Monetary Policy Convergence Among the New EU Countries and the EMU

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Abstract

In this paper we use cointegration and common trend techniques to investigate linkages in the term structure of interest rates in the 12 new EU countries, and the two core EMU countries, France and Germany. By estimating the common trends in the term structure of interest rates, we also analyse possible long run linkages between the monetary policy of each new EU country and that of the core of the EMU. The cointegration and common trends results indicate long run linkages of monetary policies for 9 out of 10 countries that joined the EU in May 2004: Cyprus, the Czech Republic, Estonia, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. On the contrary, our results indicate absence of monetary policies linkages for Hungary and for Bulgaria and Romania that joined the EU in January 2007.

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1. Introduction

The European Union (EU) experienced its biggest expansion in May 2004 when ten new countries became EU members, namely Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. In January 2007, Bulgaria and Romania also joined the EU. In order to successfully join the EU these countries had to satisfy certain economic and political criteria, which include being stable democracies, respect human rights as well as having a functioning market economy.

The next step for these countries is to satisfy the relevant nominal criteria for joining the European Monetary Union (EMU) successfully and thus adopt the euro. The Maastricht Treaty (1992) has laid down explicit nominal convergence criteria that must be satisfied before a candidate country can join the EMU. One criterion concerns the convergence of long-term interest rates to the average interest rate of the three best-performing EMU countries in terms of price stability. But for convergence to be realized the new EU countries must adjust their monetary policies in the direction of the core of the EMU countries, most important France and Germany, as has been the case with other existing members of the EMU. An interesting aspect that arises from this consideration is the possibility of interest rate linkages among the new EU countries and the core of the EMU countries. If this is the case, then the chances of a future participation of the new EU countries into the Eurozone will be higher.

In the present study we analyse interest rate linkages and monetary policy convergence among the new EU countries and the core of the EMU in order to evaluate the preparedness of the former to adopt the euro. In fact, Slovenia adopted the euro in January 2007, followed by Cyprus and Malta in January 2008. We include these three countries in the present analysis in order to examine if they satisfy the condition of monetary policy convergence. All of the remaining countries aspire to apply for EMU membership in the near future.

In the vast literature on interest rates, researchers have studied interest rate linkages mostly in the context of the testable implications of the expectations hypothesis of the term structure (EHTS), using regression and cointegration techniques; see among others Campbell and Shiller (1987 and 1991), Shiller (1990), Hall, Anderson and Granger (1992), Hardouvelis (1994), Cuthbertson (1996), Jondeau and Ricart (1999), Clarida, Sarno, Taylor and Valente (2003) and Koukouritakis and Michelis (2008). To date, a few studies have been concerned with the decomposition of the term structure into its transitory (i.e., the $I(0)$ cointegrating relation) and permanent (i.e., the $I(1)$ common trend) components, for a specific country or group of countries. Yet such decomposition can be equally useful and insightful. The cointegrating relation, which relates the spread between the long and short rates, contains information about the effects of short run monetary policies, while the common trend, in general, contains information about long run macroeconomic conditions and expectations about the course of future government policies. The properties of the permanent components across a group of countries can thus reveal information about the degree of policy convergence among the countries. This is useful information for applied economists and policy makers.

Hafer, Kutan and Zhou (1997) used the multivariate cointegration and common trends techniques of Gonzalo and Granger (1995) to study linkages in the term structures of interest rates in 4 EU countries: Belgium, France, Germany and the Netherlands. Using monthly observation over the period 1979:3-1995:6, they decomposed each term structure into its transitory and permanent components and found that the long rate is the source of the common trend in each country. Further, the common trends are cointegrated across countries and thus move together over time, but no single country dominates the common trends. Holmes and Pentecost (1997) reported similar results, using a sample of monthly observations for a group of 6 EU countries.

Our purpose in this paper is threefold. First, we use the most recent data available from the early 1990s to 2007:12, and recently developed unit roots and cointegration tests in the presence of structural breaks in the data (e.g., Lee and Strazicich (2003) for unit roots; Johansen, Mosconi and Nielsen (2000), and Lütkepohl and his associates in several recent papers noted below, for cointegration) in order to investigate linkages in the term structure of interest rates for the 12 new EU countries and the two core EMU countries, France and Germany.

Second, we use the Gonzalo-Granger methodology to identify and estimate the common trends that drive the cointegrating relations between long and short rates in the given sample of countries. Hypothesis testing in this framework provides information as to which interest rate contains the common trend in each country.

Third, we investigate the possibility of long run linkages of monetary policies across countries by analysing the co-movements between the estimated common trend in the term structure of each new EU country and that of the core of the EMU. Our empirical results indicate long run linkages between the monetary policies of the ten countries that joined the EU on May 2004: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. Cyprus, Malta and Slovenia are already members of the EMU, while the rest of them seem to be prepared to join the EMU in the near future, without major adjustments in their monetary policies. The two newest EU countries (i.e. Bulgaria and Romania) may need significant adjustments in their government policies in order to join the EMU successfully in the future.

The rest of the paper is organized as follows. Section 2 reports the minimum LM unit root tests and describes the statistical models that we employ to test for cointegration and to identify and estimate the common trends in the term structure of interest rates. Section 3 describes the data and analyses the empirical results. Section 4 contains some concluding remarks.

2. Unit Roots and Cointegration

As shown in Table 1 our sample includes 14 countries and the data span the period 1993:1-2007:12, with different data spans for different countries depending on data availability. During this period all the new EU countries in the sample have undertaken several policy reforms, such as joining the exchange rate mechanism, or following restrictive monetary and fiscal policies in order to reduce their inflation rates and contain budget deficits and national debts. Such policy reforms, in turn, are likely to have caused structural shifts in the levels and trends in their term structure of interest rates. Since the presence of structural breaks are known to have significant effects on the properties and interpretation of standard ADF-type unit root tests, in the present study, we employ recently developed tests that are valid in the presence for structural shifts in the data.

2.1 Unit Root Tests with Structural Breaks

We test for unit roots in the data using the one-break and two-break LM (Lagrange Multiplier) tests developed by Lee and Strazicich (2001, 2003 and 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.

The LM tests are also easy to implement. Consider for example the two-break LM unit test for the process y_t generated by

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

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 one wishes to examine 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 B) of y_t.Then 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; and for Model C, $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$, where and $DT_{jt} = t - T_{Bj}$ 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 (1) 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

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{i=1}^{k} \theta_i \Delta \tilde{S}_{t-i} + u_t, \tag{2}$$

where $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t \tilde{\delta},\ t = 2, \ldots, T$, 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 (2) and can be tested by the LM test statistic:

$$\tilde{\tau} = t\text{-statistic for the hypothesis } \phi = 0. \tag{3}$$

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:

$$LM_\tau = \inf_\lambda \left\{ \tilde{\tau}(\lambda) \right\} \tag{4}$$

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

In the present study, when the two-break LM test results showed that only one structural break is significant for some countries, we also computed the one-break LM test. This was done not only because the one-break LM test appears more appropriate in this case, but also because we wanted to determine if including two breaks instead of one can adversely affect power to reject the unit root hypothesis for these countries. For the same reason, when the one-break or two-break LM test results showed that no break is significant, we used the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) unit root tests.

2.2 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 literature on cointegration in a VAR framework, there are two main approaches to testing for cointegration in the presence of structural breaks. One approach developed by Johansen, Mosconi and Nielsen (2000) (henceforth the JMN approach) extends the standard VECM with a number of additional 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 then derive the asymptotic distribution of the likelihood ratio (LR) or trace statistic for cointegration and obtain critical values or p-values, for the multivariate counterparts of models A and C above with q possible breaks, using the response surface methodology.

