Regime dependence between the official and parallel foreign currency markets for US Dollars in Greece

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Abstract

This paper models the short-run as well as the long-run relationship between the parallel and official markets for US dollars in Greece in a bivariate Markov-Switching Vector Error Correction Model (MS-VECM) framework. Modelling exchange rates within this context can be motivated by the fact that the change in regime should be considered as a random event and not predictable. The results show that linearity is rejected in favour of a MS-VECM specification, which forms statistically an adequate representation of the data. Two regimes are implied by the model; the high volatility regime and the low volatility one and they provide quite accurately the state of volatility associated with economic and political events that took place in Greece during the 1970s and 1980s. Another implication is that there is evidence of regime clustering. Finally, Granger causality seems to be regime independent when we consider the hypothesis that official rate causes the parallel rate but it is regime dependent when we consider the opposite direction.

Keywords: Parallel market premium, nonlinearity, regime switching, Markov-Switching vector error correction models, Granger causality, impulse response function.

JEL Classifications: C32; F31.

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1. Introduction

In many developing countries governments indulge the existence of a dual foreign exchange market. Those markets are very often tolerated to prevent loss of foreign currency reserves. Thus, when governments restrict capital outflow by imposing various forms of restrictions, such as the requirement of a license to purchase foreign currencies or some form of taxation which eventually result to an excess demand for foreign currency leading to the evolution of a parallel market (it is legal or at least tolerable) or a black market (if it is illegal). In this market the exchange rate is determined by demand and supply and is usually higher than the official rate (although there are cases of a lower parallel rate). Certainly, the size of this market varies from country to country and depends on the type of exchange and trade restrictions imposed as well on the degree to which these restrictions are enforced by the authorities.[1]

Furthermore, it has been argued that the parallel (or black) premium (the difference between the parallel and official exchange rates) may operate as a signal of various macroeconomic misalignments. For example Kiguel and O' Connell (1995) argue that the existence of the parallel exchange market may induce speculative activities in the parallel market forcing domestic residents to hold foreign currency in excess of domestic currency and thus resulting to currency substitution. The existence of a parallel exchange market for foreign currency can in particular be very significant in countries with sustained high inflation since they can satisfy the excess demand for foreign currency given that economic agents use increased holdings of foreign currency in order to hedge against domestic inflation.

[1] Agenor, 1992; Montiel, Agenor and Haque, 1993; Kiguel and O' Connell, 1995; and Phylaktis, 1996 provide a survey of the theory of parallel markets for foreign currency.

Given the importance of the parallel market for foreign currency in the developing countries, a growing literature has emerged over the last decade in an attempt to develop the theoretical framework and to provide econometric evidence of different aspects of these markets for individual countries or group of countries in Latin American, the Pacific Basin, the Central and Eastern Europe and Africa. On the econometric side, this literature has mostly made use of cointegration theory. This is partly triggered by the evidence that often central banks adjust the official exchange rate to the parallel one in order to minimize the severity of the macroeconomic misalignments. Therefore, it has become important to study the long-run relationship between the two rates as well as the short- and long-run dynamics of these rates. Furthermore, the issues of causality between the two rates as well as that of market efficiency can also be analyzed within this context.

A parallel market for foreign currency was in force in Greece since the end of World War II until the early 1990s with a substantial size and a parallel market premium of 15% on average. This market was mainly for US dollars. During the period of fixed exchange rates as well as after the adoption of a managed float in early 1975, the development of the parallel market was the result of strict foreign exchange and trade controls. Following Greece's joining of EEC in 1981, a series of major reforms aimed to liberalize the financial markets along with the trader flows. These reforms included the abolition of foreign exchange controls and the restructuring of the financial and banking sector and the decentralization of foreign currency operations. These reforms have led to the elimination of the parallel market for US dollars by the end of 1993.

This paper investigates the short- and long-run dynamics of the parallel and official Greek drachma-US dollar exchange rates during the period April 1975 to

December 1993. Although this market has ceased to exist, we can still draw several important policy implications as to the type of distortions that capital controls create. In addition, we explore the difference of speed of adjustment of the two rates to the long-run equilibrium, their causal relationship, as well as the possibility of the introduction of regime-switching induced nonlinearities that events like devaluations, exchange rate regime switches and political instability in the long-relationship of the two rates may cause.[2]

In the present analysis, we focus on nonlinear features in the long-run relationship between the parallel and official Greek drachma-US dollar exchange rates and assess their short-run and long-run dynamics in the presence of regime switching. The motivation to model exchange rates in Greece within a nonlinear framework lies on the fact that during the period under examination we observed a transition from direct official intervention in the foreign exchange market to a completely liberalized financial environment. Additionally, from an economic point of view it is reasonable to investigate the possibility of a non-linear rather a linear type of adjustment to the long-run equilibrium since non-linear adjustment allows for the parallel exchange rate to adjust in a different way to positive or negative and to large or small deviations from its long-run equilibrium level.

We model nonlinearities in the Greek foreign exchange market by adopting regime switching models to analyze the non-linear adjustment to long-run equilibrium as well as to examine regime dependency between the parallel and official markets. Regime switching models make it possible to take into account the shifts between high and low volatility regimes and correlations due to changes in the economic and financial environment. They also result to a reduction of the persistence in variance

[2] Kouretas and Zarangas (1998, 2001a,b) and Kanas and Kouretas (2001a,b) provide extensive

and therefore the problems of underestimation of the volatility in the high volatility regime or the overestimation of the volatility in the low volatility regime are minimized.

