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Behavioural Equilibrium Exchange Rate and Total Misalignment: Evidence from the Euro Exchange Rate

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Abstract: This paper investigates whether the nominal euro exchange rate against the currencies of China, Japan, the UK and the USA converges or not to its equilibrium level. Applying cointegration and common trend techniques in the presence of structural breaks in the data, we found a valid long-run relationship between the euro/yuan, euro/yen, euro/UK pound and euro/US dollar nominal exchange rates and the fundamentals defined by the monetary model. Our modified Behavioural Equilibrium Exchange Rate model suggests that at the end of the estimated period, the euro/Chinese yuan and the euro/UK pound exchange rates follow an equilibrium process. On the other hand, the euro is considered as overvalued against the US dollar and as undervalued against the Japanese yen.

Keywords: Euro, BEER, Misalignment Rate, Cointegration, Structural Shifts

JEL Classification: E43, F15, F42

1. Introduction

The present paper aims to evaluate the dynamic behaviour of the single European currency. We attempt to examine the likelihood of emergence of significant future fluctuations of the euro exchange rate against four major currencies, namely the Chinese yuan, the Japanese yen, the UK pound and the US dollar. Future exchange rate instability is not expected to be high if the above nominal exchange rates are not significantly away from their equilibrium rates. The intuition is that even if the exchange rate is currently stable but, significantly misaligned, the exchange rate is going to be highly unstable in the future. Exchange rate volatility corresponds to short-run fluctuations of the exchange rate around its long-run trends, while exchange rate misalignment refers to a significant deviation of the observed exchange rate from its equilibrium rate. Both notions are closely related each other. This is because a highly misaligned exchange rate is going to be highly volatile at present and in the future in order to find its equilibrium rate (by its own forces or by government interventions in the foreign exchange market).

Given that the exchange rate is the link of the domestic economy with the rest of the world, a significant misaligned exchange rate can have important negative consequences on the Euro area. For instance, when euro is undervalued (below its equilibrium rate) the economy is expected to face inflationary pressures. On the other hand, if euro is overvalued (above its equilibrium rate) a competitiveness problem is more possible for the Euro area. These situations suggest the necessity of estimating the equilibrium exchange rate of the euro against the currencies of Euro area's major trading partners.

Departing from traditional theories of equilibrium exchange rates, such as the Purchasing Power Parity, Williamson (1985) proposed the "Fundamental Equilibrium Exchange Rate" (FEER), which is an alternative exchange rate determination model suitable for medium-run analysis. The FEER approach indicates that the exchange rate is at its equilibrium value when satisfies the condition of simultaneous internal and external balance. Williamson interprets the external balance condition in terms of current account balance and states that the current account must be sustainable. Combining these two macroeconomic conditions, the FEER is the rate that equates the current account at full employment with sustainable net capital flows. Very close to FEER is the Desired Equilibrium Exchange Rate (DEER) approach presented by Bayoumi et al (1994).

An additional approach about exchange rate determination is the Natural Real Exchange Rate (NATREX), which is referred in both medium-run and long-run periods. The NATREX is *"…the rate that would prevail if speculative and cyclical factors could be removed while unemployment is at its natural rate"* (Stein 1994, p. 135). This rate is consistent with simultaneous internal and external balance and equates the sustainable current account with saving and investment.

The latest approach for exchange rate determination is the Behavioural Equilibrium Exchange Rate (BEER) proposed by Clark & MacDonald (1998). The BEER is a short-run concept which involves the direct econometric analysis of the exchange rate behaviour. It does not actually rely on any theoretical model and the equilibrium rate is designated by the long-run behaviour of the macroeconomic variables. Similarly, Clark & MacDonald (1998) proposed the Permanent Equilibrium Exchange Rate (PEER) approach. The PEER approach differs from BEER in the way that the exchange rate is a function only of those variables that have a persistent effect on it.

This paper contributes to the literature of equilibrium exchange rate determination by strengthening the theoretical background of the BEER model. Our novelty lies on the fact that we combine the theoretical assumptions of the monetary model of exchange rate determination (Frenkel 1976; Kouri 1976; Mussa 1976, 1979) with the BEER methodology. This is an important issue, since the BEER approach, whose building idea is the uncovered interest rate parity (UIP) condition, does not actually rely on any theoretical model.

Furthermore, we account for structural breaks in the data. In our context, this is also an important issue because the monetary and fiscal policies of the Euro area, China, Japan, the UK and the USA are likely to have caused structural shifts in the level and trend of the euro exchange rate vis-à-vis the Chinese yuan, the Japanese yen, the UK pound and the US dollar. Since the presence of structural breaks in the data are known to have significant effects on the properties and interpretation of standard unit root and cointegration tests, we employ recently developed tests that are valid in the presence of structural shifts in the data; we discuss these issues extensively in section 3 below.

In what follows, first, we use monthly data available from the 1999:01 and unit root tests in the presence of structural breaks in the data (Lee and Strazicich 2003, 2004), in order to test for stationarity and to determine endogenously the possible structural breaks that exist.

Second, we use recently developed cointegration tests that allow for structural breaks in the data (Johansen, Mosconi and Nielsen 2000, and Lütkepohl and his associates in several papers noted below) in order to establish a valid long-run relationship between the nominal euro exchange rate vis-à-vis the Chinese yuan, the Japanese yen, the UK pound and the US dollar and the fundamental variables that defined by the monetary model of exchange rate determination.

Third, from the above long-run relationship we estimate the total equilibrium exchange rate (i.e. the BEER) in order to investigate if the nominal euro exchange rate against the currencies of China, Japan, the UK and the USA is overvalued or undervalued in relation to its equilibrium level.

In brief, our empirical results indicate that, at the end of our sample, the euro is overvalued in relation to the US dollar, undervalued in relation to the Japanese yen and moves towards its equilibrium value in relation to the Chinese yuan and the UK pound.

The rest of the paper is organized as follows. Section 2 discusses the theoretical framework of the BEER model and the way that this methodology can be combined with the theoretical assumptions of the monetary model. Section 3 describes the data and outlines the unit root and cointegration tests in the presence of structural breaks. Section 4 discusses the results for the current and total equilibrium exchange rates, while section 5 contains some concluding remarks.

2. Theoretical Framework

2.1 The Model

The estimation of the equilibrium exchange rate is based on the BEER approach of Clark and MacDonald (1998). This approach estimates the exchange rate misalignment in accordance with the deviations of the actual exchange rate from its estimated value, which is derived from the long-run relationship between the exchange rate and the macroeconomic fundamentals. The advantage of the BEER model is that the exchange rate is a function of variables that have a direct effect on the exchange rate. In other words, the equilibrium exchange rate is driven by the sustainable (equilibrium) values of the fundamentals that affect the actual exchange rate in the long run and not by overall macroeconomic balance.

The BEER approach does not actually rely on any theoretical model and the equilibrium rate is designated by the long-run behaviour of the macroeconomic variables. However, this does not mean that any theoretical concept is not required. Stein (2001) presents an evaluation of studies based on the BEER approach, in which the authors have in mind a theoretical model but there is no need to be specified. For example, most authors have in mind the condition of simultaneous internal and external balance. This implies that the building idea of the BEER approach is the UIP condition.

In this study, we strengthen the theoretical background of the BEER model by assuming that the fundamentals that affect the long-run exchange rate are those defined by the monetary model of exchange rate determination. Our approach extends the standard BEER approach in the sense that we do rely on a theoretical model.

The monetary model is briefly described as follows. Assuming that (a) prices are flexible, (b) the economy is at full employment level and (c) the purchasing power parity (PPP) and UIP conditions hold all the time, the domestic and foreign monetary equilibrium conditions are described by equations (1) and (2), respectively:

$$m_t - p_t = \varphi y_t - \mu r_t \quad , \tag{1}$$

$$m_t^* - p_t^* = \varphi^* y_t^* - \mu^* r_t^* \quad , \tag{2}$$

$$s_t = p_t - p_t^* \quad , \tag{3}$$

$$r_t = r_t^* + E_t[\Delta s_{t+1}] \quad . \tag{4}$$

Equation (3) stands for the PPP condition, while equation (4) represents the UIP condition. s is the nominal exchange rate (domestic currency per unit of foreign currency) and m, p, y, r represent the domestic real money supply, the domestic price level, the domestic real income and the domestic interest rate, respectively. * denotes the respective foreign variables.