To illustrate the JMN approach, consider briefly the simple case of model A 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 $(j+1)$ 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 $Y_{T_{j-1}+1},...,Y_{T_{j-1}+k}$:

$$\Delta Y_t = \Pi Y_{t-1} + \mu D_t + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \sum_{i=1}^{k} \sum_{j=2}^{q} g_{ji} D_{j,t-i} + \varepsilon_t, \quad \varepsilon_t \sim iidN(0,\Omega), \qquad (5)$$

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

$$LR_{JMN} = -T \sum_{i=r_0+1}^{p} \ln\left(1 - \hat{\lambda}_i\right) \tag{6}$$

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 (5), by reduced rank regression, under the additional restrictions that $\mu_j = \alpha\rho_j^{/}, j = 1,.....,q$, where ρ_j is of dimension $1 \times r$ [1].

The second approach developed by Lütkepohl and his associates (henceforth the LST approach; see among others, Lütkepohl and Saikkonen (2000), Saikkonen and Lütkepohl (2000), Trenkler, Saikkonen and Lütkepohl (2008) and references therein) assumes 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 set up, LST propose a two-step procedure to test for the cointegration. In the first step, they remove the deterministic part using a generalized least squares procedure under the hypothesis of r_0 cointegrating relations (GLS de-trending). In the second step, 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 shifts only in the level of the process or shifts in both the level and the trend. Lütkepohl and 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.

To illustrate the LST approach 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:

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[1] These restrictions are required in order to eliminate a linear trend in the level of the process Y_t. Using these restrictions in (5), it is easy to see that reduced rank regression involves the regression of ΔX_t on $(X_{t-1}^{/}, D_t^{/})^{/}$ each corrected for the regressors ΔX_{t-i} $(i = 1,.....,k-1)$ and $D_{j,t-i}$ $(i = 1,.....,k; j = 2,.....,q)$.

$$Y_t = \mu_t + X_t = \mu_0 + \mu_1 t + \delta d_t + X_t, \quad t = 1,....,T, \tag{7a}$$

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 $VAR\left(k\right)$ process with VECM representation

$$\Delta X_t = \Pi X_{t-1} + \sum\nolimits_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t \ , \quad \varepsilon_t \sim iidN(0,\Omega), \quad t = 1,...,T \ . \tag{7b}$$

We also assume that X_t is at most $I\left(1\right)$ and it is cointegrated $\left(i.e.\ \Pi = a\beta^{/}\right)$ with cointegrating rank r. Following Lütkepohl et al. (2003), the model presented in equations (7a) and (7b) can be rewritten as follows:

$$\Delta Y_t = \nu + a\left(\beta^{/} Y_{t-1} - \tau\left(t-1\right) - \theta d_{t-1}\right) + \sum\nolimits_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \sum\nolimits_{i=0}^{k-1} \gamma_i \Delta d_{t-i} + \varepsilon_t \ , t = k+1, k+2..., \tag{7c}$$

where $\nu = -\Pi\mu_0 + \Phi\mu_1, \Phi = I_n - \Gamma_1 - ... - \Gamma_{k-1}, \tau = \beta^{/}\mu_1, \theta = \beta^{/}\delta$ and $\gamma_i = \begin{cases} \delta, \, i = 0, \\ -\Gamma_i \delta, \, i = 1,...,k-1. \end{cases}$

Given the DGP in equations (7a), (7b) and (7c), 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 $H_0\left(r_0\right): rank\left(\Pi\right) = r_0$: vs. $H_1\left(r_0\right): rank\left(\Pi\right) > r_0$ (e.g., see Saikkonen and Lütkepohl (2000) for details). Having the estimated parameter $\hat{\mu}_0$, $\hat{\mu}_1$ 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 $VECM$ (7b) and computing the LR or trace statistic:

$$LR_{LST} = -T \sum\nolimits_{i=r_0+1}^{p} \ln\left(1 - \tilde{\lambda}_i\right) \ , \tag{8}$$

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 developed in 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 (8) 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 (Trenkler et al., 2008, p. 338).

Since the JMN and LST approaches are designed to test the same null hypothesis of cointegration in the presence of structural breaks in the data, we employ both the LR_{JMN} and LR_{LST} test statistics in our empirical analysis of the term structure of interest rates in the new EU countries and the core of the EMU. The break points are determined endogenously from the data on the basis of the results of the LM unit root tests discussed above. In the next section we discuss the Gonzalo and Granger common trends model that we apply, subsequently, to the de-trended short term and long term interest rates in order to study interest rate linkages and monetary policy convergence among the countries in our sample.

2.3 The Common Trends Model

Gonzalo and Granger (1995) used the $VECM$ framework in order to identify, estimate and test the significance of common trends in a system of time series. Their approach exploits the duality between cointegration and common trends, in that if elements of a $p-$dimensional vector of $I(1)$ variables are bound together by *r* cointegrating vectors, then there exist $p-r$ common trends that induce shifts in the cointegrating relations within the cointegration space.

The $VECM$ in equation (7b) is the starting point of their analysis. Using the Granger Representation Theorem, it is easy to see that the common trends in the zero mean stochastic process X_t are simply the cumulated disturbances $\alpha_{\perp}^{/}\sum_{i=1}^{t}\varepsilon_t$, where $\alpha_{\perp}$ is a $p\times(p-r)$ matrix that is the orthogonal complement to α (Johansen, 1995, p. 41). Gonzalo and Granger assume that the common trends are a linear combination of X_t, of the form $f_t=\alpha_{\perp}^{/}X_t$, and propose the following decomposition of X_t into its permanent and transitory (P-T) components:

$$X_t = A_1 f_t + A_2 w_t, \tag{9}$$

where $w_t=\beta^{/}X_t$, $A_1=\beta_{\perp}(a_{\perp}^{/}\beta_{\perp})^{-1}$ in which $\beta_{\perp}$ is a $p\times(p-r)$ matrix that is orthogonal complement to β and $A_2=a(\beta^{/}a)^{-1}$. The maximum likelihood estimator (MLE) of $a_{\perp}$ are the eigenvectors corresponding to the $(p-r)$ smallest eigenvalues of the problem

$$\left|\lambda S_{00}-S_{01}S_{11}^{-1}S_{10}\right|=0 \ , \tag{10}$$

where $S_{ij}=T^{-1}\sum_{t=1}^{T}R_{it}R_{jt}^{/}$, $i,j=0,1$, in which R_{0t} and R_{1t} are residual matrices obtained by reduced rank regression; e.g., see Johansen (1994). Solving equation (10) for eigenvalues

$1 > \hat{\lambda}_1 > ... > \hat{\lambda}_p > 0$ and eigenvectors $\hat{M} = (\hat{m}_1, ..., \hat{m}_p)$, normalized such that $\hat{M}^{/} S_{00} \hat{M} = I$, one gets the MLE of $\alpha_\perp$ as $\hat{\alpha}_\perp = (\hat{m}_{r+1}, ..., \hat{m}_p)$.

Given this framework, one can test whether or not certain linear combinations of X_t can be common trends. Null hypotheses on $\alpha_\perp$ have the form $H_0 : \alpha_\perp = G\theta$, where G is a $p \times m$ known matrix of constants and θ is an $m \times (p - r)$ matrix of unknown coefficients such that $p - r \le m \le p$. To carry out the test, solve the eigenvalue problem $\left| \lambda G^{/} S_{00} G - G^{/} S_{01} S_{11}^{-1} S_{10} G \right| = 0$ for eigenvalues $1 > \hat{\lambda}_1^* > ... > \hat{\lambda}_m^* > 0$ and eigenvectors $\hat{M}^* = (\hat{m}_1^* ... \hat{m}_m^*)$, normalized such that $\hat{M}^{*/} (G^{/} S_{00} G) \hat{M}^* = I$. Choose $\hat{\theta}_{m \times (p-r)} = (\hat{m}_{(m+1)-(p-r)} ... \hat{m}_m)$ and $\hat{\alpha}_\perp = G\hat{\theta}$. Then, the likelihood ratio statistic for testing H_0 is given by

$$L = -T \sum_{i=r+1}^{p} \ln \left[\left(1 - \hat{\lambda}_{i+(m-p)}^*\right) \Big/ \left(1 - \hat{\lambda}_i\right) \right] . \tag{11}$$

Under the null hypothesis $H_0 : a_\perp = G\theta$, the *L*-statistic in equation (11) is distributed as $\chi^2_{(p-r)\times(p-m)}$ asymptotically. In the Section 3, we construct the *L*-statistic for specific choices of the matrix *G* in order to test whether the long or the short rate is the common trend in the term structures of the 12 new EU countries and the 2 EMU countries.