In order to study the dynamics of the regime switching and the stochastic processes evolved in the foreign exchange markets in Greece, we adopt the Markov Switching Vector Error Correction Model (MS-VECM), introduced in Krolzig (1997), which is a multivariate generalisation of the univariate Hamilton (1989) model. This model allows, in a multivariate context, for shifts in the stochastic volatility regime driving the foreign exchange markets. Thus, the change in regime should be considered as a random event and not predictable. In addition, the effect of these shifts must be considered when we investigate the stochastic properties of the foreign exchange market volatility and the possible links between the official and parallel market for foreign currency.

The main findings of the paper are summarized as follows. First, there is strong evidence in favour of volatility regime switching modelling of nonlinearities which affects the parallel market premium. Second, the estimation of the MS-VECM accurately describes the two regimes based on the different pattern of adjustment of the premium when this takes positive or negative values; the estimated model captures all the events that may be responsible for the presence of nonlinear features in the premium such as the joining of EEC, the two discrete devaluations in 1983 and 1985, the financial liberalization process in the late 1980s and the political instability followed the failure of the stabilization programme of 1985-1987. Third, there is regime clustering with the likelihood that a low volatility regime will be followed by a low volatility regime greater that the likelihood a high volatility regime will be

evidence with respect to the operation of the parallel market for dollars in Greece.

followed by a high volatility regime. Fourth, when the issue of Granger causality is examined, it is shown that the official exchange rate Granger causes the parallel exchange rate irrespective of the regime, while Granger causality from the parallel to the official exchange rate is regime dependent. Finally, the impulse response functions show that the time path of the parallel exchange rate is different in each regime but has the same speed of convergence to the steady state while the time path of the official rate is also regime dependent but it also differs in speed to convergence.

The rest of the paper is organized as follows. Section 2 discusses the data and reports some preliminary results. Section 3 presents the econometric methodology. Section 4 presents and discusses the empirical results. Section 5 provides the summary and the concluding remarks.

2. Data and preliminary results

The data consist of end-of-month observations of the official and parallel drachma/US dollar exchange rates and the sample period spans from April 1975, when Greece adopted a managed floating exchange rate, to December 1993. The data for the official exchange rate were taken from the *International Financial Statistics* of the International Monetary Fund and the parallel market exchange rate data were taken from the *World Currency Yearbook*. Both series are taken in natural logarithms.

In order to avoid the problem of non-stationarity which is a well known feature of the exchange rate series, it is necessary to make use of first- (or higher) differentiated data. To examine, whether the exchange rate series are stationary, we apply the Elliot *et al*. (1996) GLS augmented Dickey-Fuller test (DF-GLS$_u$) and Ng and Perron (2001) GLS versions of the modified Phillips-Perron (1988) tests (MZ_a^{GLS} and MZ_t^{GLS}). The null hypothesis is that of a unit root against the alternative that the initial observation is drawn from its unconditional distribution and uses GLS-detrending as proposed by Elliott *et al*. (1996) and extended by Elliott (1999), to maximize power, and a modified selection criterion to select the lag truncation parameter in order to minimize size distortion. In the GLS procedure of Elliot *et al*. (1996), the standard unit root tests (without trend) are applied after the series are first detrended under the local alternative $\rho = 1 + \alpha / T$. This was found to provide substantial power gains for the DF-GLS$_u$ test resulting to power functions that lie just under the asymptotic power envelope. Ng and Perron (2001) find similar gains for the MZ_a^{GLS} and MZ_t^{GLS} tests. They also found that a modification of the AIC criterion (MIC), give rise to substantial size improvements over alternative selection rules such as BIC. For robustness, we then apply the Kwiatkowski *et al*. (1992) KPSS test for the null hypothesis of level or trend stationarity against the alternative of non-stationarity. The results of the unit root and stationarity tests are presented in Table 1. The results show that we are unable to reject the null hypothesis of non-stationarity with the DF-GLS$_u$ and MZ_a^{GLS} and MZ_t^{GLS} tests and we reject the null hypothesis of stationarity with the KPSS test for the levels of both series. The results are reversed when we take the first difference of each exchange rate series which leads us to the conclusion that the official and black drachma/dollar exchange rates are realizations of $I(1)$ processes.

Given the results of this preliminary analysis we will subsequently only consider the first differences for each exchange rate:

$$\Delta e_t = 100 * (e_t - e_{t-1})$$

which corresponds to the approximate percentage nominal return on each currency obtained from time *t* to *t-1*.[3]

Table 2 reports several preliminary statistics for monthly percentage changes in the official and parallel exchange rates. The skewness and kurtosis measures indicate that both series are positively skewed and highly leptokurtic relative to the normal distribution (this is more evident for the parallel rate). Furthermore, the Kolmogorov D-statistic as well the Bera-Jarque normality test reject the assumption of normality. Rejection of normality can be partially attributed to intertemporal dependencies in the moments of the series. Table 2 also presents the Ljung-Box (1978) portmanteau test statistics Q and Q^2 (for the squared data) to test for first- and second-moment dependencies in the distribution of the exchange rate series. The Q statistic indicates that percentage monthly returns of both rates are serial correlated. The Q^2 statistic for the official and parallel exchange rate is significant, providing evidence of strong second-moment dependencies (conditional heteroskedasticity) in the distribution of the exchange rate series.[2] Finally, the standard deviation indicates that there is greater variance of exchange rate returns in the black market than in the official market.