The foreign price level is exogenous to the domestic economy and the domestic money supply determines the domestic price level and hence the exchange rate. Combining equations (1) and (2) and assuming that the domestic and foreign coefficients are identical, the relative money demands are given by

$$(m_t - m_t^*) - (p_t - p_t^*) = \varphi(y_t - y_t^*) - \mu(r_t - r_t^*) \quad (5)$$

Solving for the relative prices and using the PPP condition, we get the exchange rate equation, which is the main expression of the monetary model:

$$s_t = (m_t - m_t^*) - \phi(y_t - y_t^*) + \mu(r_t - r_t^*) \quad (6)$$

Equation (6) shows that the nominal exchange rate depends on the relative money supply, the relative output, and the interest rate differential. Applying the UIP condition, equation (6) becomes:

$$s_t = (m_t - m_t^*) - \phi(y_t - y_t^*) + \mu E_t[\Delta s_{t+1}] \quad (7)$$

Since the PPP holds all the time, it turns out that $E_t[\Delta s_{t+1}] = E_t[\pi_{t+1}] - E_t[\pi^*{}_{t+1}]$, where π and π^* are the domestic and foreign inflation rates, respectively. Then the exchange rate equation becomes:

$$s_t = (m_t - m_t^*) - \phi(y_t - y_t^*) + \mu(E_t[\pi_{t+1}] - E_t[\pi_{t+1}^*]) \quad (8)$$

Finally, assuming that inflation expectations are rationally formed (i.e. the market agents have perfect foresight), we derive the long-run exchange rate (or, equivalently, the current equilibrium exchange rate):

$$s_t = (m_t - m_t^*) - \phi(y_t - y_t^*) + \mu(\pi_{t+1} - \pi_{t+1}^*) \quad (9)$$

According to the monetary model, the sign of the money supply differential is expected to be positive, which means that if the increase of the domestic money supply is greater than this of the foreign money supply, the domestic currency is expected to depreciate. This happens because the increased money stock increases the domestic price level and thus, the domestic goods become less competitive than the foreign ones. Thus, demand for domestic goods decreases and this of foreign goods increases.

The sign of the output differential is expected to be negative, which means that a relative higher increase in the domestic output will appreciate the domestic currency. This happens because the increase of the domestic product will increase the demand for money and given the money supply unchanged, there will be excess demand for the domestic money stock. The money market equilibrium will be restored if people reduce their expenditure on consumption. Domestic prices fall and through the PPP, the exchange rate decreases.

Also, the sign of the inflation rate differential is expected to be positive. Starting from equation (6) and following the steps to derive equation (9) we observe that the effect of the inflation rate differential on the exchange rate is correlated with the effect of the interest rate differential. The response of the exchange rate to an increase in the domestic interest rate has exactly the opposite effect with an increase in the domestic output. A higher interest rate will decrease the demand for money and given the money supply unchanged, the domestic price level increases. As a consequence, foreign goods are preferable to domestic goods since they are cheaper. The trade balance deteriorates and the domestic currency depreciates. Besides this effect, an increase in the domestic interest rate implies expectations of higher future domestic inflation rate. This will create expectations of depreciation of the domestic currency and agents with perfect foresight will sell domestic currency for foreign currency. It is obvious that, through this mechanism, a relatively higher expected inflation in the future is going to depreciate the domestic currency at the present. Thus, given the assumption of rational expectations, the future inflation rate differential is expected to enter the exchange rate equation with a positive sign.

2.2 Equilibrium Exchange Rate and Total Misalignment

Following Clark and MacDonald (1998) we set as Z_1 a vector of macroeconomic fundamentals that affect the exchange rate in the long run, as Z_2 a vector of macroeconomic fundamentals that affect the exchange rate in the medium run and as T a vector of variables that affect the exchange rate in the short run. Then, the nominal exchange rate is defined as follows:

$$s_t = \beta_1 Z_{1t} + \beta_2 Z_{2t} + \tau T_t + u_t \tag{10}$$

where, β_1, β_2 and τ are reduced form coefficients and u_t is the error term.

The current values of the medium-run and long-run fundamentals give the current equilibrium exchange rate, which is expressed by equation (11) below. By subtracting (11) from (10), we get the current misalignment, which is expressed by equation (12).

$$\overline{s}_t = \beta_1 Z_{1t} + \beta_2 Z_{2t} \tag{11}$$

$$s_t - \overline{s}_t = \tau T_t + u_t \tag{12}$$

Equation (11) is equivalent to equation (9) if Z_1 and Z_2 are filled with the variables of the monetary model. Equation 12 corresponds to the series that results by subtracting equation (9) from the actual exchange rate.

What actually matters in our analysis, is the total misalignment that is the deviation of the actual exchange rate from the total equilibrium exchange rate. To estimate the total misalignment, we replace Z_1 and Z_2 in equation (10) with the long run (or equilibrium) values of the fundamentals, $\tilde{Z}_1$ and $\tilde{Z}_2$, respectively. In other words, the total equilibrium exchange rate (BEER) is estimated by filtering the fundamentals from speculative and cyclical factors. Maintaining the theoretical affairs of the monetary model, the BEER is given by:

$$BEER = (\tilde{m}_t - \tilde{m}_t^*) - \varphi(\tilde{y}_t - \tilde{y}_t^*) + \mu(\tilde{\pi}_{t+1} - \tilde{\pi}_{t+1}^*) \tag{13}$$

Comparing the BEER with the actual exchange rate we find how the latter deviates from the former. If the actual exchange rate, s_t, exceeds the BEER, the exchange rate is said to be overvalued, while if the actual exchange rate is less than the BEER, the exchange rate is undervalued. Thus, the total misalignment rate is given by

$$\xi_t = s_t - \beta_1 \tilde{Z}_{1t} - \beta_2 \tilde{Z}_{2t} \tag{14}$$

Finally, by adding and subtracting the current equilibrium exchange rate, $\bar{s}$, from the right-hand side of equation (14) and using equation (12), we can decompose the source of exchange rate misalignment, ξ:

$$\xi_t = (\tau T_t + u_t) + \beta_1 (Z_{1t} - \tilde{Z}_{1t}) + \beta_2 (Z_{2t} - \tilde{Z}_{2t}) \tag{15}$$

Equation (15) illustrates the sources of exchange rate deviation from its equilibrium value. These are: (i) the transitory factors that have a short-run effect on the exchange rate, (ii) the disturbance term and, finally and more importantly, (iii) the deviations of the macroeconomic fundamentals from their long-run (or equilibrium) values.

Since one of the novelties of the present paper is that we take into account the presence of structural breaks in the data, we describe in section 3 below the two- and one-break LM unit root tests and system cointegration tests in the presence of structural breaks. These tests will be used in the subsequent analysis in order to estimate the BEER for the euro/Chinese yuan, euro/Japanese yen, euro/UK pound and euro/US dollar exchange rates.

3. Unit Roots and Cointegration with Structural Breaks

Table 1 presents the data that we used in the present paper along with their sources. Our sample is consisted of monthly observations from 1999:01 to 2008:08. During this period several events have taken place in the economies of China, the EMU, Japan, the UK and the USA, which are likely to have caused structural breaks in their time series. Since the presence of structural breaks is known to have significant effects on the properties and interpretation of standard ADF-type unit root tests and Johansen-type cointegration tests, we employ, as noted above, recently developed tests that are valid in the presence for structural shifts.

3.1 Unit Root Tests with Structural Breaks

We test for unit roots in the data using the two-break and one-break LM (Lagrange Multiplier) tests that developed by Lee and Strazicich (2003, 2004). These tests have several desirable properties: (a) they determine the structural breaks "endogenously" from the data, (b) their null distributions are invariant to level shifts in a variable, and (c) they are easy to interpret; by including breaks under both the null and alternative hypotheses, a rejection of the null hypothesis of a unit root implies unambiguously trend stationarity.

Consider the two-break LM unit root test for the process y_t generated by

$$y_t = \delta' Z_t + e_{t,} \qquad e_t = \beta e_{t-1} + A(L)\varepsilon_t, \qquad \varepsilon_t \sim iid\ N\left(0, \sigma^2\right) \tag{16}$$

where *A(L)* is a *k*-order polynomial in the lag operator *L* and Z_t is a vector of exogenous variables whose components are determined by the type of breaks in the process y_t. Lee and Strazicich (2003) extend Perron's (1989, 1993) single-break models to include two breaks in the level (Model A) and two breaks in both the level and trend (Model C) of y_t. For Model A, $Z_t = [1, t, D_{1t}, D_{2t}]'$ where $D_{jt} = 1$ for $t \geq T_{Bj} + 1,\ j = 1, 2$, and zero otherwise. For Model C, $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$, where $DT_{jt} = t - T_{Bj}$ for $t \geq T_{Bj} + 1,\ j = 1, 2$, and zero otherwise. T_{Bj} denotes the point in time the break occurs.

It is clear from equation (16) that y_t has a unit root if $\beta = 1$. Alternatively it is trend stationary if $\beta < 1$. According to the LM principle, a unit root test statistic can be obtained from the test regression

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{i=1}^{k} \theta_i \Delta \tilde{S}_{t-i} + u_t , \tag{17}$$

where $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}$, $t = 2,...,T$, in which $\tilde{\delta}$ is a vector of coefficients in the regression of Δy_t on ΔZ_t and $\tilde{\psi}_x = y_1 - Z_1 \tilde{\delta}$, where y_1 and Z_1 are the first observations of y_t and Z_t, respectively, and u_t is an error term that is assumed to be independent and identically distributed with zero mean and finite variance. The lagged differences of $\tilde{S}_{t-i}$ are included as necessary to correct for serial correlation in u_t. The unit root null hypothesis is described by $\phi = 0$ in equation (17) and can be tested by the LM test statistic:

$$\tilde{\tau} = t\text{-statistic for the hypothesis } \phi = 0 . \tag{18}$$

In order to endogenously determine the location of the two breaks ($\lambda_j = T_{Bj}/T$, $j = 1,2$, where T is the sample size) the two-break minimum LM test statistic is determined by a grid search over λ:

$$LM_{\tau} = \inf_{\lambda} \left\{ \tilde{\tau}(\lambda) \right\} \tag{19}$$

The critical values for this test are invariant to the break locations (λ_j) for Model A but depend on the break locations for Model C. They are also available in Lee and Strazicich (2003).

