is that shocks to money are reflected on prices, output and the rate of interest, implying that movements among these variables will be closely associated thus obeying an equilibrium constraint.

The present paper addresses two issues. Firstly, it tests whether the existence of a long run M1-velocity function is consistent with the time series analysis of the Greek data by means of the cointegration methodology developed by Johansen and Juselius (1990), thus justifying the adoption of M1 as a useful monetary target. The velocity function is studied only after testing the income homogeneity restriction on the real money demand. Then, the analysis uses vector autoregressive (VAR) modelling to test the dynamic interactions between M1 velocity and policy-controlled variables.

The rest of the paper is organised as follows. Section II discusses methodological issues. In Section III, the empirical results are reported and discussed. Concluding remarks are presented in Section IV.

II. METHODOLOGICAL ISSUES

It is an empirical fact that many macroeconomic time series are characterised by nonstationarities, implying that the classical *t*-test and *F*-test are inappropriate because the limiting distribution of the asymptotic variance of the parameter estimates is not finitely defined (Fuller, 1985). Appropriate tests have been developed by Fuller (1976), Dickey and Fuller (1981), Phillips (1987), and Perron (1988) to test whether a time series it is integrated of order one (henceforth I(1)) against the alternative of zero order integration (I(0)).

The long run linkage between a number of series can be looked at from the viewpoint of cointegration (Engle and Granger, 1987). Let x_t be a vector of n-component time series each integrated of the same order k. Then x_t is said to be cointegrated of order k,p, if there exists a vector λ such that:

$$s_t = \lambda' x_t \qquad (1)$$

is I(k-p), p>0. s_t being I(0) implies that the n variables of x_t do not drift away from one another over the long run, obeying thus an equilibrium relationship. If λ exists, it will not be unique as there can be several equilibrium relationships linking n>2 variables. Engle and Granger (1987) have suggested a testing procedure for cointegration in the case where n=2. Recent advances in cointegration theory (Johansen,1988; Johansen and Juselius,1990) have developed tests regarding the number of cointegrating vectors. The procedure is based on regressing the n element vectors Δx_t and x_{t-q} on Δx_{t-i}, i=1,...,q-1, and obtaining the associated n-element residual vectors R_{0t} and R_{qt}. The test statistic for the number of cointegrating vectors is obtained by solving the eigenvalue problem

$$|\lambda S_{qq} - S_{q0} S_{00}^{-1} S_{0q}| = 0$$

where $S_{ij} = T^{-1}\sum_{t=1}^{T} R_{it}R_{jt}'$ $i,j = 0,q$

and T denotes the number of obserbations.[1]

The likelihood ratio (LR) statistic

$$-2lnQ = -T\sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i) \qquad (2)$$

is a test that there are at most r cointegrating vectors versus the general alternative (trace), where λ_i corresponds to the n-r smaller eigenvalues. The nxr matrix of cointegrating vectors Φ can be obtained as the r n-element eigenvectors corresponding to λ_i.

The LR statistic for testing that there are r versus r+1 cointegrating vectors is given by:

$$-2\ln(Q;r|r+1) = -T\ln(1-\hat{\lambda}_{r+1}) \qquad (3)$$

Consider the following semi-log linear real money demand equation:

$$(m_t - p_t) = (m_t^d - p_t) = \alpha + \beta y_t - \gamma R_t + \delta e_t + u_t \qquad (4)$$

where α is a constant, and m_t, p_t, y_t, e_t denote the logs of the nominal money balances, the price level, the real income and the nominal effective exchange rate of the Greek drachma respectively. R_t is the interest rate and u_t is the error term. Equation 4 which assumes money market equilibrium, shows that the long run real money demand depends positively on the real incone and the exchange rate, and *negatively on the rate of return which proxies the opportunity cost of holding* money balances. Due to the underdeveloped nature of money and capital markets

in Greece, term deposits are considered to be the alternative portfolio choice. Thus, the 3-6 month interest rate is used to proxy the opportunity cost of holding transaction balances. A theoretical justification for inclusion of the exchange rate in the money demand *equation is associated with its effect on real wealth. Then as* the exchange rate falls (depreciates), if the country is a net debtor in foreign denominated assets, the home currency value of wealth falls, thus reducing the demand for money (Branson and Buiter, 1984).[2]

Equation 4 can be also written as a velocity function:

$$v_t = (y_t + p_t - m_t) = -\alpha + (1-\beta)y_t + \gamma R_t - \delta e_t + w_t \qquad (5)$$

where all the variables are defined above and w_t is the *error term. If the income* elasticity of the demand for money (β) is equal to one, changes in velocity will only depend on movements in the interest rate and the exchange rate.

