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EXCHANGE RATE DETERMINATION: EVIDENCE FROM INTERTEMPORAL ASSET PRICING AND A STRUCTURAL VAR MODEL, FOR THREE CURRENCIES

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Abstract

This paper makes uses the methodology of intertemporal asset pricing in order to assess the determinats of three currencies, the Greek drachma, the Deutsche mark and the Feench franc. The explanatory power of the model is assessed in terms of its forecasting capacity against certain competitive models. The results seem to support the superiority of a random walk model only in markets that have not developed a deep foreign exchange market, e.g., Greece. In addition, structural Vector Autoregressive (SVAR) techniques —in conjunction, with the model show that consumption shocks seem to dominate price and monetary shocks in Greece. By contrast, in the cases of Germany and France, monetary and price shocks play the leading role in explaining exchange rate movements. (JEL Classification: F31; F47; C61)

1. Introduction

This study attempts to determine empirically the determinants of three currencies, via an intertemporal general equilibrium model, as in Finn et al. (1990).

In the literature of exchange rates the strong desire of the researchers is to fing an acceptable model that explains exchange rate movements in terms of other macroeconomic variables. Therefore, monetary models, Purchasing Power Parity (PPP) models, currency, substitution models, balance of payments models, portfolio models, and 'news' models attempted to explain such movements

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(Frenkel, 1976; Dornbusch, 1976; Branson, 1976; Kouri, 1983; Baillie and Selover, 1987; Taylor and McMahon, 1988; Hardouvelis, 1988). However, estimation of exchange rate determination models has been unsatisfactory. The problem seems to be related to the evidence that exchange rate movements depend very much upon expectations as well as to the future path of the exchange rate, which in turn depend upon expectations about relative inflation rates, relative growth rates and the stances of monetary and fiscal policies. Such expectations, however, are very volatile, making them inherently difficult to model. Therefore, these models adopted simple expectations schemes, which contributed to their poor empirical performance (MacDonald, 1988; Pentecost, 1991).

A number of models have attempted to interpret the qualitative as well as the quantitative features of exchange rates in a general equilibrium framework that is actually a part of the New Classical School. Models, within the general equilibrium framework, have generated estimates of the exchange rate determination not supportive to the data. In particular, monetary exchange rate models as well as models within the portfolio-balance approach have had a hard time explaining exchange rate movements in terms of economic fundamentals such as the trade balance, output, money supply or international interest rate differentials and have generated estimates with mixed results (Bacjus, 1984; Stockman, 1988). The empirical findings have demonstrated that the random walk model seems to offer the best explanation for the behavior of the exchange rate (Meese and Rogoff, 1983). Certain —a few though— empirical attempts have been made by Hercowitz (1986) who attempted to explain the behavior of the Israeli capital account. By contrast, many theoretical explanations have been offered to introduce exchange-rate determination within an intertemporal asset pricing framework (Helpman, 1981; Liviatan, 1981; Helpman and Razin, 1982; Stockman, 1980, 1983, among others).

It is believed, however, that the estimation of the determinants of the exchange rate must take place through an intertemporal asset pricing model, because such models take explicitly into consideration the preferences of economic agents as well as the characteristics of such forces that seem to drive individual's behavior, e.g., the behavior of the central bank, (Stockman, 1988). In addition, by adopting and modeling the behavior of the government sector as well as the role of expectations with respect to certain macroeconomic variables, general equilibrium optimizing models e.g., the model employed for the puproses of this paper, seem to perform a satisfactory job (Flood, 1988). By contrast, the employment of a structural model does not seem to be the appropriate approach any longer, since the estimates of its parameters do not remain stable over time, i.e., they are subject to "Lucas' critique".

The methodology followed in this paper is close to Finn's (1989) modeling approach; in addition, a SVAR model is employed in order to assess the robustness of the intertemporal model findings. The formal model is presented and analyzed in section 2. Section 3 contains data definition, the empirical analysis and reports the empirical results. Finally, section 4 provides some concluding remarks.

2. The model

The model economy deals within an intertemporal framework with rational expectations and uncertainty. The model describes the behavior of a representative individual who maximizes an expected discounted flow of utilities, where the temporal utility level depends upon real consumption and real money balances. Thus, the individual maximizes:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[c_t^{1-\sigma} / (1-\sigma) + (M_t / P_t)^{1-\delta)} / (1-\delta) \right] \qquad (1)$$

with $0<\beta<1$ and $\sigma, \delta>0$, β is the individual' s subjective discount factor while σ and δ are preferences parameters, c is real consumption and (M/P) real money balances.