3. Econometric methodology

3.1. The Markov Switching Vector Error Correction Model

The Markov Switching Vector Error Correction Model (MS-VECM), introduced in Krolzig (1997), is a multivariate generalisation of the univariate

[3] We only apply linear unit root and stationarity tests as we are not interested in the presence of nonlinearities in the univariate series but in the relationship between the two exchange rates.

Hamilton (1989) model.[4] The advantage of using a Markov chain to model the random discontinuous shift is that it allows conditional information to be used in the forecasting process. This allows us: (i) to model and explain time series dynamics; (ii) to demonstrate the presence of regime persistence (this is the well-known cluster effect, i.e. high volatility is usually followed by high volatility) and (iii) to provide better forecasts since switching regime models generate a time conditional forecasted distribution instead of an unconditional forecasted distribution.

Consider that Δy_t is a Tx1 vector containing the observations for the single stationary time series $\{\Delta y_t\}$, and let $\Delta Y_t = (\Delta y_{1t}, \ldots, \Delta y_{Kt})'$, $t = 1, \ldots, T$ be the K-dimensional vector, where T is the sample size. A p-th order MS-VECM [MS-VECM(p)] model can be written as

$$\Delta Y_t = A_0(s_t) + A_1(s_t)\Delta Y_{t-1} + \ldots + A_p(s_t)\Delta Y_{t-p} + B(s_t)ect_{t-1} + u_t \,, \qquad (1)$$

$$u_t \sim NID(0, \Sigma(s_t))$$

where s_t is the unobservable regime, $A_0(s_t), \ldots, A_p(s_t)$ are regime-dependent autoregressive parameter matrices, $B(s_t)$ is the regime-dependent parameter matrix of the error correction term (*ect*), and u_t is the innovation process with a regime-dependent variance-covariance matrix $\Sigma(s_t)$. It is assumed that s_t follows an irreducible ergodic m-regime Markov process with the transition matrix

[4] For the same sample period Kouretas and Zarangas (2001b) have shown that there is a *linear* cointegrating relationship between the two exchange rates. This is the reason that we estimate an MS-VECM instead of an MS-VAR model. Hamilton and Susmel, (1994) and Hamilton and Lin, (1996) have estimate switching regime models of stock returns.

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1M} \\ p_{21} & p_{22} & \cdots & p_{2M} \\ \cdots & \cdots & \cdots & \cdots \\ p_{M1} & p_{M2} & \cdots & p_{MM} \end{bmatrix} \quad (2)$$

The transition probabilities p_{ij} in **P** are constant, and given by

$$p_{ij} = \Pr(s_{t+1} = j \mid s_t = i), \sum_{j=1}^{m} p_{ij} = 1, \ \forall i, j \in \{1, ..., m\} \quad (3)$$

We model the linkage between the official and the parallel currency markets by considering the 2-dimensional vector $\Delta Y_t = (\Delta e_t^O, \Delta e_t^P)$. This vector is modelled using an MS-VECM model with a regime-dependent variance-covariance matrix. To explore whether the explanatory variables have different effects across regimes, we also allow the autoregressive parameter matrices to be regime-dependent ($A_0(s_t)$, $A_1(s_t)$ …, $A_p(s_t)$). Thus, the m-regime model [MS(m)-VECM(p)] is:

$$\Delta e_t^O = a_O(s_t) + \sum_{k=1}^{p} a_{O,O,k}(s_t)\Delta e_{t-k}^O + \sum_{k=1}^{p} a_{O,P,k}(s_t)\Delta e_{t-k}^P + b_O(s_t)ect_{t-1} + Z(s_t)u_{O,t}$$

$$u_{O,,t} \sim \text{NID}(0,1)$$

$$\Delta e_t^P = a_P(s_t) + \sum_{k=1}^{p} a_{P,O,k}(s_t)\Delta e_{t-k}^O + \sum_{k=1}^{p} a_{P,P,k}(s_t)\Delta e_{t-k}^P + b_P(s_t)ect_{t-1} + Z(s_t)u_{P,t}, \quad (4)$$

$$u_{P,t} \sim \text{NID}(0,1)$$

In the above specification, the disturbances are pre-multiplied by a regime-dependent matrix $Z(s_t)$. Thus, the variance–covariance matrix $\Sigma(s_t)$ is also regime-dependent:

$$\Sigma(s_t) = E(Z(s_t)u_t u_t' Z'(s_t)) = Z(s_t)E(u_t u_t')Z'(s_t) = Z(s_t)I_2 Z'(s_t) = Z(s_t)Z'(s_t) \quad (5)$$

where u_t is the 2-dimensional vector of disturbances, $u_t \sim N(0, I_2)$.

Maximum likelihood estimation of the model in (4) is based on the Expectation Maximisation (EM) algorithm discussed in Hamilton (1989), and Krolzig (1997). As a byproduct of the maximum likelihood estimation, one can calculate the unconditional probability that the system of the two currency is in regime i, $i = 1,\ldots m$, at any given date, $\Pr(s_t = i)$.[5] Also, a set of conditional probabilities can be obtained, namely the 'smoothed' probabilities, representing the ex-post inference about the system being in regime i at date t. Further, one could date the regime switches. For instance, for 2 regimes, an observation is assigned to the first regime if $Pr(s_t = 1 \mid \Delta Y_T) > 0.5$, and to the second regime if $Pr(s_t = 1 \mid \Delta Y_T) < 0.5$. Lastly, the average duration of each regime, d_i, is calculated from the formula $d_i = (1-p_{ii})^{-1}$.