In this study, when the two-break LM test results showed that only one structural break is significant for some variables, we computed the one-break LM test of Lee and Strazicich (2004). We did this not only because the one-break LM test appears more appropriate, but also because we wanted to determine if including two breaks instead of one can adversely affect the power to reject the unit root hypothesis for these variables.

3.2 Cointegration Tests with Structural Breaks

As in the case with unit root testing, structural breaks in the data can distort substantially standard inference procedures for cointegration. Thus, it is necessary to account for possible breaks in the data before inference on cointegration can be made. In the recent cointegration literature in a VAR framework, there are two main approaches. One developed by Johansen, Mosconi and Nielsen (2000) (JMN) extends the standard VECM with a number of additional dummy variables in order to account for q possible exogenous breaks in the levels and trends of the deterministic components of a vector-valued stochastic process. JMN derive the asymptotic distribution of the likelihood ratio (LR) or trace statistic for cointegration and obtain critical or p-values, for the multivariate counterparts of models A and C with q possible breaks, using the response surface method.

Consider the simple case with only level shifts in the constant term μ of an observed $p-$dimensional time series Y_t, $t = 1,...,T$, of possibly $I(1)$ variables. JMN divide the sample observations into q sub-samples, according to the location of the break points, each of length $T_j - T_{j-1}$ for $j = 1,...,q$ and $0 = T_0 < T_1 < ... < T_q = T$, such that the last observation in the j^{th} sub-sample is T_j, while the first observation in the $(j+1)^{\text{th}}$ sub-sample is $T_j + 1$. They assume the following VECM(k) for Y_t , conditional on the first k observations of each sub-sample $Y_{T_{j-1}+1},...,Y_{T_{j-1}+k}$:

$$\Delta Y_t = \Pi Y_{t-1} + \mu D_t + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \sum_{i=1}^{k} \sum_{j=2}^{q} g_{ji} D_{j,t-i} + \varepsilon_t, \quad \varepsilon_t \sim iidN(0,\Omega), \quad (20)$$

where $\mu = (\mu_{1,........,}\mu_q)$ and $D_t = (D_{1,t,........,}D_{q,t})'$ are of dimension $(p \times q)$ and $(q \times 1)$, respectively, and the $D_{j,t}$'s are dummy variables, such that $D_{j,t} = 1$ for $T_{j-1} + k + 1 \le t \le T_j$ and $D_{j,t} = 0$ otherwise, for $j = 1,....,q$.

As is well known, the hypothesis of at most r_0 cointegrating relations $(0 \le r_0 < p)$ among the components of Y_t can be stated in terms of the reduced rank of the $(p \times p)$ matrix Π, in which case it can be written as $\Pi = \alpha\beta'$, where α and β are matrices of dimension $(p \times r)$. The cointegration hypothesis can then be tested by the likelihood ratio statistic

$$LR_{JMN} = -T \sum_{i=r_0+1}^{p} \ln\left(1 - \hat{\lambda}_i\right) \quad (21)$$

where the eigenvalues $\hat{\lambda}_j$'s can be obtained by solving the related generalized eigenvalue problem, based on estimation of the VECM(k) in equation (20), under the additional restrictions that $\mu_j = \alpha\rho_j'$, $j = 1,.....,q$, where ρ_j is of dimension

$1 \times r$. These restrictions are required in order to eliminate a linear trend in the level of the process Y_t (Johansen et al. 2000).

The second approach developed by Lütkepohl and his associates (see among others, Lütkepohl and Saikkonen 2000; Saikkonen and Lütkepohl 2000; Trenkler, Saikkonen and Lütkepohl 2008) (LST). LST assume that the structural breaks have occurred only in the deterministic part and do not affect the stochastic part of the process Y_t. Thus, LST set up the data generation process (DGP) for Y_t by adding its deterministic part μ_t to its stochastic part X_t, where the latter is an unobservable zero-mean purely stochastic VAR process, and use appropriate dummy variables to account for exogenous shifts in μ_t. Given this setup, LST propose a two-step procedure to test for cointegration. Firstly, they remove the deterministic part using a generalized least squares procedure under the hypothesis of r_0 cointegrating relations (GLS de-trending). Secondly, they test for cointegration in the de-trended series using their proposed LM-type and LR-type test statistics. Several tests statistics can be derived depending on whether there are level shifts only or shifts in both the level and the trend. Lütkepohl, Saikkonen and Trenkler (2003) study the statistical properties of their tests in the case of level shifts, and compare them to the JMN test. They find that the LR-type tests perform better than the LM-type tests in finite samples. Further, their tests have better size and power properties than the JMN test in finite samples.

For LR-type tests, consider the case of a single shift in the level of Y_t. Assuming an exogenous break at time T_B in the level of μ_t, LST specify the following DGP for Y_t

$$Y_t = \mu_t + X_t = \mu_0 + \mu_1 t + \delta d_t + X_t, \quad t = 1,....,T, \tag{22a}$$

where t is a linear time trend, $\mu_i \left(i = 0,1\right)$ and δ are unknown $\left(p \times 1\right)$ parameter vectors, d_t is a dummy variable defined as $d_t = 0$ for $t < T_B$ and $d_t = 1$ for $t \geq T_B$, and where the unobserved stochastic error X_t is assumed to follow a VAR*(k)* process with VECM representation

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t \quad , \quad \varepsilon_t \sim iidN(0,\Omega), \quad t = 1,...,T \quad . \tag{22b}$$

It is also assumed that the components of X_t are at most $I\left(1\right)$ variables and cointegrated $\left(i.e.\ \Pi = a\beta'\right)$ with cointegrating rank r_0, where $0 < r_0 \leq p$.

Given the DGP in equations (22a) and (22b), the first step of the LST approach involves obtaining estimates of the parameter vectors μ_0, μ_1 and δ using a feasible GLS procedure under the null hypothesis $H_0(r_0): rank(\Pi) = r_0$ vs. $H_1(r_0): rank(\Pi) > r_0$ (see Saikkonen and Lütkepohl 2000 for details). Having the estimated parameters $\hat{\mu}_0$, $\hat{\mu}_1$ and $\hat{\delta}$, one can then compute the de-trended series $\hat{X}_t = Y_t - \hat{\mu}_0 - \hat{\mu}_1 t - \hat{\delta} d_t$. In the second step an LR-type test for the null hypothesis of cointegration is applied to the de-trended series. This involves replacing X_t by $\hat{X}_t$ in the VECM (22b) and computing the LR or trace statistic:

$$LR_{LST} = -T\sum_{i=r_0+1}^{p} \ln\left(1-\tilde{\lambda}_i\right) \quad , \tag{23}$$

where the eigenvalues $\tilde{\lambda}_i$'s can be obtained by solving a generalized eigenvalue problem, along the lines of Johansen (1988).

Under the null hypothesis of cointegration, critical or p-values for a single level shift can be computed by the response surface techniques (Trenkler 2008). Trenkler et al. (2008) derive asymptotic results and p-values for the case of one level shift and one trend break in the Y_t process, and show that, in this case, the asymptotic distribution of the LR statistic in equation (23) depends on the location of the break point. They also discuss how the results can be extended to the general case of $q > 1$ break points.

Since the JMN and LST approaches have different finite sample properties, we employ both the LR_{JMN} and LR_{LST} test statistics in our empirical analysis. The break points are determined from the data on the basis of the results of the LM unit root tests discussed above.

4. Empirical Results

4.1 Unit Root Results with Structural Breaks

Tables 2 and 3 report the unit root results from the two- and one-break LM tests, respectively. We tested each time series for a unit root using the two-break LM test at the 1-, 5- and 10 percent levels of significance. As noted above, when this test showed that only one structural break is significant we employed the one-break LM test at the same levels of significance. In order to determine the number of lags, k, in equation (17), we used a "general to specific" procedure at each combination of break points (λ_1, λ_2) for the two-break test, and at each single break point λ for the one-break test. Initially, we set the lag-length at $k = 12$, and examined the significance of the last lagged term, at the 10 percent level. The procedure was repeated until the last lagged term was found to be significantly different than zero, at which point the procedure stops.[1]

As shown in the last column of table 2, the unit root hypothesis with two structural breaks cannot be rejected at any of the three levels of significance for all nominal exchange rates, for the Euro area/USA output differential and for the Euro area/China and Euro area/UK money supply differentials. It is also shown in this column that the unit root hypothesis with two breaks is strongly rejected for the Euro area/UK output differential and for the inflation rate differential in the cases of Euro area/China, Euro area/UK and Euro area/USA. Table 3 reports the results for the cases that one break is significant. As shown in the last column of this table, the unit root hypothesis with one break cannot be rejected for the Euro area/China and Euro area/Japan output differentials, for the Euro area/Japan and Euro area/USA money supply differentials and for the Euro area/Japan inflation rate differential.[2] Since the results in table 3 are consistent with the results of table 2 regarding the null hypothesis, there does not seem to be any detectable loss of power in using the two-break LM test to test the unit root hypothesis for the cases of table 3. Finally, as shown in column 3 of tables 2 and 3, Model A with only shifts in the deterministic levels fits the data best for Euro area/China and Euro area/Japan cases, while Model C with shifts both in the levels and trends fits the data best for the Euro area/UK and Euro area/USA cases, over the sample period.[3]

Column 5 of tables 2 and 3 reports the structural breaks in each series, estimated from the data using the two-break and one-break LM tests, respectively. Not surprisingly, the estimated breaks correspond closely to specific events that have taken place, during the sample period, in the countries that we examine.