III. EMPIRICAL RESULTS

Quarterly seasonally unadjusted data on M1, the gross domestic product (Y) at constant 1970 prices, the *consumer* price index (P), the 3-6 *month interest rate* (R) and the effective exchange rate of the Greek drachma (E) are used over the period 1975.1-1988.3 during which a managed floating regime has been adopted.[3]

With respect to the univariate time series properties of the data, the results reported in Table 1 indicate that non stationarity cannot be rejected for the levels *of all the series at the 0.05 significance level. In contrast,* when the data are differenced, non-stationarity can be rejected in all cases.[4]

The results of testing for the number of cointegrating vectors in model 4 are reported in Table 2.[5] The LR test statistics that there are *zero* cointegrating vectors reject the null hypothesis against the 95% critical value. Moreover, the null hypothesis that there is at most one cointegrating vector is also rejected at the same level of significance. The LR tests that there are at most two cointegrating vectors accept the hypothesis that at least two but possibly three cointegrating vectors are present in the data.

The results of the maximum eigenvalue which also reported in Table 2 suggest that there are two cointegrating vectors, although only the signs of the second vector make economic sense. By normalizing on that vector yields,

$$(m_t - p_t) = -5.53 + 1.15y_t - 0.02R_t + 0.25e_t \qquad (6)$$

The LR test for the income homogeneity restriction reported in Table 2 indicates that the restriction $\beta=1$ is not rejected at the significance level of 0.05.

The analysis is then carried out for M1-velocity of circulation. The Johansen and Juselius results reported in Table 3 reject the hypothesis of zero cointergating vectors in favour of one cointegrating vector: v_t-0.01R_t+0.24e_t-4.58. One implication of this finding is that shocks which affect M1-velocity are reflected on the rate of interest and the exchange rate, implying that movements in v_t will be closely associated with changes in R_t and e_t, thus obeying an equilibrium constraint.

Overall, the cointegration results suggest that the data generation mechanism of the trivariate system (v_t, R_t, e_t) should be modelled as an error correction vector autoregressive (ECVAR) specification. A trivariate ECVAR model with one cointegrating vector is specified as:

$$\Delta y_t = a_0 + A(L)\Delta y_{t-1} - b' EC_{t-1} + \varepsilon_t \qquad (7)$$

where $y=[R_t\ e_t\ v_t]'$ is a 3x1 vector of endogenous variables; a_0 is a fixed intercept

vector; $A(L)=[A_R(L)\ A_e(L)\ A_v(L)]$ is a 3x3 polynomial matrix in the lag operator, with $A_j(L)=[\xi_j(L)\ \psi_j(L)\ \omega_j(L)]'$, j=R,e,v; EC=v-0.01R+0.24e-4.58 denotes the cointegrating vector, and $b=[b_R\ b_e\ b_v]'$ is a 3x1 vector of coefficients; ε is a 3x1 vector of white noise errors with properties: $E(\varepsilon_t)=0$, $E(\varepsilon_t \varepsilon_s') = \Omega$, when t=s and zero otherwise, with Ω denoting the variance-covariance matrix of residuals.

The strategy adopted in specifying the number of lagged Δy terms in Equation 7 was based on Akaike's (1969) information criterion as implemented by Hsiao (1979). A maximum number of 4 lags was considered, in order to preserve a reasonable number of degrees of freedom. The selected lag length was also checked for the presence of serial correlation associated with the truncation of the lag structure. The selected lags are given in Table 4. Efficient estimates are obtained by using the seemingly unrelated regressions (SUR) estimator.

The results of Granger causality tests given in Table 4, suggest that changes in the rate of interest and the exchange rate provide information that helps predict future movements in M1-velocity. The significance of the EC term in the velocity equation introduces an additional channel through which Granger causality can emerge (Granger, 1988). Therefore both channels of causality are present, that is, the lagged Δr and Δe are significant, as is the coefficient on the EC term. The fact that only one of the EC coefficients is significant tells us that the adjustment to restore equilibrium is borne primarily by velocity.

It is worth noticing that the significance of the EC term shows the pitfalls of ignoring the long run properties of the data and using a traditional VAR in first difference form to detect causality patterns (Granger, 1988).

Changes in velocity have predictive power for movements in the exchange rate thus indicating that the exchange rate cannot serve as a useful indicator of the future course of M1 velocity. Finally, interest rate movements seem to be Granger exogenous with respect to changes in the exchange rate and the velocity of money.