3.2. Regime-dependent Granger Causality tests

On the basis of the estimated model in (4), one can conduct regime dependent Granger-causality tests, namely causality tests *within* each regime. To test for Granger causality from the parallel exchange rate changes to the official exchange rate changes *within* regime i, the null hypothesis of non-causality is:

$$H_0: a_{O,P,1}(s_t = i) = a_{O,P,2}(s_t = i) = \ldots = a_{O,P,p}(s_t = i) = 0, i=1\ldots,m \quad (6)$$

To test the null, we impose the restrictions in (6) on the values of the autoregressive parameters, and obtain the log likelihood value of the restricted MS-VECM model (L_R). The value of the log likelihood of the unrestricted model (L_U) is also obtained (from estimating the model in (4)), and a standard Likelihood Ratio (LR) test is conducted on the basis of the formula $LR = 2(L_U-L_R)$.

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[5] The formula is $\Pr(s_t = 1) = (1 - p_{22})/(2 - p_{11} - p_{22})$

3.3. Regime-dependent impulse responses using the Markov Switching VECM

An additional means of measuring how the official currency market reacts to disturbances from the parallel market and vice versa is to employ impulse response analysis. We use the estimated Markov Switching VECM to calculate the response of the official market to a shock in the parallel market, and the response of the parallel to a shock in the official. We seek to explore which market exercises the more persistent impact on the other. Our impulse response functions are regime dependent; they measure the expected changes in one market at time *t+h* to a one standard deviation shock to the other market at time *t* within each regime.[6] The regime dependent impulse response function for regime *i* is defined as follows:

$$\frac{\partial E_t \Delta e^o_{t+h}}{\partial u_{p,t}} | s_t = ... = s_{t+h} = i = \theta_{pi,h}, \quad \text{for } h > 0 \qquad (7)$$

where *h* is the time horizon (in months). Estimates of the response vectors can be derived by combining the parameter estimates of the unrestricted Markov Switching VECM in (4) with the estimate of the matrix $\hat{Z}(s_t)$ obtained through identification restrictions.[7] For exposition purposes, let us assume that we seek to estimate the impulse response of the official exchange rate changes from a shock in the parallel market. A one standard deviation shock to the parallel market implies that the initial disturbance vector is u_0 (0, 1). Pre-multiplying this vector by the estimate of the regime-dependent matrix $\hat{Z}(s_t)$ gives the impact responses. The remaining response vectors can be estimated by solving forward for the official exchange rate changes.

[6] Ehrmann *et al*. (2003) argue that regime-dependent impulse response functions can be a useful analytical tool.
[7] See Ehrmann *et al*. (2003).

The following expression shows the solutions linking the estimated response vectors with estimated parameters:

$$\theta_{Pi,h} = \sum_{l=1}^{\min(h,p)} A_{li}^{h-l+1} Z(s_t) u_0 \text{ ,for } h > 0 \tag{8}$$

4. Empirical findings

To address the issue of volatility regime switching and to discriminate between low and high volatility regime in the drachma/dollar official and parallel exchange rate, we estimate and test for an MS-VECM given by (4). Table 3 reports the estimated coefficients of the proposed MS-VECM along with the necessary test statistics for evaluation of the adequacy of the estimated model. The Likelihood Ratio test for the null hypothesis of linearity is statistically significant and this suggests that linearity is strongly rejected. This is a nonstandard LR test due to Davies (1987). This outcome is reinforced from the AIC and HQIC criteria.

The joint estimation of the two dynamic equations provide asymmetrically a number of statistically significant coefficients, thereby justifying the use of a regime dependent autoregressive parameters. Table 3 also reports several other diagnostics which further highlight the use of regime switching induced nonlinearities in the relationship of the two exchange rates. First, the standard deviations σ_o and σ_p take the values of 0.063 and 0.060, and 0.031 and 0.037 for regime 1 and regime 2 respectively; these values help us to identify regime 1 as the high volatility regime and regime 2 as the low volatility regime. Second, the calculated contemporaneous correlation coefficient shows that while in the case of the low volatility regime (regime 2) the correlation between the two markets is substantially high, this link breaks apart in the case of the high volatility regime (regime 1). In fact, the ratio of the two coefficients is equal to 3. In addition, the duration measure shows that the high volatility regime lasts approximately 3.5 months, whereas the low volatility regime lasts approximately 7 months. This outcome is expected, given that there is no economic or financial crisis evident during the period under investigation, normal periods last more than turbulent periods. Finally, the calculated unconditional probability shows that there is a probability of 33 percent that a high volatility regime occurs and 67 percent that a low volatility regime takes place. The transition probabilities p_{11} and p_{22} explain the possibility of regime clustering and it is shown that there is 72 percent probability that a high volatility regime will be followed by a high volatility regime, while there is a 86 percent probability that a low volatility regime will be followed by a low volatility regime. Furthermore, for both regimes, the error correction term has the correct negative and it is statistically significant either when the dependent variable is the parallel market rate or when the dependent variable is the official rate.