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[1] We computed the two-break and one-break LM tests using the Gauss codes of J. Lee available at the website http://www.cba.ua.edu/~jlee/gauss .
[2] We also tested the interest rates of all countries for a second unit root. The null hypothesis was rejected in all cases. These results are available from the authors upon request.
[3] Model A was chosen in the cases where the trend shift parameters in Model C were statistical insignificant at the 0.10 level.

Firstly, we examine the Euro area/China case. Our results indicate that the money supply and inflation differentials appear a break in level in 2001. This break coincides with a period where the European Central Bank (ECB) proceeded to several reductions of its marginal lending facility rate (MLFR). At the same time, China boosted bank lending and loosened its fiscal policy. These two actions lead to an increase of the credit and money supply growth. In the end of 2002 and in order to avoid "overheat" of the economy, the central bank of China tightened its monetary policy in order to reduce aggregate demand. This action is may reflected in the break in level of the output differential, in the beginning of 2003. In 2004 and with the ECB's MLFR unchanged at 3%, China tightened again its monetary policy in order to fight inflation. This policy action coincides with the structural break in the nominal exchange rate and inflation rate differential in that year. The nominal exchange rate appears a second break in level in 2006, while the money supply differential has a second break in early 2007. These breaks coincide with a period of several increases of the ECB's MLFR. Between March 2006 and March 2007, this rate increased from 3.5% to 4.75%.

Secondly, we examine the Euro area/Japan case. Our results indicate that the nominal exchange rate appears to have two structural breaks in level, while each of the output, money supply and inflation differentials has a single level shift. All breaks have occurred between late 2000 and early 2001 and coincide with the decisions of the Bank of Japan to (a) terminate the zero interest rate policy in August 2000, which was implemented in February 1999, and (b) introduce "quantitative easing" in March 2001, along with a zero interest rate again and with a large expansion of monetary base. Unfortunately, these policy actions did not help Japan to fight deflation successfully and to escape the "liquidity trap".

Then, we examine the Euro area/UK case. As shown in tables 2 and 3, all variables have two significant breaks in both the level and the trend. Our results indicate that the output and inflation differentials appear to have a structural break in mid-2000. The break in output differential coincides with the beginning of a period that the UK economy started gradually to slow, while the break in the inflation differential is probably related with the significant fall of the UK inflation in that period. The inflation differential has a second break in mid-2001 which is probably related with an increase in the UK inflation. During the 2000-2001 period, no remarkable changes were observed in the output growth and the inflation rate of the Euro area. The nominal exchange rate and the money supply differential appear to have a structural break at the end of 2002, which coincide with the beginning of a period of several decreases of the ECB's MLFR. Between November 2002 and June 2003, this rate fell from 4.25% to 3%. During that period, the UK rates remained unchanged. The output differential has a second break at the end of 2003, which coincides with the beginning of a period of increasing growth of the Euro area's industrial production. Also, the nominal exchange rate and the money supply differential have a second structural break in 2006. In that year, the ECB gradually raised its MLFR from 3.25% in January to 4.5% in December. In the same year, the Bank of England slightly increased its base rate from 4.5% to 4.75%.

Finally, we examine the Euro area/USA case. The output and inflation differentials appear to have a structural break at the end of 2000. This break coincides with a period where US output growth started gradually to slow. As a consequence, the unemployment rate increased and the inflation rate was edging lower. In order to fight the slowdown of the economy, the Federal Reserve (FED) cut the federal funds rate, bringing the cumulative reduction in that rate to 3% by August 2001. The nominal exchange rate has a structural break in early 2002. This break reflects the beginning of a period that followed the terrorist attacks in September 11, 2001. This period was characterized by a significant cut of the FED's federal fund rate, together with a remarkable increase of government spending by the Bush administration in order to finance the war against Afghanistan and Iraq. The single structural break in money supply differential in mid-2003 coincides (a) with a significant increase in the US money supply during this year and (b) with a reduction of the ECB's MLFR from 3.75% in January 2003 to 3% in June 2003. The second structural break in the nominal exchange rate and the output differential is estimated in early 2005, while the second break in the inflation differential is estimated in late 2005. This break initiates a period where (a) there is a continuous depreciation of the US dollar against the euro that is connected with the increasing deficit in the US balance of payments, (b) the growth rate of US industrial production is increasing and (c) there is an increase in the US inflation rate that is mainly caused by the increase of the oil price. Also, since 2005, both the ECB and the FED were gradually raising the MLFR and the federal funds rate, respectively.

4.2 Cointegration Results with Structural Breaks

In this section we examine the cointegration results with structural breaks based on the JMN and LST procedures described in Section 3.2. In each case, the vector Y_t contains the nominal exchange rate and the output, money supply and inflation differentials. Since we are interested in determining the exchange rate of the euro/Chinese yuan, euro/Japanese yen, euro/UK pound and euro/US dollar cases, we used the estimated structural breaks of the nominal exchange rate reported in table 2. In the case of the JMN procedure we estimated the VECM in equation (20) for each case and computed the LR_{JMN} test statistics and the corresponding response surface p-values using the JMulti software, available at the website http://www.jmulti.de .

In the case of the LST procedure, we estimated the model in equations (22a) and (22b) by adjusting (22a) to account for the structural breaks specific to each case. Thus, for each of the Euro area/China and Euro area/Japan cases, which have two significant breaks in the level, we added a second step dummy to equation (22a). For each of the Euro area/UK and Euro area/USA cases, which were found to have two significant breaks in both level and trend, we extended equation (22a) by adding a second step dummy and two linear trend dummies. Then, for each country we computed the LR_{LST} test statistic and the corresponding response surface p-value using GAUSS routines.[4]

Table 4 reports the LR_{JMN} and LR_{LST} test statistics and p-values, for each case. The lag length, k , for each VECM, was selected using the Akaike information criterion (AIC). As shown in the table, the JMN test results indicate two cointegrating vectors for the Euro area/China case, three cointegrating vectors for the Euro area/Japan and Euro area/UK cases and a single cointegrating vector for the Euro area/USA case at the 5 or 10 percent level of significance. The LST test results indicate a single cointegrating vector in each case. As noted in section 3.2, the LST test has better size and power properties than the JMN test in finite samples. Thus, we can conclude that there is a single cointegrating vector in each case.

[4] We are grateful to Carsten Trenkler for kindly providing us with the Gauss codes for these estimations.

Having established a valid long-run relationship between the nominal exchange rate and the fundamentals, we estimate the corresponding VECMs, based on equations (22a) and (22b). Table 5 presents the estimated coefficients of the reduced form equations along with the results from the long-run exclusion test. The latter investigates whether any of the macroeconomic fundamentals can be excluded from the cointegrating space. To perform this test, we first normalize the cointegrating vector on the nominal exchange rate and then, we test if any of the above variables do not determine the value of the exchange rate in the long run. Using the likelihood ratio test statistic, our results imply that the real income differential can be excluded from the cointegrating equation for the Euro area /China and Euro area /USA cases. Similarly, money supply and inflation rate differentials should be excluded from the Euro area /Japan and Euro area/UK cointegrating equations, respectively. This means that these variables cannot explain the long-run behaviour of the corresponding exchange rates. When it comes to the implied structural breaks, the long-run exclusion test shows that none of the breaks can be excluded from the cointegrating space for the Euro area /China case. On the contrary, both structural changes are found statistically insignificant for the euro/US dollar exchange rate in the long run. For the Euro area/Japan case the first break is statistically insignificant, while for the Euro area/UK case, the second break seems to not affect the nominal exchange rate in the long run.

Finally, we performed weak exogeneity tests, in order to investigate whether a variable can be considered as weakly exogenous to the long-run parameters. A variable is said to be weakly exogenous if the corresponding adjustment coefficient cannot be statistically different from zero. This test provides us information about the fundamentals that drive the system to equilibrium. Starting from the Euro area/China case, table 6 shows that the nominal exchange rate and the real income differential are found to be weakly exogenous to the exchange rate. This implies that the exchange rate itself and the real economic activity drive the exchange rate to the long-run equilibrium. The driving force for the euro/Japanese yen rate is the exchange rate itself, while for the euro/UK pound exchange rate weak exogeneity has been established for the exchange rate, the money supply and the inflation rate differentials. This implies that for the latter case, the exchange rate is driven to equilibrium by its own and monetary policy developments. Finally, the euro/US dollar rate is driven to the long-run equilibrium by developments in the real economic activity.

4.3 Estimated Current and Total Equilibrium Exchange Rates

Since we found evidence of cointegration between the exchange rate and the macroeconomic fundamentals, we can claim that the monetary model can be considered as a long-run equilibrium condition. However, the estimated coefficients of the variables are not always signed as the monetary model predicts. Removing any statistically insignificant coefficient, table 5 shows that the sign of the money supply differential is as expected only in the Euro area/China case. In contrast, the results show that the long-run exchange rate of the euro against the UK pound and the US dollar is expected to appreciate when the eurozone's monetary expansion is relatively higher. This positive sign can be possibly explained if we assume that the money demand remains unchanged. Then, a higher level of domestic money supply will reduce interest rate and thus, will lead to lower expected inflation. Given that eurozone's money supply grows more than the foreign one and assuming rational expectations, the relatively lower eurozone's inflation makes domestic goods preferable than the foreign ones. Thus, the trade balance improves and the domestic currency appreciates.