3. Data and Empirical Results

3.1 Data

The data set consists of short and long rates for each of the 12 new EU countries and for France and Germany. Due to lack of data availability for the new EU countries, we collected data on two interest rates of the term structure for each country: treasury bill yields (short term) and government bond yields (long term). For Estonia, Latvia, Lithuania, Romania and Slovenia, no sufficient time series data on treasury bill rates or government bond yields are available, and we used commercial banks' average lending rates instead. Our sample consists of monthly data of varying time spans for different countries determined by data availability. The data details and their sources are given in Table 1.

3.2 Unit Root Results with Structural Breaks

Tables 2 and 3 report the unit root results from the two- and one-break minimum LM tests, respectively. We tested each interest rate series for a unit root using the two-break minimum LM test at the 10 percent level of significance. As noted above, when this test showed that only one structural break is significant we employed the one-break minimum LM test at the same level of significance. In order to determine the number of lags, k, in equation (2), 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[2]. Table 4 presents the ADF and the PP unit root test results, for the countries that the two-break minimum LM test results showed that both structural breaks are insignificant. To select the appropriate lag length for the ADF test regression, we used the Akaike's information criterion (AIC).

As shown in Table 2, the unit root hypothesis with two structural breaks cannot be rejected for the interest rates of the Czech Republic, Hungary, Lithuania, Malta, Poland, Romania and Slovakia. Table 3 reports similar results for the interest rates of Bulgaria, Cyprus, Estonia, Latvia and Slovenia, all of which have experienced one break in their term structures. Table 4 presents the ADF and PP test results for the interest rates of France and Germany, for which the results of Tables 2 and 3 implied no significant break. As shown in Table 4 for each of the two EMU countries, the unit root hypothesis cannot be rejected at the 5 percent level of significance[3].

As shown in the third column of Tables 2 and 3, Model C fits the term structure data best for the Czech Republic, Hungary, Lithuania and Malta, regardless of the presence of one or two structural breaks detected in the data. Hence, these countries have, likely, experienced one or two shifts both in the deterministic levels and trends of their term structures, over the sample period. Model A fits the data best for Bulgaria, Cyprus, Estonia, Latvia, Poland, Romania, Slovakia and Slovenia, which means that these countries have, likely, experienced one or two shifts only in the deterministic levels[4]. Overall, the results in Tables 2, 3 and 4

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[2] The Gauss codes for the one-break and the two-break minimum LM tests have been downloaded by the website http://www.cba.ua.edu/~jlee/gauss .

[3] We also tested the interest rates of all countries for a second unit root. The null hypothesis was rejected in all cases. For the sake of brevity, these results are not presented here but are available under request.

[4] In the cases where the trend shift parameters in Model C were statistical insignificant at the 0.10 level, we choose Model A.

provide strong evidence that the term structures of the twelve new EU countries have unit roots and are integrated of order one.

In general, our results indicate the existence of one or two structural breaks for all the new EU countries. These breaks were estimated endogenously by the two-break and one-break LM tests, and are reported in column 5 of Tables 2 and 3, respectively. Not surprising, the estimated breaks correspond closely to specific events that have taken place in the new EU countries over the sample period. For the interest rates of Bulgaria, the one-break minimum LM test detects one break in 1999 for the long rate, which coincides with the replacement of the German mark with the euro as the peg currency and the subsequent real appreciation of the domestic currency. The short rate break in early 2003 may be related with the improvement of the country's international competitiveness that took place on that year. For Cyprus, the long rate break in 2001 has been probably caused by the widening of the fluctuation bands against the euro on that year, while the short rate break in 2003 may be related with the increase of the country's inflation. For the Czech Republic, both rates appear to have a break in 1997 and a break in 1999. The first break coincides with the decision of the country's monetary authorities to introduce a managed float of the domestic currency against the German mark on that year. The second break is, likely related with the replacement of the German mark with the euro as benchmark currency and the subsequent considerable exchange rate fluctuation since then.

For Estonia, we detect one break for the long rate in 2002 and for the short rate in 1997. The long rate break is, likely, related with the rapid decrease on inflation that took place in 2002, while the short rate break is closely related with the real appreciation of the domestic currency on that year. Two breaks are detected for the interest rates of Hungary. The long rate breaks in 1998 and 2000 are probably related with the effects of the Russian financial crisis in 1998 and the significant appreciation of the domestic currency in 2000, which lowered imported inflationary pressures. The first short rate break in 2003 coincides with the speculative attack at a time when the domestic currency was close to the upper end of its trading band and the subsequent interest rate cut by the country's central bank. The second short rate break in 2005 may be related with the significant decrease of inflation on that year. One break is detected in the interest rates of Latvia. Both rates appear a break in late 1994, which is probably related with the domestic currency appreciation against the US dollar and the British pound and the subsequent decrease in interest rates that took place on that year.

The two-break minimum LM test detects two breaks for the Lithuanian interest rates. One break is around late 2000 and early 2001 and another break is in 2003. The first break coincides with the uncertainty about the future of the currency board in Lithuania after the Russian financial crisis, which added a considerable risk premium to the country's interest rates. The second break coincides with the rapid decline of inflation that affected the country's interest rates, together with the signing of the EU Accession Treaty that took place on April 2003. Two breaks detected for the Maltese interest rates. Both rates appear a break in the period between late 1995 and early 1996, which related with the deterioration of the country's budget deficit that lasted for the following 5-year period. The long rate appears a second break in 2004 that is, likely, related with the high fiscal deficit on that year. The second break in the short rate in early 2003 is related with the depreciation of the Maltese lira against the euro. Two breaks also detected for the interest rates of Poland. Both rates appear a break in early 1996, which coincides with the significant widening of the bands that the domestic currency could fluctuate. The second long rate break in late 1999 is, likely, related with the implementation of a free floating exchange rate for the domestic currency that is not subject to any restrictions. The second short rate break in early 1998 coincides with the introduction of an "inflation targeting" monetary regime, which led to a significant decrease of the inflation.

The interest rates of Romania also appear two breaks. Both rates appear a break in 1998, which is related with a serious deterioration in the country's current account deficit. This led Romania to abandon its policy of seeking a real appreciation in the exchange rate for fighting inflation. The second break for both rates is appeared between mid-1999 and mid-2000 and is, likely, related with the domestic currency depreciation against the euro and the US dollar. For both rates of Slovakia, we detect two structural breaks between late 1997 and early 1999, which coincide with a high-inflation period. This led Slovakian central bank to allow domestic currency to float since October 1998, because it could not defend it against devaluation pressures. Finally, one break is detected for the interest rates of Slovenia in 1998 and is probably related with a real appreciation of the domestic currency that took place on that year.

3.3 Cointegration Tests with Structural Breaks

We proceed with the cointegration results following the JMN and LST approaches described in Section 2.2. In the case of the JMN approach, in each of the new EU countries we included the respective level shifts or trend breaks denoted by Tables 2 and 3. The LR_{JMN} test statistics and the respective response surface p-values were obtained using the JMulTi software[5] and the related textbook (Lütkepohl and Krätzig, 2004).