The estimation of MS-VECM using all the available data allows us to make inference of being in one of the two volatility regimes for each month of the sample. Figure 1 shows the resulting smoothed probabilities of being in the high and the low volatility regimes for the parallel market premium. As shown in this figure, several months of the sample are characterized by high volatility and this may be attributed to several economic and political events that took place during the period under investigation. Table 4 provides a full account of the data falling in the two regimes, regime 1 (high volatility) and regime 2 (low volatility). It is very interesting to note that the estimated MS-VECM provides an accurate account of the distinction between regimes of high volatility and low volatility and we note that most of the economic and political events that could substantially increase the volatility of the two rates fall in the high volatility regime. Specifically, the first significant change of regime occurs in the mid 1975 and lasts till the early 1977, and reflects the substantial increase in volatility of the exchange rate as a result of the abandonment of the fixed exchange rate and the adoption of a managed float regime of the form of a trade-weighted system, where the US dollar had the greatest weight. The second important event occurred when Greece joined the EEC in January 1981 which generated a major shift in the political scene of Greece and its economic policies. Subsequent important events that resulted to high volatility in the exchange rate in the two markets and clearly identified in the high volatility regime are considered to be the devaluation of the drachma in January 1983 and the introduction of the drachma in the composition of the ECU in September 1984. Further, events that have definitely contributed to a change from low to high volatility were the second devaluation of October 1985 as well as the implementation of the capital flows liberalization process which began in January 1986. The failure of the stabilization programme of 1985-1987 and the political crisis of 1989-1993 may also being considered as sources of high volatility over the last part of our sample.

Table 5 reports the results from Granger causality test between the two markets and within each regime identified. We begin by examining the causality direction in the high volatility regime (regime 1). It is clear that the null hypothesis of no Granger causality from the official to the parallel markets is rejected. The same conclusion holds for the low volatility regime (regime 2). Next, we test for Granger causality from the parallel market to the official market. As shown in table 5, the evidence is mixed. The null of no causality is rejected in the case of the high volatility regime, but it cannot be rejected in the low volatility regime. These results suggest that when some kind of news cause high volatility then in the parallel market this effect is amplified transmitting side-effects to the official market but not vice-versa.

Overall, the finding of a negative statistically significant error-correction term in both dynamic equations and the rejection of the null of no Granger causality in most cases have some important implications for market efficiency. Clearly, we can argue that agents use information from one foreign exchange market to predict the future path of exchange rate in the other, and this can be taken as a rejection of the weak form market efficiency.

The final issue of our analysis concerns the impulse response functions of the parallel exchange and the official exchange rates. Figures 2 and 3 provide the time paths of each rate for both regimes. The time path of the parallel rate to a one unit shock in the official rate seems to follow a rather different pattern in the high volatility regime compared to that in the low volatility regime, although the convergence occurs at the same time about 17 months later. In the case of the official exchange rate, its time path following a one unit shock in the parallel rate is considerably different in the two regimes, and shows quick convergence to equilibrium in the high regime case but significant persistence in the low volatility regime.

5. Summary and Concluding Remarks

This paper aims to model volatility regime switching for the Greek drachma-US dollar bilateral parallel and official exchange rates using monthly data for the recent float. It further analyzes the effect regime switching such nonlinearities on the short-run dynamics of the parallel market premium. To conduct our study, we adopt the multivariate MS-VECM developed by Krolzig (1987). There are several important findings that stem from the present analysis. First, there is strong evidence in favour of regime switching modelling of nonlinearities in the parallel market premium implying that the adjustment to equilibrium can be described better in a nonlinear form than in a linear one. Second, the estimation of the MS-VECM accurately describes the two regimes based on the different pattern of adjustment of the premium when this takes positive or negative values; and finally the estimated model captures all the events that are responsible for the presence of nonlinear features in the premium such as the joining of EEC, the two discrete devaluations in 1983 and 1985, the financial liberalization process in the late 1980s and the political instability followed the failure of the stabilization programme of 1985-1987. Third, there is a high probability for regime clustering with the likelihood that a low volatility regime will be followed by a low volatility regime greater that the likelihood a high volatility regime will be followed by a high volatility regime. Fourth, when the issue of Granger causality is examined, it is shown that the official exchange rate Granger causes the parallel exchange rate irrespective of the regime, while Granger causality from the parallel to the official exchange rate is regime-dependent. Finally, the impulse response functions show that the time path of the parallel exchange rate is different in each regime but has the same speed of convergence to the steady state while the time path of the official rate is also regime dependent but it also differs in speed to convergence.

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Table 1. Unit root and stationarity tests

Variables	DF-GLS$_u$ t_μ	t_τ	MZ_a^{GLS}	MZ_t^{GLS}	KPSS η_μ	η_τ
e_o	-0.465 [0]	-1.422 [0]	1.095 [13]	1.3988 [13]	1.921*	0.262*
Δe_0	-4.385* [9]	-4.390* [9]	-22.758 [9]	-3.369 [9]	0.128	0.118
e_p	-0.429 [12]	-1.882 [12]	1.043 [13]	1.093 [13]	1.904*	0.162*
Δe_p	-7.745* [4]	-7.563* [4]	-16.234 [10]	-2.838 [10]	0.103	0.094

Notes: e_o and e_p are, respectively, the official and parallel exchange rate. Δe_o and Δe_p are the first differences.

- The DF-GLS$_u$ is due to Elliot et al. (1996) and Elliott (1999) is a test with an unconditional alternative hypothesis. The standard Dickey-Fuller tests are detrended (with constant or constant and trend). The critical values for the DF-GLS$_u$ test at the 5% significance level are:-2.73 (with constant) and -3.17 (with constant and trend), respectively (Elliott,1999).
- MZ_a and MZ_t are the Ng and Perron (2001) GLS versions of the Phillips-Perron tests. The critical values at 5% significance level are: -8.10 and -1.98 (with constant), respectively (Ng and Perron, 2001, Table 1).
- η_μ and η_τ are the KPSS test statistics for level and trend stationarity respectively (Kwiatkowski *et al*. 1992). For the computation of theses statistics a Newey and West (1994) robust kernel estimate of the "long-run" variance is used. The kernel estimator is constructed using a quadratic spectral kernel with VAR(l) pre-whitening and automatic data-dependent bandwidth selection [see, Newey and West, 1994 for details]. The 5% critical values for level and trend stationarity are 0461 and 0.148 respectiveley, and they are taken from Sephton (1995, Table 2).