At the same time, the individual faces a sequence of constraints. In particular:

$$y_t + B_{t-1} / P_t + T_t / P_t + M_{t-1} / P_t = c_t + B_t / P_t + B_t P_t^B / P_t + M_t / P_t \qquad (2)$$

with y = real income
e = the exchange rate
T = lump-sum transfers from the central bank
B = domestic bond holdings
P^B = the price of a domestic bond (= $1/(1+R)$), with R being the interest rate.

According to (2), the intertemporal budget constraint, aggregate liquidity at the beginning of period t is determined by money carried over from the last period (t - 1), production activities, monetary transfers from the central bank, and by bond holdings. At the beginning of period t this liquidity is split into consumption, money holdings, and bond holdings.

The budget constraint of the central bank is described by:

$$T_t + B_{t-1}^{G} + M_{t-1}^{G} = M_t^{G} + B_t^{G\,P_t^B} \tag{3}$$

The superscript G denotes variables concerning central bank's behavior. Solving (3) for T_t and replacing it in (2) the aggregate budget constraint is derived:

$$y_t + B_{t-1}/P_t + P_t^{B}\, B_t^{G}/P_t + M_t^{G}/P_T - B_{t-1}^{g}/P_t - M_{t-1}^{g}/P_t +$$

$$+ M_{t-1}/P_t - c_t - B_t\, P_t^{B}/P_t - M_t/P_t = 0 \tag{4}$$

Through the maximization process in which the household is assumed to maximize (1) subject to (4) by choosing C, M, and B, the first -order conditions- along with (4) - yield:

$$C_{t+1} = \{ P_{t+1} / \beta P_t [c_t^{-\sigma} - (M_t/P_t)^{-\delta}] \}^{-1/\sigma} \tag{5}$$

$$P_{t+1} = \beta\, P_t\, (C_{t+1} / C_t)^{-\sigma}\, (1 + R_t) \tag{6}$$

The general equilibrium solution of the model involves the simultaneous solution of equations (5), (6), and the equilibrium condition in the money market, i.e., $M_t = M_t^{G}$, Thus, the following relationship emerges:

$$-\delta \log M_t + \delta \log P_t = \sigma \log c_t + \log R_0 + 1/R_0\, (R_t - R_0) \tag{7}$$

where R_0 is the mean of R (for the complete details see the Appendix).

We also assume that the following conditions hold:

$$R_t = P_t^{*} + \log e_{t+1} - \log e_t \tag{8}$$

$$R_t^{*} = r^{*} + \log P_{t+1} - \log P_t^{*} \tag{9}$$

$$P_t = e_t\, P_t^{*} \tag*{(9)´}$$

with R^* being the foreign (nominal) interest rate, r^* the (constant) foreign real interest rate, e_t the exchange rate, and P_t^* the foreign price level. Equation (8) is the uncovered interest parity condition, while equation (9) demonstrates the Fisher condition between foreign nominal interest rates and foreign inflation. Finally, equation (9)´ is the Purchasing Power Parity (PPP) condition. The combination of equations (7) - (9)´ provides the equation for the exchange rate:

$$\log e_t = A - A_1 \log C_t + A_2 \log M_t + A_3 \log e_{t+1} + A_3 \log P^{*}_{t+1} - \log P_t^{*} \tag{10}$$

where,

$$A = [\log R_0 + (r^* - R_0) / R_0] / (\delta + 1 / R_0)$$
$$A_1 = \sigma / (\delta + 1 / R_0)$$
$$A_2 = \delta / (\delta + 1 / R_o)$$
$$A_3 = 1 / [R_0 (\delta + 1 / R_0)]$$

Next, through equation (6) and forward iterating equation (10) we get:

$$\log e_t = A + A_2 \sum_{j=0}^{\infty} \{ [1/ (\delta + 1/R_o)]^j \log M_{t+j} \} + A_3 \sum_{j=0}^{\infty} \{ [1/ (1 + R_0\delta)]^j \log P_{t+j+1} \}$$

$$- \sum_{t=0}^{\infty} \{ [1 / (1 + R_0\delta)]^j \log P_{t+j}^* \} - \sigma *\delta \log c_t \qquad (11)$$