Similarly, output differential has the expected negative sign in the euro/Japanese yen exchange rate equation. But, the long-run euro/UK pound exchange rate is positively related to output differential. This means that a relatively higher output growth in the eurozone is expected to depreciate the single European currency. Although this finding seems to be strange, a possible explanation is given if we consider the effect of productivity shocks on the real exchange rate. Benigno & Thoenissen (2003) show that improvements on the supply-side of the UK economy (i.e. increase in total factor productivity or increase in the degree of market competition) are expected to depreciate the real exchange rate of the pound against the euro. This finding is consistent with the Lukas (1982) and Stockman (1980) view of real exchange rate determination. Namely, a positive shock on the supply-side of the domestic economy increases the supply of home goods relative to foreign ones, which in turn leads to a decrease in the relative price of home goods and to a depreciation of the real exchange rate. Engels et al. (2007) find that a 1% increase in UK productivity is expected to depreciate the pound's real exchange rate against the euro by 3.5%.[5] In general, higher productivity at home country lowers marginal cost of the domestic producers and thus, reduces their prices. Assuming that foreign goods' prices are stable, a positive productivity shock at home country deteriorates its terms of trade.

Finally, inflation rate differential enters all the exchange rate equations with the expected sign. In other words, if the eurozone's inflation grows more than the foreign one, euro is expected to depreciate in the long-run. Now, we move on to the estimation and discussion of the long-run (behavioural) equilibrium exchange rate.

4.3.1. Euro/Chinese yuan equilibrium exchange rate

Based on the information of table 5, the long-run exchange rate of the euro vis-à-vis the Chinese yuan is given by the following expression:

$$s_t = 2.032(m_t - m_t^*) + 0.066(\pi_{t+1} - \pi_{t+1}^*) + 0.018trend - 0.313SB_1 - 0.327SB_2 \quad (24)$$

The above corresponds to the current equilibrium exchange rate and by subtracting this rate from the actual exchange rate we get the current misalignment rate. As explained in the theoretical section of the paper, our aim is to estimate the total equilibrium exchange rate, which is the BEER. To do so, we get the equilibrium values of the macroeconomic fundamentals via the Hodrick and Prescott (1997) filter. This is a smoothing approach, which estimates the long-run components of any given variable. However, the statistical properties of the Hodrick-Prescott (H-P) filter have been criticised a lot. One issue is its poor performance near the end of the sample. Mise et al. (2005), Kaiser and Maravall (1999) and Baxter and King (1999) provide evidence of suboptimal H-P filtering at the endpoints. To avoid this inconsistency, we followed Kaiser and Maravall (1999) and estimated optimal ARIMA forecasts. Then, we applied the H-P filter to the extended series. As noted by Mise et al (2005), this approach minimizes revision standard deviation.

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[5] On the other hand, a 1% increase in euro area's productivity is expected to appreciate the UK pound's real exchange rate vis-à-vis the euro by 5.16%. This means that productivity shocks have an asymmetric effect on domestic and foreign output growth. The authors show that this asymmetry can be attributed to the difference between labor supply elasticities across countries. Specifically, their results coincide with the assumption that UK labour supply is more elastic than the euro area's labour supply.

Getting the smoothed values of the fundamentals and introducing them into equation (24), we estimate the total equilibrium exchange rate (BEER). Both rates along with the actual series are presented in figure 1. The left-hand side of the figure illustrates the relationship between the actual exchange rate and the long-run exchange rate. In addition, the right-hand side of the graph plots the actual exchange rate with the BEER. If the actual exchange rate is higher than any of the long-run exchange rate (LRER) and the behavioural equilibrium exchange rate (BEER), euro is said to be undervalued. If the actual exchange rate is below the computed series, euro is considered as overvalued. Both parts of figure 1 show that the actual exchange rate is continually below the long-run (current equilibrium) and behavioural (total equilibrium) exchange rates. This means that the euro has been monotonically overvalued for the whole period. Equivalently, at the same time, the Chinese yuan has been constantly below its equilibrium value. It is hardly surprising that this finding does not contradict with the common view that the Chinese currency is in general undervalued. Funke and Ruan (2005) and MacDonald & Dias (2007) find that the real effective exchange rate of the Chinese currency is significantly undervalued. Similarly, Coudert and Couharde (2005) and Cline (2007) show that the real exchange rate of the Chinese yuan against US dollar is undervalued as well.[6]

The undervaluation status of the Chinese yuan does pretty well explain the huge increase in Chinese foreign exchange reserves and the expansion of the China's global current account surplus.[7] These facts reflect the Chinese applied exchange rate policy during the period from October 1997 to July 2005, in which the nominal exchange rate was pegged to US dollar. Figure 1 shows that, despite the permanent undervaluation of the yuan, the general trend of the actual exchange rate is consistent with the movements implied by the current and total equilibrium exchange rates. Apart from the period 1999-2002, in which the actual exchange rate moves upward but the BEER is relatively stable, the subsequent appreciation (depreciation) trend of euro (yuan) is in line with the trend of the BEER. This implies that Chinese authorities have retained technically, by

[6] For a comprehensive survey of recent estimates of the equilibrium effective and bilateral exchange rate of the Chinese currency vis-à-vis US dollar, see Cline and Williamson (2007).

[7] China runs a growing trade surplus with the European countries and the US, but it runs increasing deficits with developing and emerging Asian economies.

intervening in the foreign exchange (Forex) market, the exchange rate below its equilibrium value.

However, this external imbalance has raised a current academic debate on the effectiveness of the above exchange rate policy and the necessity of exchange rate policy reform.[8] The exchange rate revaluation, as a result of the abandonment of the fixed regime, has changed the nature of exchange rate misalignment. Since July 2005, the actual exchange rate has begun to move towards BEER implying that the euro/yuan exchange rate follows an equilibrium process. Although the BEER implies that euro (yuan) should continue to appreciate (depreciate), the actual exchange rate is moving upward reflecting the need for appreciation of the Chinese currency (due to the exchange rate policy reform). Of course, this difference in the trend does not necessarily imply further exchange rate misalignment. In contrast, this can be seen as a disequilibrium correction movement. At the end of the estimated period, the euro overvaluation rate (yuan undervaluation rate) is very small (about 1%), indicating that the exchange rate almost meets its equilibrium value.

4.3.2. Euro/Japanese yen equilibrium exchange rate

The long-run value of the euro per Japanese yen exchange rate is estimated by equation (25):

$$s_t = -4.163(y_t - y_t^*) + 2.015(\pi_{t+1} - \pi_{t+1}^*) - 0.019trend + 0.443SB_2 \qquad (25)$$

The above expression corresponds to the long-run exchange rate (LRER) presented in the left-hand side of figure 2. As before, the estimation of the total equilibrium exchange rate (BEER) requires the derivation of the smooth values of the fundamentals. Applying again the modified H-P filter, the actual series in equation (25) are substituted by their filtered series. Then, the BEER is illustrated in the right-hand side of figure 2. The plot of the actual exchange rate shows that, apart from the period 1999-2001, euro follows a stable appreciating trend for the remaining period of examination. Besides, both the long-run exchange rate

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[8] From one point of view a more flexible exchange rate regime, accompanied with an appreciation trend, is needed for a higher level of monetary policy autonomy. In addition, the policy reform is expected to reduce the excessive trade surplus, implying lower dependence on external demand. The sustainable economic growth should rely on domestic consumption demand. On the other hand, Wu (2007) believes that the exchange rate revaluation is expected not to reduce the excessive current account surplus. He argues that the sustainable economic growth requires restructuring the Chinese economy.

(LRER) and the BEER confirm the appreciation of euro but they imply that, after 2004, the appreciation rate should were higher.

As in shown in the right-hand side of figure 2, the estimated period can be decomposed into three sub-periods with different misalignment implications. The first sub-period, running from the beginning of our sample period until the first half of 2001, implies that euro was overvalued. In the subsequent period, form the 2nd half of 2001 to the 1st half of 2003, the euro per yen exchange rate seems to be very close to its equilibrium rate. On the contrary, the period from the 2nd half of 2003 until the end of the estimated period corresponds to an undervaluation period for euro. Obviously, the Japanese yen is considered as undervalued in the first sub-period and overvalued during the final sub-period. It is highly interesting that the evidence of an overvalued yen contradicts with the general view that the yen is undervalued.[9] It is generally argued that the Japanese monetary authorities technically devaluate the exchange rate to retain the yen below its equilibrium level. Given that the yen depreciates more against euro than against the US dollar, one could argue that Japanese authorities aim to manipulate the euro per yen exchange rate.

However, our findings refuse the above argument. Instead, we have reasons to believe that the depreciation of the yen (or equivalently, the appreciation of euro) is fully compatible with the macroeconomic status of the Japanese economy. Japan is facing significant internal and external imbalances: while the current account surplus (external imbalance) pushes the yen upward, the continuous economic recession (internal imbalance) eventually depreciates the yen.[10] Besides to the extended slump and deflation, Japanese economy suffers from financial sector's problems. The inefficient function of the domestic financial sector along with the global financial crisis deteriorates even more the efficiency and the performance of domestic financial intermediaries.[11] This means that Japanese

[9] The vast majority of the existing studies in the literature reveal that the yen is permanently undervalued against the US dollar.

[10] Rosenberg (2003) states that the Japanese yen is expected to depreciate because the internal imbalance will offset any positive developments on the external balance.