(*) indicates significance at the 95% confidence level.

Table 2. Summary statistics on monthly exchange rate changes

Statistic	Δe_o	Δe_p
Mean	0.009	-0.009
Standard deviation	0.032	0.056
Skewness	1.38*	-0.40
Kurtosis	7.90*	17.63*
D-statistic	0.296*	0.258*
B-J	295.26	2781.47*
$Q(24)$	59.32*	50.87*
$Q^2(24)$	33.74*	93.27*

Notes: $\Delta e_t = 100 * [\log e_t - \log e_{t-1}]$**;** D-statistic is the Kolmogorov-Smirnov statistic for the null of normality; B-J is the Bera-Jarque test for the null hypothesis of normality; $Q(24)$ and $Q^2(24)$ are the Ljung-Box test statistics for up to 24th-order serial correlation in the Δe_t and Δe_t^2 series, respectively. An asterisk denotes statistical significance at the 5% critical level.

Table 3. Estimation of the MS-VECM

Parameters	Regime 1	Regime 2
a_O	-0.001188 (-0.3299)	0.014986* (4.6703)
$a_{O,O,1}$	-0.119738 (-1.2403)	-0.104615 (-0.9299)
$a_{O,O,2}$	0.265112 * (2.7085)	0.054269 (0.4951)
$a_{O,O,3}$	0.110679 (1.1971)	-0.066536 (-0.5978)
$a_{O,P,1}$	-0.183906 * (-2.0552)	-0.077044 (-1.2995)
$a_{O,P,2}$	0.235390 * (2.9472)	-0.000354 (-0.0049)
$a_{O,P,3}$	0.076554 (1.1691)	0.015332 (0.2444)
a_P	-0.010119 (-1.1880)	-0.006762 (-1.7965)
$a_{P,O,1}$	-0.685583* (-2.8310)	-0.572826* (-4.3095)
$a_{P,O,2}$	-0.376191 (-1.5298)	-0.093492 (-0.7175)
$a_{P,O,3}$	-0.009787 (-0.0425)	0.157893 (1.1818)
$a_{P,P,1}$	-0.167308 (-0.8045)	-0.662588* (-9.4127)
$a_{P,P,2}$	0.149212 (0.7772)	-0.225866* (-2.6764)
$a_{P,P,3}$	0.106371 (0.6409)	-0.078299 (-1.0474)
$ect_{O,t-1}$	-0.040850* (-2.5526)	-0.267535* (-3.4579)
$ect_{P,t-1}$	-0.491961* (-2.5969)	-0.300461* (-3.3424)
σ_O	0.063	0.031283
σ_P	0.060	0.037282
Contemporaneous correlation	-0.29	-0.88
Duration	3.57	7.14
Unconditional probability	0.333	0.667
p_{11}	0.72	
p_{22}	0.86	
Null hypothesis: The variance and autoregressive parameters are equal across regimes (Linear VECM) Alternative: The variance and autoregressive parameters are different across regimes (MS-VECM)		
Likelihood	905.40{828.70}	
LR	153.4 [0.000]	
AIC	-7.83 {-7.32}	
HQIC	-7.21 {-7.03}	

Notes:

1. LR denotes the likelihood ratio test for the null of a linear VECM. The value in squared brackets next to LR is the marginal significance level of this test, based on Davies (1987).
2. The values in curly brackets report the respective values from the linear VECM(3).
3. t-statistics are reported in parentheses. * denotes statistical significance at the 5% level.

Table 4. Regime classification.

Period	Regime 1 (High Volatility) or Regime 2 (Low Volatility)
1975.08 – 1977.11	Regime 2
1977.12 – 1978.01	Regime 1
1978.02 – 1980.09	Regime 2
1980.10 – 1980.11	Regime 1
1980.12	Regime 2
1981.01 – 1981.06	Regime 1
1981.07	Regime 2
1981.08 – 1981.09	Regime 1
1981.10 – 1981.12	Regime 2
1982.01 - 1982.05	Regime 1
1982.06 – 1982.09	Regime 2
1982.10 – 1983.01	Regime 1
1983.02 – 1983.07	Regime 2
1983.08	Regime 1
1983.09 – 1983.10	Regime 2
1983.11 – 1983.12	Regime 1
1984.01 – 1984.07	Regime 2
1984.08 – 1985.02	Regime 1
1985.03 – 1985.05	Regime 2
1985.06 – 1986.10	Regime 1
1986.11 – 1986.12	Regime 2
1987.01 – 1987.05	Regime 1
1987.06 – 1987.10	Regime 2
1987.11 – 1987.12	Regime 1
1988.01 - 1988.05	Regime 2
1988.06 – 1988.08	Regime 1
1988.09	Regime 2
1988.10	Regime 1
1988.11 – 1989.06	Regime 2
1989.07	Regime 1

Table 4. Regime classification. (continued)

Period	Regime 1 (High Volatility) or Regime 2 (Low Volatility)
1989.08 – 1991.02	Regime 2
1991.03	Regime 1
1991.04 – 1992.09	Regime 2
1992.10 – 1992.11	Regime 1
1992.12 – 1993.05	Regime 2
1993.06	Regime 1
1993.07 – 1993.12	Regime 2

Notes: Regime chronology according to MS-VECM for parallel exchange rate (e_p) and official exchange rate (e_o) for Greek drachma versus US dollar.