According to (11), the spot exchange rate is determined by the infinite sum of future domestic money supply, the infinite sum of the future foreign price level as well as the level of current consumption. In order to transform (11) into a more operational equation, the future values are replaced by their conditional —with respect to the information set at period t— expected values. Thus, (11) is written as:

$$\log e_t = A + A_2 \sum_{t=0}^{\infty} \{[1 / (\delta + 1/ R_o)]^j E_t \log M_{t+j}\} + A_3 \sum_{t=0}^{\infty} \{ [1 / (1 + R_0\delta)]^j E_t \log P_{t+j+1}^* \}$$

$$- \sum_{t=0}^{\infty} \{[1 / (1 + R_0\delta)]^j E_t \log P_{t+j}^* \} - \sigma / \delta \log c_t \qquad (12)$$

Equation (12) shows that the exchange rate is determined by monetary factors - M - demand factors - P* - and by consumption factors - C. The intensity of the impact factors depends upon the value of $1 / R_0\delta$. Higher relative values of this magnitude indicate that the exchange rate is greatly influenced by disturbances in domestic money supply and foreign prices and very little by consumption disturbances. In order now to make (12) even more operational, the technique of Hansen and Sargent (1980) and Flavin (1981) - on operationalizing infinite-discounted sums of expectational terms - is employed. The technique shows that equation (12) is equivalent to:

$$\log e_t = a_0 + a_1 \log M_t + a_2 \log M_{t-1} + a_3 \log M_{t-2} + a_4 \log P^*_t + a_5 \log P^*_{t-1} +$$

$$+ a_6 \log P^*_{t-2} + a_7 \log P^*_{t-3} + a_8 \log P^*_{t-4} + a_9 \log c_t \qquad (13)$$

Therefore, in the empirical analysis (section 3) first, a random walk model, an ARIMA model, and the model described by (13) will be compared in terms of their forecasting performance, and second, a four -variable SVAR model - based on the intertemporal asset pricing model - will be constructed to determaine whether nominal, monetary, consumption or none of the above factors seem to affect exchange rates.

3. Data and the Empirical Analysis

The focus is on three European economies, namely Greece, Germany and France. The two latter countries have been constantly members of the European Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) since its establishment in 1979.

3.1. Data

The variables involved in the model are the exchange rate (E) defined as drachmae against one dollar, the U.S. consumer price index (PUS), aggregate consumption expenses (C), the interest rate measured by the 3-month T-bill yield (R), and money supply measured as Ml (M). The data are on a quarterly basis over the period 1975:1 to 1993:4. The sources for the E, PUS and M variables were various issues of OECD Main Economic Indicators, for the C variable in the case of Greece various publications of the Monthly Bulletin of the Greek Statistical Service, while for the cases of Germany and France, various issues of the OECD National Accounts; for the R variable in the case of Greece the author acknowledges the assistance of the Research Department at the Bank of Greece, while for the same variable in the cases of Germany and France, data were obtained from various issues of the OECD Main Economic Indicators. Finally, lower case letters denote variables expressed in logarithms.

3.2. The forecasting performance

In this part of the paper, the model described by equation (13), an **ARIMA** model, and a random walk model are assessed in terms of their forecasting performance. In particular, once the model exchange rate equation (13) is generated, its forecasting performance must be evaluated compared to alternative types of economic models, i.e., an ARIMA model and the random **walk** model (with a drift). Identification tests resulted in an **ARIMA (1, 1,0) model** for the drachma /U.S. dollar series, an ARIMA (1,1,0) model for the DM /U.S. dollar exchange rate series, and an ARIMA (0, 1, 1) model for the case of the French Frame /U.S. dollar exchange rate series.

Then, out-of-sample forecasting was attempted and, via the ARIMA model, the model equation (13), and the random walk model, the results were evaluated by the U-Theil statistic and the Root Mean Square Error statistic, the average quartetly forecast error, and the standard deviation of the quarterly forecast errors (as in Fama and Gibbons, 1984)[2]. The results are reported in Table 1. They demonstrate that for the case of Greece the model proxied by equation (13) exhibits inferior forecasting performance, a fact that is in accordance with the empirical reality (Meese and Rogoff, 1983; MacDonald and Taylor, 1992) regarding the forecasting superiority of a naive model, such as the random walk model to forecast exchange rates. In other words, despite the adequate information provided by an intertemporal asset pricing model, the random walk seems to retain its power in explaining exchange rate movements in the Greek case.