To test for instantaneous causality between the variables concerned, the contemporaneous innovation correlations of the model have been calculated. The results of Table 4 do not show the presence of significant contemporaneous correlations.

In view of these findings, the Engle and Granger (1987) two-step procedure is applied to the following EC model of M1-velocity of circulation:

$$\Delta v_t = -0.03 - \underset{[0.01]}{} 0.25 \Delta v_{t-1} - 0.02 \Delta R_{t-1} - 0.23 \Delta e_{t-2} - 0.55 \hat{w}_{t-1}$$

[0.01] [0.13] [0.008] [0.11] [0.13]

$R^2=0.93$, see=0.020, Durbin's h=0.85, $X^2_{SC}(4)=3.82$, $X^2_{SK}(12)=10.14$, $X^2_{FF}(1)=0.17$, $X^2_{NO}(2)=0.89$, $X^2_{HE}(1)=3.14$, $X^2_{ARCH}(12)=14.66$, $X^2_{PF}(11)=14.12$, $X^2_{CHOW}(8)=13.41$.[6]

The term $\hat{w}_{t-1}$ denotes the OLS estimated residuals from the cointegrating regression 5, under the restriction that $\beta=1$. The rate of change in the effective rate has a significant negative impact on the rate of change in the velocity with a time lag of two quarters. In other words, a fall in the exchange rate reduces the demand for money; for a given path of the nominal money supply, money market equilibrium requires a price level which is higher than the price which would have prevailed otherwise. The higher domestic price level, achieved through the depreciation of the domestic currency, increases the nominal income and velocity. The rate of change in the interest rate significantly affects Δv_t with a time lag of one quarter. The EC term $\hat{w}_{t-1}$ significantly affects Δv_t, indicating the existence of market forces in the money market that operate to restore long run equilibrium after a short run disturbance. Finally, all the diagnostic tests reject any sort of misspecification.

IV. CONCLUDING REMARKS

This paper has concentrated on the analysis of M1-velocity function in Greece. Cointegration tests have revealed the existence of a systematic relationship between velocity, the rate of interest and the exchange rate. One implication of these findings is that shocks which affect v_t are reflected on R_t and e_t, implying that movements among these variables will be closely associated thus obeying an equilibrium constraint. An interesting aspect of the trivariate error correction vector autoregressive analysis is the evidence of bidirectional causality between the exchange rate and M1-velocity of circulation. Furthermore, changes in the rate of interest provide information that hepls predict future movements of velocity. Finally, the results derived from Engle and Granger two-step procedure suggest that M1-velocity of circulation is subject to control through policy-induced interest rate and exchange rate movements, thus justifying the adoption of M1 as a useful monetary target.

NOTES

1. The calculation of the eigenvectors of $S_{q0}S_{00}^{-1}S_{0q}$ with respect to S_{qq} can be transformed into a standard eigenvalue problem by using Choleski decomposition $S_{qq}=CC'$, since the eigenvalues that solve $|\lambda S_{qq}-S_{q0}S_{00}^{-1}S_{0q}|$ also solve $|\lambda I-C^{-1}S_{q0}S_{00}^{-1}S_{0q}C'^{-1}|=0$. Premultiplying the eigenvectors of the standardized problem by C'^{-1}, one can obtain the original eigenvectors normalized such that $E'S_{qq}E=I$. The calculations of the eigenvectors have been performed using the computer package *RATS 3.0, VAR Econometrics, Inc/Doan Associates.*

2. *The presence* of the exchange rate in the money demand equation is also justified on empirical grounds. Some attempts to include the rate of change in the *effective rate, were unsuccessful. The inclusion of the exchange* rate may also be justified by reference to the currency substitution literature.

3. The data for M1 and R have been obtained from Bank of Greece's Monthly Statistical Bulletin, *various issues. The* data for the effective exchange rate was kindly provided from the economic research department of the Bank of Greece. The data for Y and P are taken from the National Accounts of Greece, February 1989, and IMF's International Financial Statistics, various issues respectively.

4. The rejection of a unit root in the level of real income based on Phillips (1987) and Perron (1988) test is due to the presence of a *nonzero mean* ($Z_{\alpha}=-5.07$, $Z(\Phi_3)=9.44$). The distribution of the DF test is not however invariant with respect to the presence of a nonzero mean or a time trend (Dickey and Fuller, 1979). *Dickey et al.(1986) recommend* against the inclusion of a time trend in a univariate time series model, since such an inclusion would make a random walk model looks stationary, with the DF test having low power. They also argue that first differencing will remove a deterministic trend if it is present, thus the lower power

of the DF statistic may be more comforting than alarming. Furthermore, Hylleberg and Mizon *(1989)* recommend *the use of the* DF distribution in small samples unless the drift is enormous.