In the case of LST approach, for each of Cyprus and Slovenia that appear to have a single break in level, we estimated a *VECM* of the form described by the model described by equations (7a) to (7c). For Bulgaria, Estonia and Latvia that also have a single break level, we estimated a *VECM* of the same form, but we did not include a linear trend. For Poland, Romania and Slovakia that appear to have two breaks in level, we added to the model described by equations (7a) to (7c) a second step dummy and we did not include a linear trend[6]. For each of the Czech Republic, Hungary, Lithuania and Malta that appear to have two breaks in both level and trend, we extended the model described by equations (7a) to (7c) by adding a second step dummy and two linear trend dummies, following Trenkler et al. (2008). The LR_{LST} test statistics and the respective response surface p-values were obtained using the Gauss software[7].

Finally, for each of France and Germany that appear to have no breaks, we employed the standard Johansen cointegration approach. In order to determine which of the five sub-models analysed in Johansen (1994), describes best the variables of each of France and Germany, we tested the sub-models against each other using the likelihood ratio tests in Johansen (1995, Chapter 11, Corollary 11.2 and Theorem 11.3, pp. 161-162). These tests are also distributed as χ^2 with degrees of freedom determined by the pairs of models being tested as follows: $0 \underset{r}{\subset} 1^* \underset{p-r}{\subset} 1 \underset{r}{\subset} 2^* \underset{p-r}{\subset} 2$. Also, the Akaike's information criterion (AIC) was used to select the appropriate lag length, k, for each of our sample countries.

Table 5 reports the LR_{JMN} and LR_{LST} test statistics for cointegration and their respective p-values, for each of the countries that appear to have one or two structural breaks in levels[8]. Table 6 reports the Johansen and Juselius (1990) Trace and $\lambda_{\max}$ statistics for cointegration, for each of France and Germany. As shown in these tables, there is evidence of one cointegrating vector between the long term and the short term interest rates for seven out of

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[5] This software has been downloaded from the by the website http:///www.jmulti.de.

[6] Our decision about the inclusion or not of a linear trend in each of the new EU countries was based on the plots of the time series.

[7] We thank Professor Carsten Trenkler for providing us the Gauss codes for these estimations.

[8] For the results of Table 5, we used the structural break or breaks that correspond to the long rate. Similar results are obtained, when we used the break or breaks that correspond to the short rate. These results are not presented here but are available under request.

twelve new EU countries (Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Slovakia and Slovenia) and for France and Germany.

Columns 8 and 9 of Table 5 and columns 7 and 8 of Table 6 report the parameter estimates of the cointegration vectors, normalized on the long rate, for the countries for which there is evidence of cointegration between long and short rates. Numbers in parentheses are likelihood ratio statistics, which are distributed as χ_1^2 asymptotically, under the null hypothesis that each component of the cointegration vector is insignificantly different from zero. The parameters of the cointegrating vectors $\beta_i 's$ are statistically significant in all cases, which means that the long and the short interest rates enter significantly each cointegrating vector. Overall, the VECM cointegration results point to cointegration between long and short rates in 9 out of 14 countries.

3.4 Common Trends Results

As noted in Section 2.2, the Gonzalo and Granger methodology applied to the de-trended short term and long term interest rates $\left(\hat{X}_t\right)$. In the first set of our common trends results we examine whether the long or the short rate is the common trend, for the countries in which the two rates are cointegrated. Thus, for each country, we test hypotheses on $\alpha_\perp$, by computing the *L*-statistic in equation (11) for specific choices of the G matrix. In particular, to test the null hypothesis that the long term interest rate is the common trend, we set $G = (1,0)^{/}$. Alternatively, to test the hypothesis that the short term interest rate is the common trend, we set $G = (0,1)^{/}$.

Table 7 reports the computed *L*-statistics for the long rate and the short rate, respectively. For all the countries that there is evidence of cointegration between their interest rates (i.e. Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Slovakia, Slovenia, France and Germany), the null hypothesis that the long rate is the common trend cannot be rejected at the 5 percent level of significance. For these countries, the evidence suggests that the short rate adjusts to deviations from the long run equilibrium, while the long rate is weakly exogenous, affected primarily by fundamental factors such as the future state of the economy and expectations about the future path of government policies. In other words, the long rate is not affected by past disequilibria and thus “drives” the common trend.

Figures 1 to 9 show the graphs of the P-T decomposition of the long and short rates, for each country that there is evidence of cointegration, based on equation (9). These graphs are consistent with the statistical properties of each series. In each plot the permanent component of either interest rate is close to and tracks well, over time, the actual interest rate. This is an expected result, as both series are $I(1)$ processes and should be more correlated to each other than to the transitory component, which is an $I(0)$ process.

3.5 Convergence of Monetary Policies

Now we examine the possibility of convergence among the monetary policies of the new EU countries and the EMU, by analysing long run linkages in interest rates across countries. First, we examine linkages among the new EU countries, for which the short and long rates cointegrate (i.e. Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Slovakia and Slovenia), and the two EMU countries. We do this by testing for cointegration between the common trend in each new EU country's term structure and the French/German common trend. Second, we investigate interest rate linkages for Bulgaria, Latvia, Malta, Poland and Romania, for which the short and long rates do not cointegrate, and the French/German common trend. For example, it is possible that either rate of each country may move together with the French/German common trend.

a) Countries for which the short and long rates cointegrate

If the common trend in the interest rates of each new EU country is driven by the common trend of the two EMU countries, it is reasonable to argue that the latter countries' monetary policies set the trend, and the new countries' monetary policies adjust to them. To carry out this analysis, we proceed sequentially as follows. First, we test for cointegration between the two estimated common trends of France and Germany. Second, having found that these two common trends cointegrate, we then test for cointegration in 2-dimensional $VECMs$, each consisting of the common trend of each country and the French/German common trend. The appropriate lag length, k, for each $VECM$ and the sub-model that describes best each set of variables were chosen following the same procedures discussed above. Then, in all cases where there is evidence of cointegration we also test if the French/German common trend determines the estimated common trend in each $VECM$. If it does, we claim that the EMU influences the monetary policy of the country in the long run.

Table 8 reports the results for the two EMU countries. As shown in columns 3 and 4, both the Trace and $\lambda_{\max}$ statistics point to one cointegrating vector and one shared common trend between the French and German common trends. We also tested the null hypothesis that either of the latter trends is the shared common trend. As shown in the last column of the table, this null hypothesis is strongly rejected for France but not for Germany. This result, in turn, provides support for the “German dominance hypothesis” within the EMU, from a long run perspective.

Table 9 reports the results for each country in relation to the core of the EMU. The cointegration results indicate that Cyprus, the Czech Republic, Estonia, Lithuania, Slovakia and Slovenia each share a single common trend with France and Germany (columns 3 and 4) and that each trend is determined by the French/German common trend (column 7), at the 5 percent level of significance. Consider Cyprus for instance. Both the Trace and the $\lambda_{\max}$ tests indicate one common trend in the VECM consisting of the Cyprian common trend and the French/German common trend. Further, the null hypothesis, that the former common trend is the French/German common trend is not rejected at the 5 percent level of significance (i.e., the observed value of the L-statistic is 0.11). Similar interpretations apply to the results for the Czech Republic, Estonia, Lithuania, Slovakia and Slovenia. On the contrary, there is no evidence of cointegration between the Hungarian common trend and the French/German common trend.

b) Countries for which the short and long rates do not cointegrate

For the Bulgaria, Latvia, Malta, Poland and Romania, the long and short rates do not cointegrate, which means that each of them is driven by a different common trend. In this case, it is still possible to analyze long run convergence of policies by examining long run linkages between each interest rate and the French/German common trend. To do this, we consider a 2-dimensional VECM for each country twice: one time with the long rate and the French/German common trend, and a second time with the short rate and the French/German common trend.