By contrast, for the cases of Germany and France the model describied by (13) seems to behave better in terms of its forecasting performance. It seems that deeper foreign exchange rate markets in these economies allow the exchange rate to reflect in a stronger way all information available from macrofundamental variables. In Greece, decisions taken ad hoc about the future trend of the exchange rate seems to have deprived equation (13) from its power to explain exchange rate movements.

3.3. Estimation of the (deep) parameters

To estimate the deep parameters (β, σ, δ) of the model, the Euler or first-order conditions are used. The Generalized-Method-of Moments (GMM) technique and associated tests -chi-squared tests - proposed by Hansen and Singleton (1982) are employed. The main advantage of the GMM methodology is not only its computational simplicity but also that other estimators - via Maximum Likelihood techniques - sometimes fail to be consistent if the distribution of the utilized variables has been misspecified. The results made use of the following starting guesses for the model parameters:

$$\beta = 1.0, \quad \sigma = 1.0, \quad \delta = 2.0$$

The number of lags was three, since higher lags specifications provided statistically insignificant results[3].

The results are presented in Table 2. They reveal that the model performs relatively well. Not only the standard errors are satisfactorily low but also the values of the chi-squared statistics demonstrate an adequate performance of the model concerned. Furthermore, in terms of the β parameter, relevant studies - within a close economy framework (Kankiw et al., 1985, Huh, 1989, Finn et al., 1990) - have generated estimates very close to one, i.e., 0.999. The estimates of this study are also very close to unity. In particular, for Greece, Germany and France the value of the parameter turns out to be 0.996, 0.996 and 0.998, respectively. In terms now of the σ parameter, other studies in this area (Hansen and Singleton, 1982, 1983 and 1984) generated values for the parameter ranking from zero to two, while the study of Finn et al. (1988) found values ranking between 0.02 and 4.8. This study has generated parameter values ranging from 0.343 to 0.539. Finally, in terms of the parameter δ, other relevant studies have estimated values - in the U.S. case - (Apergis, 1992) - ranking from 0.27 to 0,49, while in this study parameter values are ranking from 0.650 to 0.790.

3.4. A SVAR Model

The economic model considered is described as follows: First, it is assumed that money is exogenously determined:

$$M = f_1 (v^M) \tag{14}$$

with v^M being an exogenous disturbance.
From equation (12) e turns to be a function of M, P*, and c:

$$e = f_2 (M, P^*, c) \tag{15}$$

Equation (15), in conjunction with equation (9)′, gives:

$$e = f_3 (M, P, c) \tag*{(15)′}$$

From equation (6) we get:

$$P = \varphi_4 (c, R) \text{ or } c = g_4 (P, R) \tag{16}$$

while from equations (5) and (6) we get:

$$M = f_5 (P, c, R) \text{ or } R = f_6 (M, P, c) \tag{17}$$

Equations (16) and (17) provide:

$$M = f_7 (c) \text{ or } c = g_7 (M) \tag{18}$$

Finally, equations (17) and (16) give:

$$P = f_8 (c, M) \tag{19}$$

Thus, the economic model consists of equations (14), (15)′, (18), and (19). In terms of the VAR representation the model consists of the vector $X' = (c, M, P, e)$, while the dynamic behavior of the model is driven by the vector of economic disturbances $v' = (v^c, v^M, v^P, v^e)$.

3.4.1. The SVAR methodology

The structural VAR model is based on the obtained residuals from an unrestricted VAR model (Blanchard and Watson, 1986; Bernanke, 1986). Let:

$$X(t) = \sum_{j=0}^{n} B(j)\, X(t-j) + v(t) \tag{20}$$

$$\begin{aligned} E[v(t)\, v'(t-s)] &= \Omega, \quad \text{if } t = s \\ &= 0, \quad \text{if } t \neq s \end{aligned}$$

with Ω being a diagonal matrix

be a structural model which connects the vector of variables X with the vector of driving forces (structural shocks) v. B is a coefficient square matrix.

The VAR model for X has the form:

$$X(t) = \sum_{j=1}^{n} A(j)\, X(t-j) + r(t) \tag{21}$$

$$\begin{aligned} E[r(t)\, r'(t-s)] &= \Phi, \quad \text{if } t = \sigma \\ &= 0, \quad \text{if } t \neq s \end{aligned}$$

$$A(j) = (I - B_0)^{-1} B(j)$$

The estimation of the elements of the square matrix B_0, which are the structural parameters of the contemporaneous endogenous variables, is based on the following model which allows the recovering of the structural shocks v:

$$r = B_0\, r + v \tag{22}$$

For the purposes of this paper, r and v denote 4 × 4 vectors of X variables and structural shocks, respectively. B_0 is a 4 × 4 coefficient matrix.