5. *The two sets of regressions which discussed in Section* II fitted to the data with three lags and seasonal dummies. The constant term was excluded from the regressors but appeared in model (4).

6. Numbers in squared brackets are *standard errors. Subscripts* SC,FF,NO and HE refer to the test statistics for serial correlation, functional misspecification, normality and heteroscedasticity. The predictive failure test (PF) is calculated over *the period* 1986.1-1988.3.

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Table 1. Unit Root Tests

V/bles	DF	PP	DF	PP
	Levels		*First Difference*	
m-p	-0.85[2]	-2.51	-4.62[1]	-8.74
	(5.47)		(5.26)	
v	-0.25[1]	-2.33	-11.10[0]	-10.64
	(1.06)		(1.14)	
y	-2.55[2]	-5.07	-7.30[1]	-9.08
	(6.42)		(4.50)	
R	-0.68[2]	0.63	-6.08[1]	-5.98
	(1.77)		(2.27)	
e	1.138[0]	1.29	-6.88[0]	5.23
	(0.23)		(0.52)	

DF, PP denote the Dickey-Fuller and Phillips-Perron unit root tests respectively. The PP test is calculated with a lag length equals to 5. Figures in squared brackets denote the number of lagged dependent variables in the regression. The selection between zero and nonzero lags was based on the Lagrange multiplier(LM) test for fourth-order serial correlation of the residuals. Figures in parentheses refer to the values of the LM(4) statistic. The rest of the entries are the values of the unit root tests, the critical value of which at the 0.05 level is -2.93 for T=50 (Fuller,1976, p.373).

Table 2. Johansen-Juselius Cointegration Tests: $(m_t-p_t)=\alpha+\beta y_t-\gamma R_t+\delta e_t+u_t$

-2lnQ	r=0	r≤1	r≤2	r≤3
Trace	82.12	41.4	19.43	0.51
Max λ	40.72	21.97	18.92	0.51

LR-statistic for Testing Long Run Income Homogeneity

Tested Restriction	Eigenvalues	LR-Test	$X^2_{df=0}$
-	(0.55 0.35 0.31 0.01 0.0)	-	-
H_0 β=1	(0.53 0.35 0.06 0.09)	2.2185	2

Max.λ refers to the maximal eigenvalues. The entry 2 denotes the number of degrees of freedom of $X^2_{df=0}$ statistic. Critical values are taken from Johansen and Juselius (1990).

Table 3. Johansen-Juselius Cointegration Tests: $v_t=-\alpha+\gamma R_t-\delta e_t+w_t$

-2lnQ	r=0	r≤1	r≤2
Trace	69.36	12.75	6.12
Max.λ	56.61	6.63	6.12

Normalised eigenvector

λ	*R*	*e*	*v*	*cnst*
0.67	-0.01	0.24	1.00	-4.58
0.12				
0.11				

The column λ reports the calculated eigenvalues. see also notes to Table 2.

Table 4. Granger-Causality Tests and Correlation Coefficients in an ECVAR Model

system	*Dep. V/ble*	*Lags/Q(21)*	*MSL of X^2* H^1_0	H^2_0	H^3_0	*t-ratio of* EC term
ΔR,Δe,Δv	ΔR	(2,1,1)/0.95	0.00*	0.67	0.63	-1.56
	Δe	(1,1,1)/0.36	0.98	0.97	0.08**	-0.54
	Δv	(1,2,1)/0.48	0.01*	0.06**	0.02*	-4.51*

Correlation Coefficients of Innovations

V/bles	(ΔR,Δe)	(ΔR,Δv)	(Δe,Δv)
Values	-0.1	-0.08	0.08

H^1_0 (H^2_0, H^3_0) tests the hypothesis that the lagged rates of interest (exchange rates, velocity) are jointly insignificant in each regression. The column lags denotes the number of lagged dependent and independent variables in each equation. Q(21) refers to the marginal significance level (MSL) of the Ljung-Box (1978) Q statistic for serial correlation at 21 degrees of freedom. * (**) indicates significance at 5% (10%). $EC_{t-1}=v_{t-1}-0.01R_{t-1}+0.24e_{t-1}-4.58$.

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