The results are presented in Table 10. As shown in columns 4 and 5, the long rate of each of Latvia, Malta and Poland, cointegrates with the French/German common trend, and thus, each country shares a single common trend with the core of the EMU, at the 5 percent level of significance. Also, as shown by the L-statistics in column 7, the null hypothesis that this common trend is the French/German common trend cannot be rejected at the 5 percent level of significance for these four countries. Further, no cointegration exists between the short rate of each country and the French/German common trend. For the two newest EU countries, Bulgaria and Romania, the results indicate no evidence of cointegration between either the long or the short rate of these two countries and the French/German common trend.

Overall, the common trends results show that the EMU has an important long run impact on the behaviour of interest rates of the new EU countries. Of the 12 new EU countries, the common trends of term structures of Cyprus, the Czech Republic, Estonia, Lithuania, Slovakia and Slovenia are influenced by the French/German common trend. Thus, these countries' monetary policies seem to have adjusted towards those of the core of the EMU. Further, the long rates of Latvia, Malta and Poland are influenced by the monetary policies of the two EMU countries. For Hungary and the 2 newest EU countries (i.e. Bulgaria and Romania) there is no evidence of long run monetary policy convergence with the EMU.

We can shed some light on these findings by looking at the economic conditions and the government policies pursued by the new EU countries since the early-1990s. First, we consider the countries that have made efforts to adjust their monetary policies in the direction of the EMU. For example, Cyprus managed to reduce the excessive fiscal deficit that was facing during the 1990's, has kept inflation under control, while the debt-to-GDP ratio is below 60%. The country entered the ERM II on May 2005 and finally became EMU member on January 2008. The Czech Republic has adopted a monetary policy regime of inflation targeting since 1998, which allowed the country to fight inflation successfully. Also, the existing managed floating exchange rate regime is fully compatible with the country's EU membership prior to entering ERM II.

Estonia established a currency board vis-à-vis the German mark in 1992, and has continued this arrangement vis-à-vis the euro since 1999, when the euro replaced the German mark. Also, in June 2004, the country joined the Exchange Rate Mechanism II (ERM II). Latvia had pegged its currency to the Special Drawing Rights (SDR) currency basket of the International Monetary Fund in 1994, and replaced the SDR currency with the euro in January 2005. In May 2005 the country joined the ERM II. Lithuania has made considerable progress in liberalizing and stabilizing its economy. The country established a currency board vis-à-vis the US dollar in 1994, while from 2002 its currency has pegged to the euro. Also, in June 2004, the country joined the ERM II. Malta had pegged its currency, in the late 1970s, to a basket of three low inflation currencies, consisting the US dollar, the euro (or its predecessor the ECU) and the British pound. Upon entry of the country in the ERM II in May 2005, the three-currency basket was replaced by the euro. Finally, the country became EMU member on January 2008. Poland introduced a crawling peg for its exchange rate in 1991 and changed its monetary policy regime to "inflation targeting" since 1998. In late 1999, the country's monetary authorities implemented a free floating exchange rate for the domestic currency that is not subject to any restrictions. Poland plans to enter the ERM II soon, and adopt the euro in the near future.

Slovakia had pegged its currency to a basket of currencies comprising the German mark and the US dollar, since 1995. This monetary regime was abandoned on October 1998 and replaced it with an “inflation targeting” regime. As a result of this regime shift, the country’s inflation rate declined significantly since 2002. The country has also managed to reduce fiscal deficit, while the debt-to-GDP ratio is below 60%. Finally, in November 2005, Slovakia joined the ERM II. Slovenia introduced a new currency ("tolar") and adopted a "managed float" exchange rate regime in October 1991, based on monetary aggregates targeting. After January 1999 and until the country's accession in the ERM II in June 2004, the euro was used informally as reference currency. Also, during the EU accession negotiations, the country had already managed to reduce its fiscal deficit, stabilize its exchange rate and almost fully liberalize the movement of capital. As a result, the country’s inflation rate declined significantly since 2002. Finally, Slovenia became the thirteenth member of the EMU in January 2007, having fulfilled all the Maastricht Treaty criteria.

For Hungary, Bulgaria and Romania the empirical results suggest no monetary policy convergence to the two core EMU countries. Hungary faces serious economic problems, which do not allow the adjustment of its monetary policy towards the EMU-core monetary policy. Even though the country has pegged its currency to the euro since 2001, it still faces high inflation and excessive government deficit, while its long term interest rate surpasses the reference value of the respective Maastricht criterion. Hungary has not yet entered the ERM II, which implies delay in the EMU participation for a few more years.

These two newest EU members face serious macroeconomic problems that have not allowed them to adjust their monetary policies towards those of the EMU countries yet. For example, Bulgaria is currently experiencing economic stagnation, while its current account and trade deficits continue to deteriorate. Further, the country needs to improve fiscal transparency and the business environment, in order to accelerate foreign investments. Romania has high inflation and current account deficits, and its government deficit is expected to increase as it tries to absorb structural funds from the EU. A tightening of monetary policy is required to fight inflation, and fiscal reforms are necessary, in order to improve government revenues. Obviously, major reforms are required, before the two countries can apply to enter the ERM II and adopt the euro eventually. Bulgaria seems to be one step ahead of Romania, as it operates under a euro-based currency board since 1997, and has managed to improve its structural fiscal balance in 2006. Romania is currently considering a currency board vis-à-vis the euro, in order to reduce inflation and gain monetary policy credibility.

In summary, the above findings indicate that nine out of the ten countries, which joined the EU in May 2004, seem to have made good progress in adjusting their monetary policies to the long term trend set by the core of the EMU. Hungary and the two countries that joined the EU in January 2007 need major adjustments in their government policies, if they wish to successfully join the EMU in the future.

4 Concluding Remarks

In this paper we studied interest rate linkages and monetary policy convergence among the new EU countries and the two core EMU countries, France and Germany. Since the interest rates follow random walks, we evaluated these issues using cointegration and common trend techniques.

Our empirical findings show that the long and the short rates of 9 out of 14 countries (i.e. Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Slovakia, Slovenia, France and Germany) are cointegrated, and thus tend to be move together in the long run. Further, the decomposition of each term structure into its transitory and permanent components shows that for these countries the long term interest rate is weakly exogenous and drives the common trend in each term structure.

Our common trends analysis provides useful insights about the degree of monetary convergence of the new EU countries to the core of the Eurozone. There is some clear evidence of long run convergence of the monetary policies of the Czech Republic, Estonia, Lithuania and Slovakia, and to some extent of Latvia and Poland to the monetary policies of the core of the EMU. Therefore, only these countries may be ready to join the EMU successfully in the near future, without a major overhaul of their monetary policies. The same is true for Slovenia, which is already member of the eurozone since January 2007, and for Cyprus and Malta that adopted the euro in January 2008. Hungary and the two newest EU countries (i.e. Bulgaria and Romania) may need major reforms in their government policies in order to join the EMU.