Table 5. Regime-dependent Granger causality testing: From the official to the parallel currency market

Model	Log likelihood value	Likelihood ratio test	p-value	Result
Null: The official exchange rate changes do not Granger cause the parallel exchange rate changes *within* Regime 1				
Alternative: The official exchange rate changes Granger cause the parallel exchange rate changes *within* Regime 1				
Restricted	900.30	10.20	0.019	Reject the null
Unrestricted	905.40			
Null: The official exchange rate changes do not Granger cause the parallel exchange rate changes *within* Regime 2				
Alternative: The official exchange rate changes Granger cause the parallel exchange rate changes *within* Regime 2				
Restricted	899.00	12.80	0.005	Reject the null
Unrestricted	905.40			

Notes:

1. The number in parentheses next to the likelihood ratio test denotes the degrees of freedom (df) in the χ^2 statistic (i.e χ^2 (3)).

Table 6. Regime-dependent Granger causality testing: from the parallel to the official currency market

Model	Log likelihood value	Likelihood ratio test	p-value	Result
Null: The parallel exchange rate changes do not Granger cause the official exchange rate changes *within* Regime 1				
Alternative: The parallel exchange rate changes Granger cause the official exchange rate changes *within* Regime 1				
Restricted	900.00			
		10.80	0.012	Reject the null
Unrestricted	905.40			
Null: The parallel exchange rate changes do not Granger cause the official exchange rate changes *within* Regime 2				
Alternative: The parallel exchange rate changes Granger cause the official exchange rate changes *within* Regime 2				
Restricted	904.40		0.58	Accept the null
		2.00		
Unrestricted	905.40			

Notes:

1. The number in parentheses next to the likelihood ratio test denotes the degrees of freedom (df) in the χ^2 statistic (i.e. χ^2 (3)).