[11] The inefficiency of the domestic financial sector is expected to affect negatively domestic economic growth. There are a huge number of studies which examine the way financial development affect economic growth, employment and social welfare. The key issue under examination is the direct effect of stock market developments on economic growth (Arestis & Demetriades, 1997, Levine & Zervos, 1998, Van Nieuwerburgh et al, 2006.) and the impact of financial liberalization and internationalization on the whole financial sector and economic activity (Gardener et al, 2001, Goldfinger, 2002, De Avila, 2003).

authorities should continue the monetary expansion (quantitative easing), which may lead to a significant devaluation of the yen. Furthermore, the yen is pressured downward by Japan's fiscal position. The high government deficit and the persistent public debt obligate Japanese authorities to apply fiscal discipline. But, the combination of an expansionary monetary policy with a restrictive fiscal policy causes expectations of depreciation of the yen. Moving one step further, we claim that the depreciating trend of the yen is not only normal but also that the depreciation rate is smaller than it should be. This argument is in line with the implications derived from figure 2. During the final sub-period, shown in the right-hand side of figure 2, the exchange rate follows disequilibrium rather than equilibrium process. This can be explained by the pressures of the advanced Western economies for a stronger yen. As long as Japan's internal imbalances remain together with the prevailing view that the Euro area's international trade is negatively affected by a weak yen, the exchange rate is not likely to approach its equilibrium level.

4.3.3. Euro/UK pound equilibrium exchange rate

Similarly, the long-run (current equilibrium) exchange rate is given by expression (26) and the BEER comes up by filtering the macroeconomic fundamentals of equation (26).

$$s_t = -0.116(m_t - m_t^*) + 3.618(y_t - y_t^*) - 0.007trend - 0.002SB_1 \qquad (26)$$

Both rates (current and total equilibrium) are shown in figure 3. The left-hand side of figure 3 plots the current equilibrium exchange rate along with the actual exchange rate, while the right-hand side of the same figure illustrates the relationship between the total equilibrium exchange rate and the observed exchange rate. Although the long-run exchange rate is highly volatile, it is not difficult to observe that the current equilibrium exchange rate implies an appreciating trend for the euro. The appreciating trend of the euro is clearly shown by the BEER line, shown in the right hand-side of figure 3. Staying on the same part of the figure, we can decompose the whole estimated period into four sub-periods according to the sign of exchange rate misalignment. The first year after the launch of the single European currency, 1999, corresponds to an overvaluation period for the euro. Accordingly, the actual euro per UK pound exchange rate was close to its equilibrium level for the period from 2000 to mid-2001. The elimination of the euro overvaluation rate can be attributed to the upward movement (towards the BEER) of the actual exchange rate that started from 1999. Gomez et al (2007) show that the depreciation of the euro after its introduction should not be considered as a surprising fact. Based on their theoretical model, a higher transaction cost associated with the euro than the German mark may be a possible reason for the depreciation of the euro. In our analysis, we argue that the depreciation of the euro vis-à-vis the UK pound was nothing more than a disequilibrium correction movement.

In the subsequent period, from the 2nd half of 2001 to the end of 2007, the euro (pound) is in general undervalued (overvalued). The actual exchange rate has followed a decreasing trend since 2002, while the BEER has started to decline since 2001. This implies that although both the actual and the equilibrium exchange rates follow similar pathways the appreciation of the euro has been held by delay. While the increase of the UK inflation in the mid-2001 would cause the depreciation of the pound (i.e. appreciation of the euro), this happens only in the equilibrium exchange rate (i.e. the BEER). Instead, the actual exchange rate continuous to increase until the beginning of 2002. Similarly, the actual exchange rate decreased to reach the BEER around mid-2003, but the following appreciation of the pound was not consistent with the BEER which continued to decrease. All of these show that the euro exchange rate vis-à-vis the UK pound had a tendency to remain in a higher level than its equilibrium level. This finding is consistent with the study of Alberola et al. (1999), which mentions that the transformation of the UK economy from a net creditor to a net debtor should depreciate the pound. Another study which argues that the pound was overvalued against the euro is that of Wren-Lewis (2003). The author explains that the strength of the pound may be attributed to the increased capital flows into the UK.

Finally, from the 2nd half of 2007 until the end of the estimated period, the actual exchange rate seems to follow an equilibrium process. In other words, while the BEER implies a stable exchange rate, the actual exchange rate follows a decreasing pathway. This means that the euro per UK pound exchange rate moves towards its equilibrium value. The appreciation of the euro (or equivalently, the depreciation of the pound) continues until the time that the actual exchange rate meets the BEER, which happens at the beginning of 2008. Thus, at the end of the estimated period the euro exchange rate vis-à-vis the UK pound does not deviate significantly from its equilibrium rate.

4.3.4. Euro/US dollar equilibrium exchange rate

Moving on to the final exchange rate under investigation, the long-run (current equilibrium) exchange rate is represented by the following equation:

$$s_t = -1.05(m_t - m_t^*) + 0.559(\pi_{t+1} - \pi_{t+1}^*) - 0.003trend \qquad (27)$$

As shown in the left-hand side of figure 4, the actual exchange rate is mainly below the current equilibrium exchange rate apart from few and small in duration time periods. By removing the cyclical components from the long-run exchange rate, the estimated total equilibrium exchange rate (BEER) implies that the euro was persistently overvalued against US dollar. Even though the BEER is consistent with the general trend of the actual exchange rate, we provide evidence of exchange rate misalignment in the sense that the euro has appreciated more than the macroeconomic fundamentals have indicated.

In contrast to the general appreciation of the euro, the sub-period 1999-2002 corresponds to a period that euro has been gradually depreciating against US dollar. Although the BEER suggests that the euro should have been appreciating against the US dollar, this depreciating pathway can be considered as a disequilibrium correction movement. Indeed, the right-hand side of figure 4 illustrates that the actual exchange rate approached the total equilibrium exchange rate at least three times during the period 2000-2002. Rosenberg (2003) argues that the appreciation of the dollar (or equivalently, the depreciation of the euro) was a result of positive market expectations about the long-run perspectives of the US economy. On the other hand, Belloc & Federici (2008) show that the depreciation of the euro (or equivalently, the appreciation of the dollar) during this period can be explained through the portfolio balance model. Specifically, the authors state that the excess supply of euro assets combined with the increasing confidence on the US economy enforced the Euro area's residents to hold foreign (US) assets.

Given that the BEER is described by a linear curve with a negatively constant slope (figure 4), the magnitude of exchange rate misalignment fluctuates depending on the behaviour of the actual exchange rate. So, during the period from 2002 to 2004, the actual exchange rate is moving away from its equilibrium level. This is because since the 2nd half of 2002, the euro has begun a significant appreciating process against the US dollar. Belloc & Federici (2008) present evidence that the depreciation of the dollar was the outcome of the high increase of the US current account deficit. Furthermore, Rosenberg (2003) argues that the depreciation of the dollar has been dictated by (a) the excessive increase in the US investment spending that led to an unsustainable savings-investment balance, and (b) the fact that the increase in the US productivity in late 1990's was not symmetrically distributed across all sectors of the US economy. Moreover, the rapid depreciation of the dollar was not irrelevant to the aftermaths of the terrorist attacks upon the USA on September 11, 2001. The depreciating process was interrupted for the period 2004-2006, especially during 2005, in which the dollar appreciated against the euro. This movement has been motivated by the increase in the US output growth rate. However, neither the terrorist attack nor the higher output growth has been reflected to the behaviour of the BEER. This is because the former as an unanticipated shock and the latter as a temporary effect cannot determine the total equilibrium exchange rate.[12] From 2006 onwards, the dollar continues to depreciate against the euro as a result of the low level of the US output growth.

Overall, our evidence implies that the euro is persistently overvalued against the US dollar. Belloc & Federici (2008) estimated the NATREX for the real exchange rate and show that the euro was undervalued during the period 1999-2003. But, their out-of-sample NATREX estimation implies overvaluation of the euro at the end of 2007. Similarly, Benassy-Quere et al (2008) illustrate the BEER and FEER estimates for the euro per dollar exchange rate. The BEER implies that the euro was overvalued at 2005, while the FEER shows that euro was undervalued at the same time. The authors state that when the effect of asset price crash on US assets has been considered, the FEER estimate was very close to the actual exchange rate. Comparing our BEER estimate with the FEER and NATREX estimates, which are presented in the recent literature, one can easily observe the difference in the misalignment implications. While our BEER model is based on the fundamentals of the monetary model, the FEER and NATREX

[12] As it has been explained in the theoretical section, the total equilibrium exchange rate (BEER) is a function of the equilibrium values of the fundamentals. Namely, temporary shocks as well as the macroeconomic policy with only temporary effects on the economy can explain why exchange rates deviate from their equilibrium values in the long-run.

methodologies use as a building variable the current account deficit. Thus, the continuously increasing US current account deficit explains why the FEER and NATREX models imply that dollar was overvalued.

5. Concluding Remarks

The aim of this paper was to investigate if the nominal euro exchange rate against the currencies of China, Japan, the UK and the USA converges or not to its equilibrium level. We used the BEER model, having strengthened its theoretical background by using the theoretical assumptions of the monetary model of exchange rate determination. We evaluated these issues using cointegration and common trend techniques, in the presence of structural breaks in the data.