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Table 1
Description of data

Country	Time span	Variables	Source
Bulgaria	1997:07-2007:12	12-month treasury bill rates	IFS (line 60c)
		2-year government bond yields	IFS[a] (line 61)
Cyprus	1997:01-2007:12	3-month treasury bill rates	IFS (line 60c)
		5-year government bond yields	Central Bank of Cyprus
Czech Republic	1993:08-2007:12	3-month treasury bill rates	IFS (line 60c)
		5-year government bond yields[b]	IFS (line 61)
Estonia	1994:01-2007:12	3-month lending rates	Central Bank of Estonia
		10-year lending rates	Central Bank of Estonia
Hungary	1997:01-2007:12	3-month treasury bill rates	Central Bank of Hungary
		5-year government bond yields	Central Bank of Hungary
Latvia	1993:01-2007:12	3-month lending rates	Central Bank of Latvia
		5-year lending rates	Central Bank of Latvia
Lithuania	1997:01-2007:12	6-month lending rates	Central Bank of Lithuania
		5-year lending rates	Central Bank of Lithuania
Malta	1993:01-2007:12	3-month treasury bill rates	IFS (line 60c)
		5-year government bond yields	Central Bank of Malta
Poland	1994:02-2007:12	12-month treasury bill rates	Polish Ministry of Finance
		2-year government bond yields	Polish Ministry of Finance
Romania	1997:01-2007:12	3-month lending rates	Central Bank of Romania
		5-year lending rates	Central Bank of Romania
Slovakia	1994:12-2007:12	6-month treasury bill rates	Central Bank of Slovakia
		10-year government bond yields[c]	IFS (line 61)
Slovenia	1996:01-2007:12	3-month lending rates	Central Bank of Slovenia
		5-year lending rates	Central Bank of Slovenia
France	1994:01-2007:12	12-month treasury bill rates	Central Bank of France
		5-year government bond yields	Central Bank of France
Germany	1993:01-2007:12	12-month treasury bill rates	Bundesbank
		10-year government bond yields	Bundesbank

[a] International Financial Statistics CD-ROM of the International Monetary Fund. [b] For the period 1993:8-1999:12 the source is the Central Bank of the Czech Republic, because the IFS data series begins at 2000:1. [c] For the period 1994:12-2000:8 the source is the Central Bank of Slovakia, because the IFS data series begins at 2000:9.

Table 2
Two-break minimum LM unit root test results

Country	Interest rate	Model	$\hat{k}$ [a]	$\hat{T}_B$ [b]	$\hat{\lambda}_1$, $\hat{\lambda}_2$ [c]	Test statistic
Bulgaria	$R_{n,t}$	A	12	1999:06, 1999:08[n]	Not affected	-3.03
	$r_{m,t}$	A	3	1999:01[n], 2003:02	Not affected	-3.42
Cyprus	$R_{n,t}$	A	4	2001:09, 2004:12[n]	Not affected	-3.46
	$r_{m,t}$	A	6	2002:12, 2005:12[n]	Not affected	-3.34
Czech Republic	$R_{n,t}$	C	9	1997:02, 1999:07	0.2, 0.4	-4.18
	$r_{m,t}$	C	9	1997:08, 1999:01	0.2, 0.4	-4.85
Estonia	$R_{n,t}$	A	2	1998:11[n], 2002:08	Not affected	-2.07
	$r_{m,t}$	A	9	1997:06, 1998:02[n]	Not affected	-2.46
Hungary	$R_{n,t}$	C	3	1998:08, 2000:11	0.2, 0.4	-5.12
	$r_{m,t}$	C	12	2003:04, 2005:10	0.6, 0.8	-4.85
Latvia	$R_{n,t}$	A	12	1994:11, 1995:03[n]	Not affected	-2.25
	$r_{m,t}$	A	12	1994:09, 1996:07[n]	Not affected	0.12
Lithuania	$R_{n,t}$	C	9	2000:07, 2003:02	0.4, 0.6	-5.12
	$r_{m,t}$	C	12	2001:03, 2003:11	0.4, 0.6	-4.28
Malta	$R_{n,t}$	C	12	1996:02, 2004:09	0.2, 0.8	-4.69
	$r_{m,t}$	C	11	1995:10, 2003:01	0.2, 0.6	-3.71
Poland	$R_{n,t}$	A	9	1996:01, 1999:11	Not affected	-3.32
	$r_{m,t}$	A	5	1996:01, 1998:01	Not affected	-2.39
Romania	$R_{n,t}$	A	4	1998:09, 2000:05	Not affected	-3.17
	$r_{m,t}$	A	12	1998:04, 1999:05	Not affected	-2.74
Slovakia	$R_{n,t}$	A	11	1997:10, 1999:01	Not affected	-3.42
	$r_{m,t}$	A	11	1998:07, 1998:09	Not affected	-3.32
Slovenia	$R_{n,t}$	A	10	1998:08[n], 1998:12	Not affected	-3.38
	$r_{m,t}$	A	1	1997:04[n], 1998:09	Not affected	-2.40
France	$R_{n,t}$	A	9	1995:08[n], 1996:01[n]	Not affected	-3.12
	$r_{m,t}$	A	10	1996:01[n], 1996:05[n]	Not affected	-3.43
Germany	$R_{n,t}$	A	8	1997:01[n], 1998:12[n]	Not affected	-3.16
	$r_{m,t}$	A	9	1995:02[n], 2002:04[n]	Not affected	-2.50

Model A Critical values 1%	Model A 5%	Model A 10%	Model C Break points $\lambda = (\lambda_1, \lambda_2)$	Model C Critical values 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
			λ=(0.6, 0.8)	-6.32	-5.73	-5.32

$R_{n,t}$ and $r_{m,t}$ are the long term and short term interest rates respectively. [a] $\hat{k}$ is the optimal number of lagged first-differenced terms included in the unit root test to correct for serial correlation. [b] $\hat{T}_B$ denotes the estimated break points. [c] $\hat{\lambda}_1$ and $\hat{\lambda}_2$ are the estimated critical value break points. The critical values for Model C depend on the location of the breaks $\lambda = (\lambda_1, \lambda_2)$ and are symmetric around λ and $(1-\lambda)$. The critical values shown above come from Table 2 in Lee and Strazicich (2003). [n] denotes that the respective break is not significant at the 0.10 level. As shown, the unit root hypothesis cannot be rejected for any interest rate.

Table 3
One-break minimum LM unit root test results

Country	Interest rate	Model	$\hat{k}$ [a]	$\hat{T}_B$ [b]	Test statistic
Bulgaria	$R_{n,t}$	A	12	1999:06	-2.67
	$r_{m,t}$	A	3	2003:01	-3.07
Cyprus	$R_{n,t}$	A	4	2001:09	-3.13
	$r_{m,t}$	A	12	2003:06	-2.67
Estonia	$R_{n,t}$	A	2	2002:08	-1.86
	$r_{m,t}$	A	9	1997:06	-2.05
Latvia	$R_{n,t}$	A	12	1994:11	-0.68
	$r_{m,t}$	A	12	1994:09	0.45
Slovenia	$R_{n,t}$	A	10	1998:12	-2.43
	$r_{m,t}$	A	12	1998:03	-1.92
France	$R_{n,t}$	A	9	1996:01[n]	-3.09
	$r_{m,t}$	A	10	1996:05[n]	-2.50
Germany	$R_{n,t}$	A	3	1998:12[n]	-2.74
	$r_{m,t}$	A	9	2002:02[n]	-2.37

Model A
Critical values

1%	5%	10%
-4.24	-3.57	-3.21

$R_{n,t}$ and $r_{m,t}$ are the long term and short term interest rates respectively. [a] $\hat{k}$ is the optimal number of lagged first-differenced terms included in the unit root test to correct for serial correlation. [b] $\hat{T}_B$ denotes the estimated break point. The critical values shown above come from Table 1 in Lee and Strazicich (2004). [n] denotes that the respective break is not significant at the 0.10 level. As shown, the unit root hypothesis cannot be rejected for any interest rate.

Table 4
Augmented Dickey-Fuller and Phillips-Perron unit root tests

Country	ADF test		PP test	
	$R_{n,t}$	$r_{1,t}$	$R_{n,t}$	$r_{m,t}$
France	-1.59	-1.75	-1.55	-1.74
Germany	-1.44	-2.40	-1.55	-2.25

$R_{n,t}$ and $r_{m,t}$ are the long term and short term interest rates respectively. The ADF and PP test regressions include a constant term. As shown, the unit root hypothesis cannot be rejected for any interest rate at any level of significance.