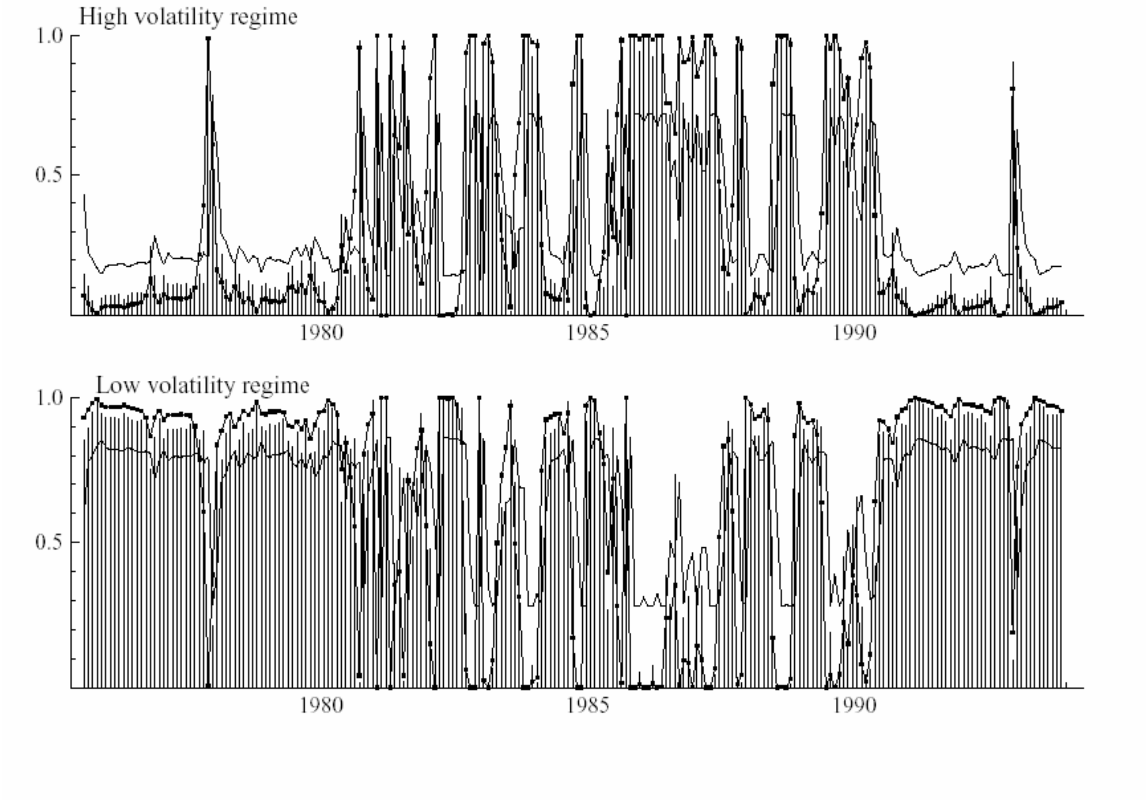

Figure 1. Smoothed probabilities

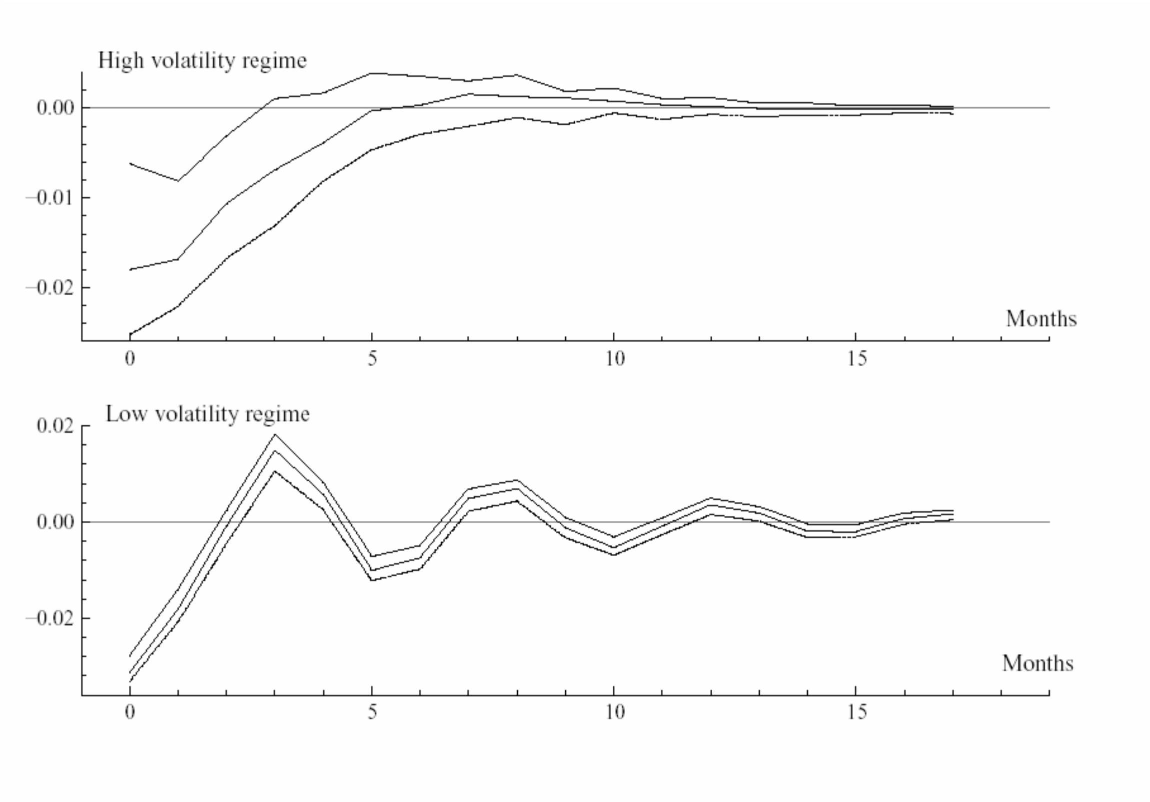

Figure 2. Impulse response of the parallel currency market to a shock to the official currency market

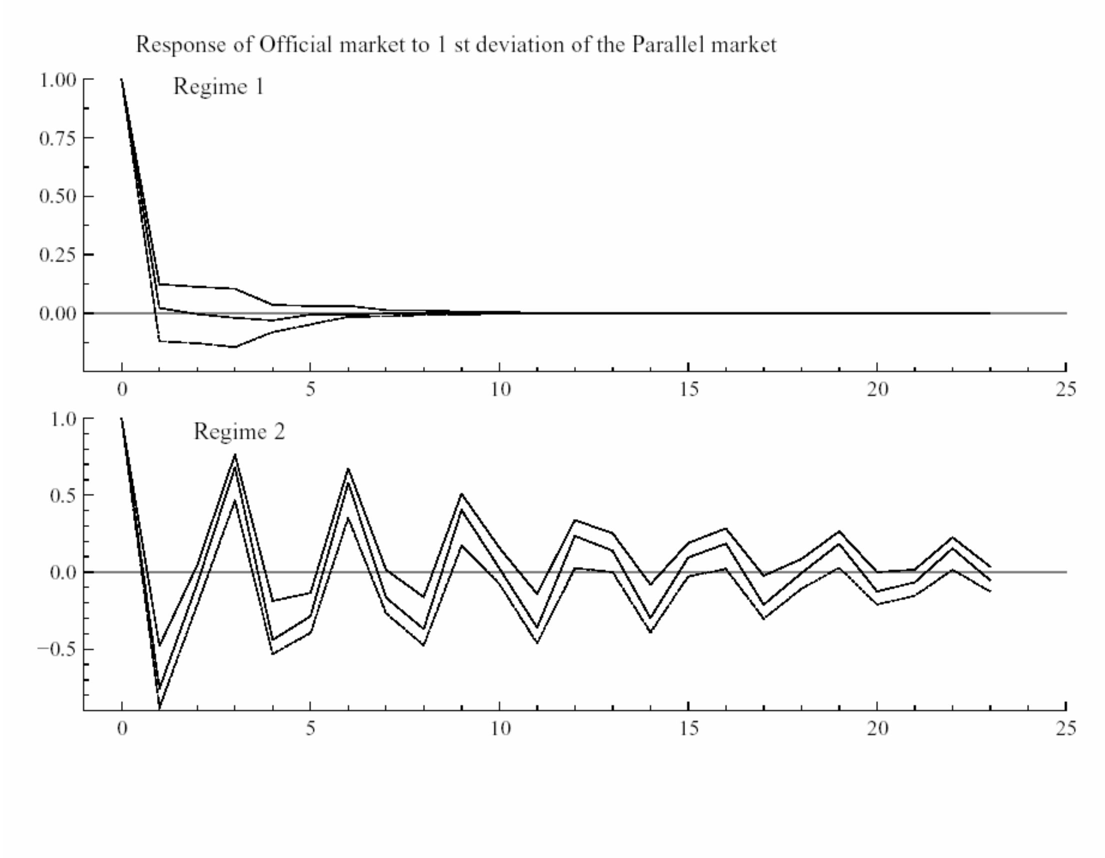

Figure 3. Impulse response of the official currency market to a shock to the parallel currency market