The empirical findings establish a valid long-run relationship between the euro/yuan, euro/yen, euro/UK pound and euro/US dollar nominal exchange rates and the fundamentals defined by the monetary model. The BEER analysis indicates that the euro is overvalued in relation to the Chinese currency for the whole sample period apart from the end of the estimated period, in which the exchange rate move towards its equilibrium value. This finding is along with the view that the Chinese currency is in general undervalued and well explains the huge increase of the country's foreign exchange reserves and the expansion of its global current account surplus. Our BEER results about the euro/yen nominal exchange rate indicate that even though the euro was overvalued until mid-2001, is considered us undervalued after mid-2003. The latter result contradicts the general view of an undervalued yen and can be explained by the depreciation expectations that were created from the combination of expansionary monetary and restrictive fiscal policies followed by the Japanese government, together with the pressures of the advanced Western economies for a stronger yen.

The BEER results for the euro/UK pound nominal exchange rate show that even though the euro was undervalued during the 2001-2007 period, the euro/ UK pound exchange rate moves towards its equilibrium value from early 2008. Finally, our evidence implies that the euro is persistently overvalued against the US dollar, which means that the single European currency has appreciated more than the macroeconomic fundamentals have indicated.

Concerning the main motivation of the paper, which is the examination of the possibility of internal and external imbalance in the euro zone, we found evidence that would threaten stability for the euro/Japanese yen and the euro/US dollar exchange rates. This is because the observed misalignment may lead to future exchange rate fluctuation even though the exchange rate is currently stable. On the other hand, the euro exchange rates vis-à-vis the Chinese yuan and the UK pound are found to be very close to the equilibrium rate at the end of the estimated period. This fact indicates that the above exchange rates follow an equilibrium process implying that we do not expect significant future exchange rate fluctuation.

In addition, we do not expect that the dynamic behaviour of the euro can weaken internal balance in the euro zone. This conclusion is based on the fact that the euro/Chinese yuan and the euro/UK pound exchange rates follow an equilibrium process and that the euro is both overvalued and undervalued in the two remaining exchange rates. We would expect significant internal imbalances if the euro were monotonically overvalued or undervalued in all the examined exchange rates. Hence, any loss of competitiveness caused by the overvalued euro vis-à-vis the US dollar can be offset by the undervalued euro against the Japanese yen. Actually, the final outcome depends on the relevant size of the misalignment rate (i.e. overvaluation rate vs. undervaluation rate) and the relevant importance of euro zone's trade with Japan and the USA.

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Figure 1: Current and total equilibrium euro per yuan exchange

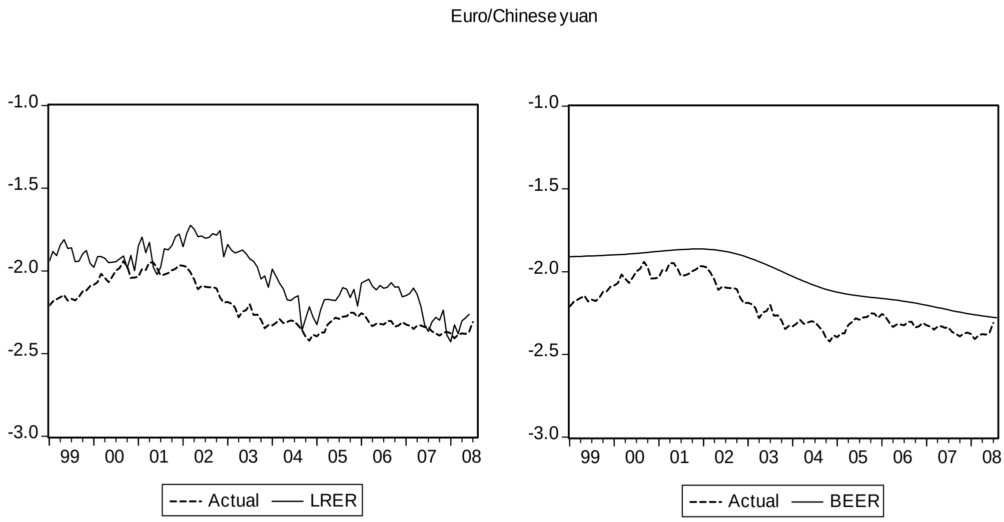

Figure 2: Current and total equilibrium euro per yen exchange rate

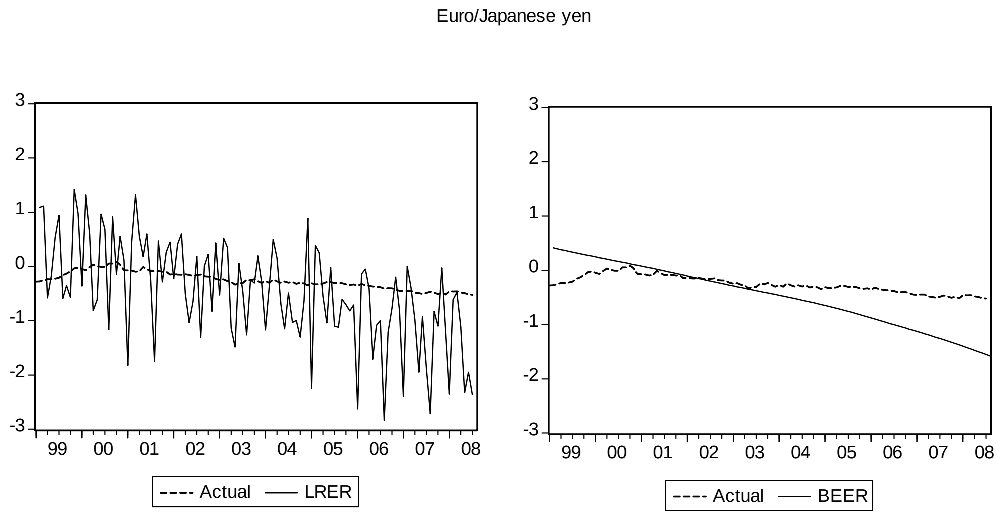

Figure 3: Current and total equilibrium euro per pound exchange rate

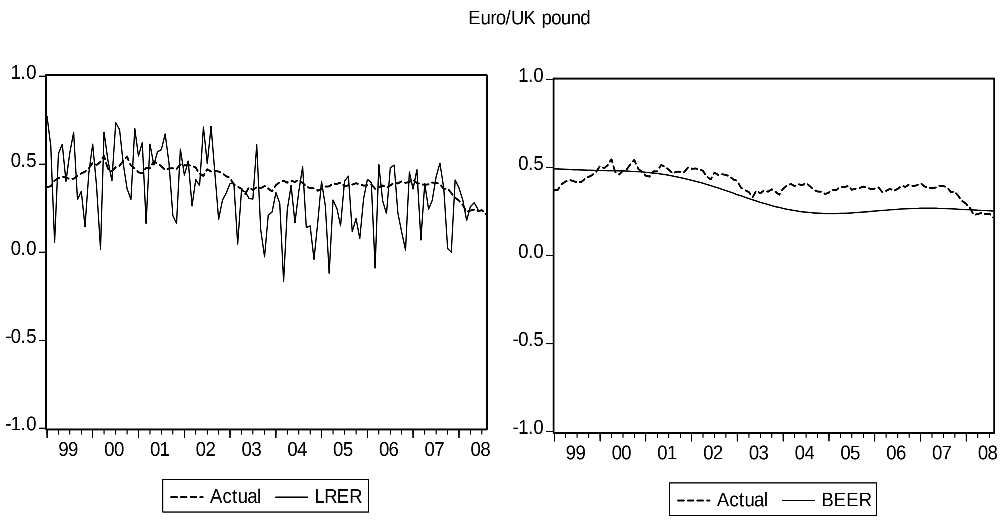

Figure 4: Current and total equilibrium euro per dollar exchange rate

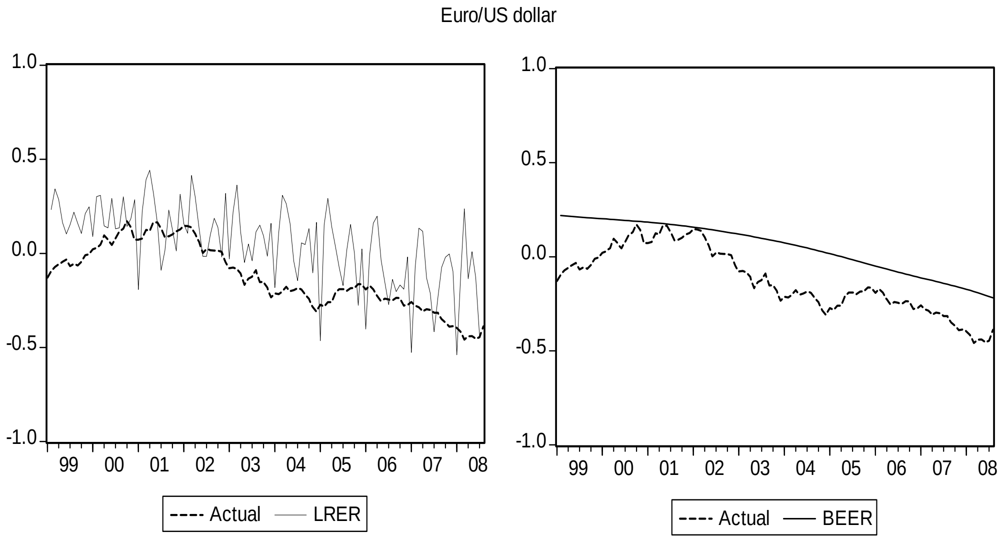

Table 1: Description of data

Country	Exchange rate (euro against foreign currency)	Consumer price index	Money supply	Industrial production
Euro area		64H	M2 (59MBU)	66
China	WE	64	M2 (59MB)	66
Japan	AE	64	M2 (59MBA)	66
UK	AG	64H	M4[a]	66
USA	AE	64	M2 (59MB)	66

All data were obtained from the International Financial Statistics (IFS) of the International Monetary Fund. The entry in each cell refers to the line of the IFS database. [a] M4 for the UK was obtained from the Bank of England. For China and Japan the IFS data series report the nominal exchange rates against the US dollar. To obtain the nominal exchange rates against the euro, we used cross exchange rates. The time span is 1999:01-2008:08.