Table 5
Testing for cointegration: JMN and LST approaches

Country	$(p-r)$	$LR_{JMN}(r_0)$	$LR_{LST}(r_0)$	p-values JMN	p-values LST	k [a]	β_R	β_r
Bulgaria	2	20.77	9.89	0.164	0.124	7	NA	NA
	1	7.11	0.09	0.301	0.818			
Cyprus	2	39.91**	25.99**	0.001	0.001	2	1.00**	-1.03**
	1	7.05	4.43	0.464	0.171		(13.24)	(13.24)
Czech Republic	2	69.96**	10.18*	0.000	0.063	7	1.00*	-1.45*
	1	17.69	0.38	0.205	0.999		(15.00)	(15.48)
Estonia	2	30.99**	15.52**	0.003	0.014	1	1.00**	-0.78**
	1	8.84	0.99	0.213	0.372		(10.30)	(13.55)
Hungary	2	43.44**	16.03**	0.047	0.004	1	1.00**	-0.84**
	1	8.52	6.34	0.798	0.960		(10.68)	(10.58)
Latvia	2	19.28	8.73	0.211	0.187	4	NA	NA
	1	7.31	0.01	0.257	0.958			
Lithuania	2	57.66**	10.64*	0.004	0.060	10	1.00**	-0.81**
	1	19.21	3.45	0.212	0.999		(12.29)	(11.00)
Malta	2	29.98	6.01	0.593	0.318	3	NA	NA
	1	9.05	1.00	0.832	0.999			
Poland	2	27.44	5.49	0.112	0.505	5	NA	NA
	1	8.11	0.14	0.459	0.764			
Romania	2	25.60	3.84	0.158	0.732	8	NA	NA
	1	8.84	0.11	0.339	0.792			
Slovakia	2	52.45**	23.68**	0.000	0.000	11	1.00**	-0.90**
	1	9.91	1.41	0.252	0.276		(20.78)	(19.87)
Slovenia	2	59.30**	13.93*	0.000	0.098	1	1.00**	-2.63**
	1	11.70	0.00	0.136	0.999		(7.81)	(18.34)

[a] k denotes the lag length in the VECM. R and r denote the long and short rate, respectively. The $\beta's$ are the parameters of the cointegrating vectors, normalized on the long rate Numbers in parentheses in the β_R and β_r columns are likelihood ratio test statistics for $H_0 : \beta_i = 0$. ** and * denote rejection of the null hypothesis at the 0.05 and the 0.10 level of significance, respectively. NA stands for “Not Applicable”.

Table 6
Testing for cointegration: Johansen methodology

Country	$(p-r)$	Trace	λ_{max}	k [a]	Model	β_R	β_r
France	2	13.37*	11.39*	6	0	1.00*	-1.18*
	1	1.97	1.97			(9.42)	(9.32)
Germany	2	13.89*	11.94*	5	0	1.00*	-1.37*
	1	1.95	1.95			(9.94)	(9.84)

[a] k denotes the lag length in the VECM. The Trace and the λ_{max} statistics are compared to the critical values of MacKinnon, Haug and Michelis (1999). R and r denote the long and short rate, respectively. The $\beta's$ are the parameters of the cointegrating vectors, normalized on the long rate. Numbers in parentheses are likelihood ratio test statistics for $H_0 : \beta_i = 0$. * denotes rejection of the null hypothesis at the 0.05 level of significance. NA stands for "Not Applicable".

Table 7
Testing if the long rate or short rate is the common trend

Country	L_R	L_r
Cyprus	0.26 (0.608)	9.62* (0.002)
Czech Republic	1.41 (0.235)	14.76*(0.000)
Estonia	1.64 (0.200)	8.31* (0.004)
Hungary	2.50 (0.114)	4.80* (0.029)
Lithuania	0.13 (0.716)	13.00* (0.000)
Slovakia	1.88 (0.171)	8.88* (0.003)
Slovenia	0.61 (0.436)	14.10* (0.000)
France	0.02 (0.879)	6.65* (0.010)
Germany	2.12 (0.145)	4.76* (0.029)

The L-statistics, L_R and L_r , are computed under the null hypothesis that either the long rate or the short rate is the common trend, respectively Each statistic is distributed as χ_1^2 under the null. Numbers in parentheses are p-values * denotes rejection of the null hypothesis at the 0.05 level of significance.

Table 8
Common trend linkages between France and Germany

Group	$(p-r)$	Trace	λ_{max}	k [a]	Model	$L-$statistic
EMU-2	2	22.03*	21.29*	11	0	10.14* (0.001)
	1	0.74	0.74			0.40 (0.527)

[a] k is the lag length in the VECM. The first and second $L-$statistics are computed under the null hypothesis that either the French or the German common trend is the shared common trend, respectively. Under the null each $L-$statistic is distributed as χ_1^2. Numbers in parentheses are p-values.
* denotes rejection of the null hypothesis at the 0.05 level of significance.

Table 9

Common trend linkages between the new EU countries and the core-EMU: New EU countries for which the long and short rates cointegrate.

Group	$(p-r)$	Trace	$\lambda_{\max}$	k [a]	Model	$L-$statistic
Cyprus-EMU	2	15.21**	13.15**	11	0	0.11
	1	2.06	2.06			(0.738)
Czech Republic-EMU	2	15.48**	13.97**	7	0	0.65
	1	1.51	1.51			(0.419)
Estonia-EMU	2	12.69**	11.00*	1	0	0.11
	1	1.69	1.69			(0.742)
Hungary-EMU	2	7.26	7.12	1	0	NA
	1	0.14	0.14			
Lithuania-EMU	2	21.34**	21.21**	1	0	0.03
	1	0.13	0.13			(0.859)
Slovakia-EMU	2	14.26**	14.12**	12	0	1.91
	1	0.15	0.15			(0.167)
Slovenia-EMU	2	12.78**	12.56**	9	0	1.73
	1	0.22	0.22			(0.189)

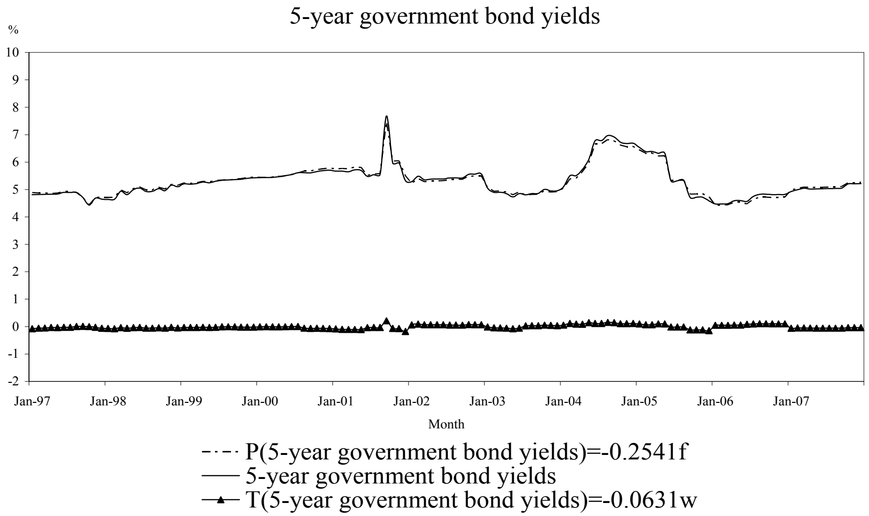
[a] k is the lag length in the VECM. The $L-$statistics are computed under the null hypothesis that the French/German permanent component determines the common trend. Under the null each $L-$statistic is distributed as χ_1^2. Numbers in parentheses are p-values. ** and * denote rejection of the null hypothesis at the 0.05 and the 0.10 level of significance, respectively. NA stands for “Not Applicable”.

Table 10
Common trend linkages between the new EU countries and the core-EMU: New EU countries for which the long and short rates do not cointegrate.