3.4.2. Integration and cointegration analysis

It is crucial that the series involved in the VAR model specification are differenced the correct number of times to obtain stationarity. Augmented Dickey-Fuller (ADF) tests - developed by Fuller (1976) - and Phillips-Perron (PP) tests - developed by Phillips (1987), Perron (1988) and Phillips and Perron (1988) - were performed to test for unit roots. The results are reported in Table 3. The results point out the rejection of a unit root in the first differences of the variables concerned. Next, Likelihood Ratio (LR) tests corrected for the degree of freedom, developed by Sims, were employed to identify the optimal number of lags in the VAR model. The LR test results are shown in Table 4 along with the cointegration tests, developed by Johansen and Juselius (1990). The cointegration findings revealed that in all three cases the null hypothesis of no cointegration is rejected. In the cases of Greece and Germany more than one cointegrating vectors were found; however, visual inspections of the residuals from the cointegrating vector suggested the selection of only one cointegrating vector. The implication of the reported results is that the estimated VAR model should be in levels, otherwise, it could be over-differenced (Lutkepohl, 1993).

In order to generate the structural variance decompositions, the structural contemporaneous model to be estimated is described by the following set of equations:

$$r^M = v^M \tag{23}$$

$$r^c = b_1 r^M + v^c \tag{24}$$

$$r^p = b_2 r^M + b_3 r^c + v^p \tag{25}$$

$$r^e = b_4 r^M + b_5 r^c + \beta_6 r^p + v^e \tag{26}$$

To estimate the model (23) - (26), the methods of moments (MOM) is used.

High values of $(1/R_o\delta)$ indicate that monetary and demand (price) shocks are more important in explaining exchange rate movements. By contrast, low values indicate that consumption (real) shocks are more important. In this paper we get a value of 0.0931 which implies that consumption shocks should be more important in explaining exchange rate determination.

For the purpose of this paper we get:

	Greece	Germany	France
$(1/\delta R_0)$	0.0931	0.145	0.159

According to these figures, monetary shocks are expected to play a substantial role in explaining exchange rate movements in the cases of Germany and France, while in the case of Greece it is consumption disturbances that should be more important in explaining exchange rate movements.

3.4.3. Causality Tests

The Granger causality approach will examine whether lagged values of prices, consumption, and money help to explain the exchange rate over and above the explanation provided by lagged values of inflation itself. For the purposes of the Granger-causality tests, the Error Correction (EC) approach was used, i.e., the VAR model in which the residuals from the cointegrating vectors have explicitly been introduced as an additional deterministic variable. The results, reported in Table 5, suggest that for the cases of Germany and France money supply does cause the behavior of the exchange rate. The estimated F-statistics are significant at the 5 percent level. By contrast, for the cases of Greece it is consumption that seems to cause the exchange rate. The corresponding F-statistic is significant at the 5 percent level. Finally, in all three cases a feedback from the exchange rate to either money or consumption does not exist (the results are not reported, but they are available upon request from the author).

3.4.4. Variance decompositions

The variance decompositions are reported in Table 6. Each row presents the percentage of the variance of the k-quarter ahead forecast error of the levels of the variables that is attributable to each of the shocks for k= 1, 4, 8, 20. According to the decomposition tests, consumption innovations seem to affect substantially exchange-rate behavior in Greece. In particular, in the short-run consumption shocks account for 16% of the exchange-rate forecasting variance, while the figure amounts to 46.1% in the long-run. By contrast, in the cases of Germany and France are primarily monetary shocks that determine the exchange-rate forecasting variance (36.6% in the short-run and 42.8% in the long-run, and 32.46% in the short-run and 33.34% in the long-run, respectively) and to a lesser extent demand shocks (10.29% in the short-run and 24.71% in the long-run, and 13.91% in the short-run and 17.97% in the long-run, respectively).

In other words, the variance decompositions for Germany and France seem to support the empirical findings of section 2, i.e., that exchange rates respond to macrofundamental changes, i.e., monetary disturbances. These economies have oriented their monetary policy to the control of the exchange rate under the guidelines of the ERM. In the case of Greece, exchange rate movements seem to be affected by changes in consumption (consumer's preferences). In the Greek economy changes in consumption seem to require an exchange rate change in order to resolve trade balance deficit problems.