Table 2: Two-break LM unit root test results

	Variables	Model	$\hat{k}$	$\hat{T}_B$	$\hat{\lambda}_1$, $\hat{\lambda}_2$	*LM*
Euro area/	s	A	11	2004:10, 2006:04	NA	-2.36
China	(y-y*)	A	12	2001:11[n], 2003:01	NA	-2.72
	(m-m*)	A	12	2001:05, 2007:01	NA	-2.61
	(π-π*)	A	11	2001:11, 2004:11	NA	-3.95*
Euro area/	s	A	7	2000:07, 2001:04	NA	-2.80
Japan	(y-y*)	A	12	2000:09, 2003:01[n]	NA	-3.15
	(m-m*)	A	12	2001:01, 2002:02[n]	NA	-2.57
	(π-π*)	A	11	2000:04[n], 2000:07	NA	-3.38
Euro area/	s	C	11	2002:12, 2006:08	0.2, 0.8	-4.69
UK	(y-y*)	C	11	2000:05, 2003:10	0.2, 0.6	-6.54**
	(m-m*)	C	12	2002:12, 2006:04	0.2, 0.8	-5.06
	(π-π*)	C	11	2000:06, 2001:07	0.2, 0.4	-7.05**
Euro area/	s	C	11	2002:03, 2005:03	0.2, 0.8	-4.43
USA	(y-y*)	C	12	2000:09, 2005:05	0.2, 0.8	-4.18
	(m-m*)	C	12	2000:12[n], 2003:11	0.4, 0.6	-4.89
	(π-π*)	C	12	2000:10, 2005:11	0.2, 0.8	-7.73**

Model A			Model C			
Critical values			Break points	Critical values		
1%	5%	10%	$\lambda = (\lambda_1, \lambda_2)$	1%	5%	10%
-4.54	-3.84	-3.50	λ=(0.2, 0.4)	-6.16	-5.59	-5.27
			λ=(0.2, 0.6)	-6.41	-5.74	-5.32
			λ=(0.2, 0.8)	-6.33	-5.71	-5.33
			λ=(0.4, 0.6)	-6.45	-5.67	-5.31

s is the natural logarithm of the nominal exchange rate of the euro against the foreign currency; y is the natural logarithm of the industrial production, m is the natural logarithm of the money supply and π is the inflation rate. $\hat{k}$ is the estimated number of lags in the unit root test regression (17) to correct for serial correlation. $\hat{T}_B$ denotes the estimated break points. $\hat{\lambda}_1$ and $\hat{\lambda}_2$ are the estimated relative break points. NA means ''not affected" by the break points. The critical values for Models A and C are from table 2 of Lee and Strazicich (2003). [n] signifies that the relevant break is not significant at the 0.10 level of significance. ** (*) denotes rejection of the unit root hypothesis at the 0.01 (0.05) level of significance.

Table 3: One-break LM unit root test results

	Variables	Model	$\hat{k}$	$\hat{T}_B$	$\hat{\lambda}$	LM
Euro area/ China	(y-y*)	A	12	2003:01	NA	-2.29
Euro area/ Japan	(y-y*)	A	12	2000:09	NA	-3.11
	(m-m*)	A	12	2001:01	NA	-2.52
	(π-π*)	A	12	2000:07	NA	-3.17
Euro area/ USA	(m-m*)	C	12	2003:07	0.5	-3.30

Model A Critical values			Break points	Model C Critical values		
1%	5%	10%	λ	1%	5%	10%
-4.24	-3.57	-3.21	λ=0.5	-5.11	-4.51	-4.17

m is the natural logarithm of the money supply. $\hat{k}$ is the estimated number of lags in the unit root test regression (17) to correct for serial correlation. $\hat{T}_B$ denotes the estimated break points. $\hat{\lambda}$ is the estimated relative break point. NA means ‘‘not affected” by the break points. The critical values for Models A and C are from table 1 of Lee and Strazicich (2004). ^{n} signifies that the relevant break is not significant at the 0.10 level of significance.

Table 4: The JMN and LST cointegration tests with structural breaks

Country	$(p-r_0)$	$LR_{JMN}(r_0)$	$LR_{LST}(r_0)$	p-values JMN	p-values LST	$\hat{k}$
Euro area/	4	95.41**	48.62**	0.006	0.022	3
China	3	56.76*	17.62	0.079	0.580	
	2	29.82	4.50	0.248	0.910	
	1	11.40	0.04	0.408	0.998	
Euro area/	4	164.73**	54.55**	0.000	0.004	5
Japan	3	102.79**	20.61	0.000	0.354	
	2	46.65**	11.31	0.002	0.256	
	1	14.10	0.32	0.172	0.960	
Euro area/	4	110.32**	64.77**	0.000	0.004	5
UK	3	59.58**	24.83	0.001	0.511	
	2	32.88**	8.58	0.022	0.881	
	1	10.12	0.35	0.327	0.999	
Euro area/	4	120.36**	53.78*	0.003	0.060	9
USA	3	66.28	31.55	0.203	0.176	
	2	37.04	15.08	0.384	0.382	
	1	13.75	2.38	0.626	0.910	

$\hat{k}$ denotes the estimated lag length in the VECM. ** and * denote rejection of the null hypothesis at the 0.05 and the 0.10 level of significance, respectively.

Table 5: Estimated coefficients of the cointegrating vectors

Parameter estimates	Euro area/ China	Euro area/ Japan	Euro area/ UK	Euro area/ USA
β_S	1.000	1.000	1.000	1.000
$\beta_{(y-y*)}$	0.049	-4.163**	3.618**	-0.157
	(0.147)	(7.253)	(26.647)	(0.029)
	[0.702]	[0.007]	[0.000]	[0.865]
$\beta_{(m-m*)}$	2.032**	2.328	-0.116**	-1.050**
	(36.999)	(2.225)	(198.692)	(4.908)
	[0.000]	[0.136]	[0.000]	[0.027]
$\beta_{(\pi-\pi*)}$	0.066**	2.015**	-0.065	0.559**
	(18.455)	(67.123)	(0.273)	(14.026)
	[0.000]	[0.000]	[0.601]	[0.000]
Trend	0.018**	-0.019**	-0.007**	-0.003*
	(16.799)	(5.302)	(14.936)	(2.933)
	[0.000]	[0.021]	[0.000]	[0.087]
SB_1	-0.313**	0.136	-0.002*	-0.003
	(10.506)	(1.098)	(2.769)	(2.325)
	[0.001]	[0.295]	[0.096]	[0.127]
SB_2	-0.327**	0.443**	-0.002	-0.002
	(6.723)	(4.049)	(2.545)	(0.997)
	[0.009]	[0.044]	[0.111]	[0.318]

$\beta's$ are the parameters of the cointegrating vectors, normalized on the nominal exchange rate, SB_1 is the first structural break and SB_2 is the second structural break. Numbers in parentheses are likelihood ratio statistics for $H_0:\beta_i = 0$, $H_0: trend = 0$ or $H_0: SB_i = 0$ and numbers in brackets are the respective p-values. For the Euro area/UK and Euro area/USA cases the structural breaks are trend breaks, while for the Euro area/China and Euro area/Japan cases the structural breaks are breaks in the constant term. ** (*) denotes rejection of the null hypothesis at the 0.05 (0.10) level of significance.

Table 6: Adjustment coefficients and weak exogeneity tests

Parameter estimates	Euro area/ China	Euro area/ Japan	Euro area/ UK	Euro area/ USA
α_S	-0.006	-0.011	-0.026	-0.251**
	(0.172)	(0.770)	(0.756)	(22.650)
	[0.679]	[0.380]	[0.385]	[0.000]
$\alpha_{(y-y^*)}$	0.029	-0.076**	0.414**	0.001
	(0.036)	(16.216)	(23.465)	(0.003)
	[0.851]	[0.000]	[0.000]	[0.955]
$\alpha_{(m-m^*)}$	0.034**	0.007**	-0.004	-0.036**
	(41.405)	(7.568)	(0.111)	(9.016)
	[0.000]	[0.006]	[0.739]	[0.003]
$\alpha_{(\pi-\pi^*)}$	1.481**	0.981**	0.238	2.157**
	(17.848)	(43.113)	(0.339)	(11.425)
	[0.000]	[0.000]	[0.560]	[0.000]

$\alpha's$ are the adjustment coefficients. Numbers in parentheses are likelihood ratio statistics for $H_0 : \alpha_i = 0$ and numbers in brackets are the respective p-values. ** (*) denotes rejection of the null hypothesis at the 0.05 (0.10) level of significance.