Concluding Remarks

This study first, attempted to assess - in terms of forecasting performance -the capability of an intertemporal asset pricing model to explain exchange rate movements in the case of the Greek drachma, the Deutche mark, and the French franc. The results indicated, that such a model could beat the random walk model, in terms of forecasting superiority, only in markets that are deep enough to ensure appropriate exchanges rate responses to macrofundamentals, which occurs in the cases of the DM and the FFR. In the second part of the paper and via the methodology of a structural VAR model, variance decompositions demonstrated that real (consumption) shocks seem to dominate exchange rate movements in the Greek case. By contrast, in the cases of Germany and France monetary disturbances seem to be the primary source of exchange rate changes.

TABLE 1

Forecasting tests

	Random walk model	ARIMA model	Model Economy
Greece			
U-Theil	0.025294	0.051814	0.342538
RMSE	12.253540	25.101010	164.772100
$\overline{\text{FE}}$	0.171750	4.331011	11.399500
s(FE)	0.113416	1.458314	3.7985500
Germany			
U-Theil	0.079071	0.08018	0.053515
RMSE	0.185984	0.21037	0.123675
$\overline{\text{FE}}$	0.002858	0.32674	0.000977
s(FE)	0.000988	0.23191	0.000033
France			
U-Theil	0.048900	0.051700	0.007336
RMSE	0.209688	0.317003	0.135468
$\overline{\text{FE}}$	-0.000240	0.869749	-0.000170
s(FE)	0.001163	0.500896	0.000086

Notes: RMSE denotes the root mean square error and U-Theil the Theil forecasting statistic. Both are defined in note 1.

$\overline{\text{FE}}$ is the average quarterly forecast error and s(FE) is the standard deviation of the quarterly forecast errors.

TABLE 2

GMM estimates

	β	σ	δ	χ^2
Greece	0.966	0.343	0.650	7.21(9)
	(0.009)	(0.008)	(0.258)	Iteration-3
Germany	0.966	0.520	0.770	10.05(12)
	(0.023)	(0.161)	(0.238)	Iteration-4
France	0.998	0.539	0.790	5.98(9)
	(0.008)	(0.184)	(0.124)	Iteration-3

Notes: The figures in parentheses indicate standard errors except in the chi-squared column where the figure denotes degrees of freedom. Iteration-3 indicates that the algorith converged after three iterations.

TABLE 3

Unit root tests

Variable:	m	p	e	c
Greece				
ADF				
Levels	-2.14	-2.18	-1.80	-1.44
	(4)	(4)	(3)	(4)
First differences	-7.69*	-4.72*	-6.56*	-4.43*
	(3)	(4)	(3)	(2)
PP1				
Levels	-0.88	-1.47	-1.59	-0.68
First differences	-10.46*	-10.25*	-70.91*	-78.68*
PP2				
Levels	-1.02	-1.91	-1.66	-1.40
First differences	-19.03*	-11.29*	-8.46*	-30.77*
PP3				
Levels	0.45	1.85	1.37	2.84
First differences	17.46*	41.31*	22.83*	94.12*
PP4				
Levels	0.50	1.38	1.14	2.51
First differences	48.86*	62.72*	34.75*	73.03*
Germany				
ADF				
Levels	-1.49	-1.68	-1.97	-2.16
	(4)	(3)	(3)	(5)
First differences	-4.95*	-5.06*	-4.18*	-4.28*
	(2)	(2)	(3)	(3)
PP1				
Levels	-1.80	-2.85	-1.02	-0.49
First differences	-72.70*	-37.97*	-66.63*	-84.16*
PP2				
Levels	-1.10	-1.28	-1.99	-1.08
First differences	-8.58*	-5.09*	-7.93*	-19.04*
PP3				
Levels	1.51	2.76	1.24	1.58
First differences	23.58*	8.32*	20.09*	85.53*
PP4				
Levels	0.94	1.57	1.74	1.83
First differences	35.89*	12.30*	30.96*	95.37*

TABLE 3

Unit root tests

Variable:	m	p	e	c
France				
ADF				
Levels	-0.92	-0.38	-1.97	-1.83
	(3)	(4)	(3)	(3)
First differences	-4.12*	-4.91*	-4.07*	-3.98*
	(3)	(1)	(2)	(3)
PP1				
Levels -0.58	-1.20	-1.42	-0.03	
First differences	-77.32*	-52.20*	-72.49*	-71.85*
PP2				
Levels	-0.42	-1.31	-1.57	-0.04
First differences	-10.13*	-6.61*	-7.92*	-8.25*
PP3				
Levels	2.69	1.72	1.04	1.65
First differences	30.79*	14.17*	20.45*	21.83*
PP4				
Levels	1.21	1.49	1.41	1.37
First differences	47.43*	21.61*	30.64*	32.94*

Notes: ADF = the Augmented Dickey-Fuller test with a constant and a time variable. The regression involved is:

$$\Delta x = a_1 + a_2\,\text{TIME} + \alpha_3\, x(-1) + \sum_{i=1}^{m} b_i\, \Delta x(-i) + u$$

with u being a random term.

PP1, PP2, PP3, PP4 = Phillips-Perron tests. The regressions involved are:

PP1: $\Delta x = \mu + (\alpha - 1)\, x(-1) + \varepsilon_1$

PP2: $\Delta x = \mu^* + \delta^*\,\text{TIME} + (\alpha^* - 1)\, x(-1) + \varepsilon_2$

PP3: $\Delta x = \mu^* + \delta^*\,\text{TIME} + (\alpha^* - 1)\, x(-1) + \varepsilon_3$

PP4: $\Delta x = \mu^* + \delta^*\,\text{TIME} + (\alpha^* - 1)\, x(-1) + \varepsilon_4$

with null hypothesis: $H0{:}\alpha = 1$, $H0{:}\alpha^* = 1$, $H0{:}\mu^* = \delta^* = 0$ and $\alpha^* = 1$, $H0{:}\ \delta^* = 0$ and $\alpha^* = 1$, respectively. The first hypothesis uses the simple Dickey-Fuller τ_τ test, the second the Dickey-Fuller τ_μ test, the third the Φ_2 test, and the last the Φ_3 test.

Figures in parentheses indicate the appropriate number of lags in the ADF term that ensures white noise residuals

* denotes significant at 5%.

TABLE 4

Jahansen - Juselius maximum likelihood tests for cointegration

List of variables included in the cointegrating vector:
m c p e Intercept

r	n-r	m.λ.	95%	Tr.	95%
Greece (Lags = 4)					
r = 0	r = 1	54.1589	28.1380	96.9737	53.1160
r<= 1	r = 2	27.4798	22.0020	42.8149	34.9100
r<= 2	r = 3	12.4105	15.6720	15.3351	19.9640
r<= 3	r = 4	2.9246	9.2430	2.9246	9.2430
Germany (Lags = 3)					
ρ = 0	ρ = 1	38.6189	28.1380	68.4193	53.1160
r<= 1	r = 2	23.3815	22.0020	39.8004	34.9100
r< = 2	r = 3	8.8365	15.6720	16.4189	19.9640
r< = 3	r = 4	7.5825	9.2430	7.5825	9.2430
France (Lags = 3)					
r = 0	r = 1	39.0117	28.1380	63.9582	53.1160
r<= 1	r = 2	16.8238	22.0020	24.9465	34.9100
r<= 2	r = 3	5.0285	15.6720	8.1227	19.9640
r<= 3	r = 4	3.0942	9.2430	3.0942	9.2430

Notes: r= number of cointegrating vectors
n-r = number of common trends
m.λ. = maximum eigenvalue statistic
Tr. = trace statistic

TABLE 5

Granger - causality tests

Dep. var.	Hypotheses tested	F-statistic	p-values
Greece			
Δe	Lagged Δm do noy Granger-cause Δe	0.39	0.81
	Lagged Δp do not Granger-cause Δe	1.55	0.20
	Lagged Δc do not Granger-cause Δe	4.22*	0.02
$R^2 = 0.99$ Q(24) = 20.27[0.68]			
Germany			
Δe	Lagged Δm do not Granger-cause Δe	4.27*	0.03
	Lagged Δp do not Granger-cause Δe	1.42	0.24
	Lagged Δc do not Granger-cause Δe	0.56	0.70
$R^2 = 0.93$ Q(24) = 33.16[0.10]			
France			
Δe	Lagged Δp do not Granger-cause Δe	4.62*	0.02
	Lagged Δp do not Granger-cause Δe	0.36	0.83
	Lagged Δp do not Granger-cause Δe	1.17	0.34
$R^2 = 0.94$ Q(24) = 20.9[0.64]			

Notes: Q denotes the Box-Pierce statistic testing for serial correlation. Numbers in parentheses denote degrees of freedom, while in brackets p-values.

* indicates significance at 5%.

TABLE 6

Variance decompositions

	Percentage of exchange rate variance due to			
Quarters	v^M	v^c	v^p	v^e
Greece				
1	0.03	16.00	0.39	83.57
4	2.58	25.40	1.33	70.69
8	6.94	42.32	0.81	49.93
20	11.41	46.10	2.31	40.17
Germany				
1	36.60	1.43	10.29	51.68
4	40.77	1.89	13.92	43.43
8	37.92	6.78	19.30	66.00
20	42.80	9.84	24.71	52.65
France				
1	32.46	0.19	13.91	53.44
4	30.75	7.46	16.96	44.83
8	30.53	12.12	18.10	39.24
20	33.34	13.83	17.97	34.86

Appendix

The appendix demonstrates the derivation of equation (10). From equations (5) and (6) we get:

$$(M_t / P_t)^{-\delta} = c_t^{-\sigma} [1 - 1 / (1 + R_t)] \tag{A1}$$

By taking the logarithm of (A1) we have:

$$-\delta \log M_t + \delta \log P_t = -\sigma \log c_t + \log R \tag{A2}$$

since $\log [1 - 1 / (1 + R_t)] \cong \log R_t$

The first-order Taylor-series expansion of $\log R_t$ gives:

$$\log R_t = \log R_0 + 1 / R_0 (R_t - R^0) \tag{A3}$$

Equations (A3), (8) and (9) - after tedious arrangements - give:

$$\log e_t = A - A_1 \log c_t + A_2 \log M_t + A_3 \log e_{t+1} + A_3 \log P^*_{t+1} - \log P^*_t \tag{10}$$

with the coefficients A, A_1, A_2 and A_3 to have been defined in the main text.

Footnotes

1. The forecasting performance of the model economy was based on the estimation of the following equation:

Greece

$$\log\Delta e = \underset{(0.84)}{0.592} - \underset{(0.056)}{0.147} \log\Delta c + \underset{(0.033)}{0.177} \log \Delta m + \underset{(0.034)}{0.295} \log\Delta m(-1) - \underset{(0.07)}{0.253} \log\Delta m(-2) +$$

$$\underset{(0.84)}{3.57} \log\Delta p - \underset{(0.05)}{0.477} \log\Delta p(-1) - \underset{(0.076)}{0.151} \log\Delta p)\text{-}2) + \underset{(0.03)}{0.373} \log\Delta p(-3) + \underset{(0.60)}{0.368} \log\Delta p(-4)$$

$R^2 = 0.97$ DW = 2.04 SEE = 0.0125

Germany

$$\log\Delta e = \underset{(0.38)}{5.64} - \underset{(0.18)}{1.131} \log\Delta c + \underset{(0.11)}{0.026} \log\Delta m + \underset{(0.14)}{0.0112} \log\Delta m(-1) - \underset{(.11)}{0.215} \log\Delta m(-2) + \underset{(.201)}{1.1} \log\Delta p$$

$$- \underset{(0.0785)}{0.0423} \Delta\log p(-1) - \underset{(0.076)}{0.0303} \log\Delta p(-2) + \underset{(0.784)}{0.339} \log\Delta p(-3) + \underset{(0.151)}{1.461} \log\Delta p(-4)$$

$R^2 = 0.49$ D-W = 2.03 SEE = 0.00152

with figures in parentheses denoting standard errors, SEE is the standard error of the regression.

2. The U-Theil (U) and the Root Mean Square Error (RMSE) statistics are given by:

$$U = \sqrt{[1/m \sum_{i=1}^{m} (R(ti) - F(ti))^2]} / \sqrt{[1/m \sum_{i=1}^{m} R(ti)^2]}$$

and

$$RMSE = \sqrt{[1/m \sum_{j=0}^{m} (\Phi(\tau\iota) - P(\tau\iota))^2]}$$

with F being the forecasting values and r the actual values of the variable concerned.

3. For the purposes of the MOM methodology the following sets of instruments were used for equations (5) and (6), respectively:

$$c(t) / c(t-1), \quad p(t) / p(t-1), \quad m(t) / p(t) \qquad (5)'$$

$$p(t) / p(t-1), \quad c(t) / c(t-1), \quad 1 - R(t) \qquad (6)'$$

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