Country	Interest rate	$(p-r)$	Trace	λ_{max}	k [a]	Model	$L-$statistic
Bulgaria	Long rate	2	4.27	4.02	4	0	NA
		1	0.25	0.25			
	Short rate	2	5.58	5.43	8	0	NA
		1	0.15	0.15			
Latvia	Long rate	2	30.83*	30.78*	12	0	0.15
		1	0.05	0.05			(0.701)
	Short rate	2	3.63	3.61	9	0	NA
		1	0.01	0.01			
Malta	Long rate	2	13.93*	13.89*	8	0	1.68
		1	0.04	0.04			(0.195)
	Short rate	2	8.15	6.59	3	0	NA
		1	1.56	1.56			
Poland	Long rate	2	13.67*	13.47*	1	0	2.61
		1	0.21	0.21			(0.107)
	Short rate	2	6.86	5.31	1	0	NA
		1	1.54	1.54			
Romania	Long rate	2	7.57	7.55	4	0	NA
		1	0.03	0.03			
	Short rate	2	7.06	6.67	11	0	NA
		1	0.39	0.39			

k is the lag length in the VECM The $L-$statistics are computed under the null hypothesis that the French/German permanent component determines the common trend. Under the null each $L-$statistic is distributed as χ_1^2. Numbers in parentheses are p-values. * denotes rejection of the null hypothesis at the 0.05 level of significance. NA stands for “Not Applicable”.

Figure 1: P-T Decomposition of Interest rates: Cyprus



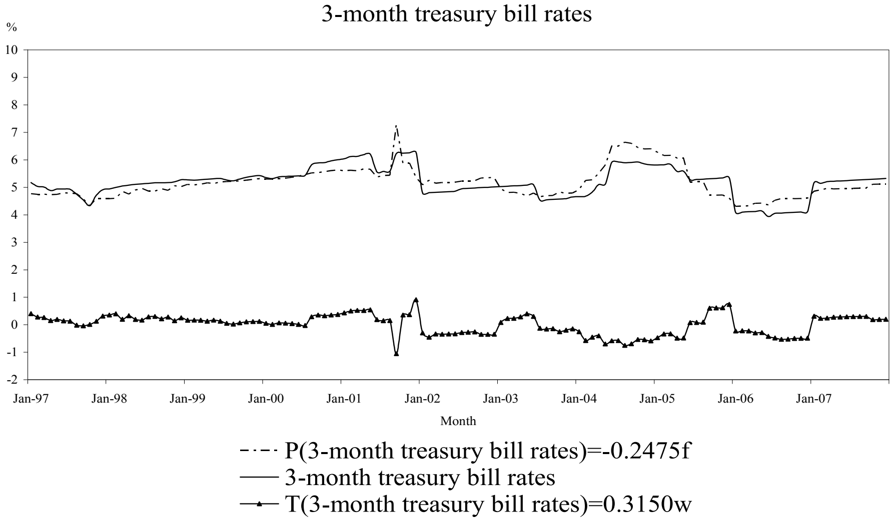
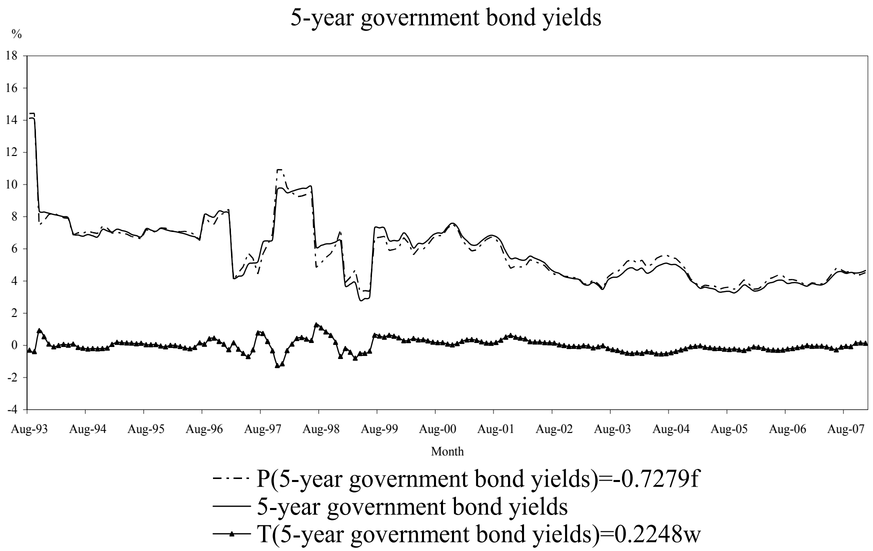


Figure 2: P-T Decomposition of Interest rates: Czech Republic



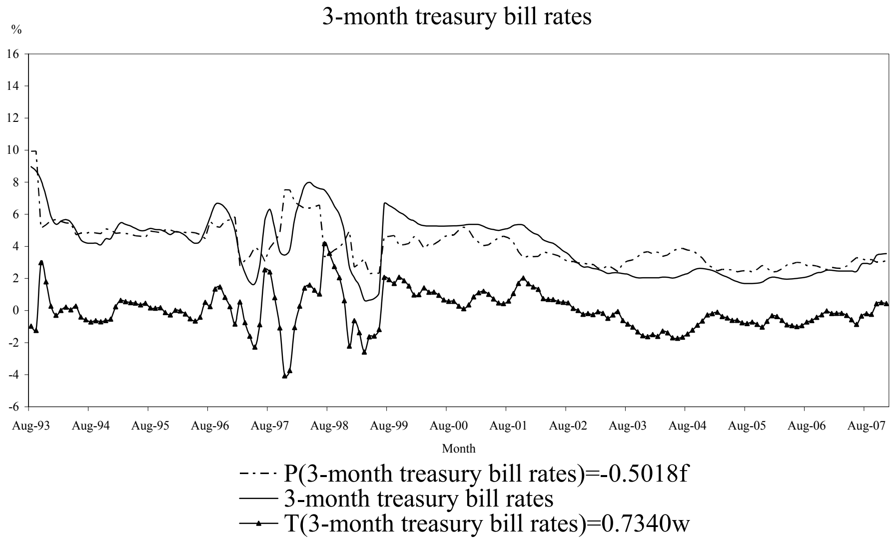
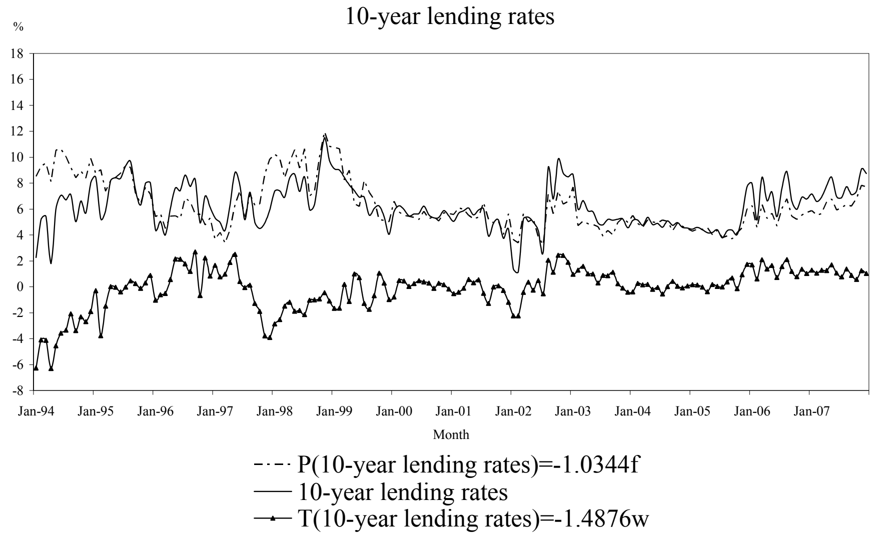


Figure 3: P-T Decomposition of Interest rates: Estonia



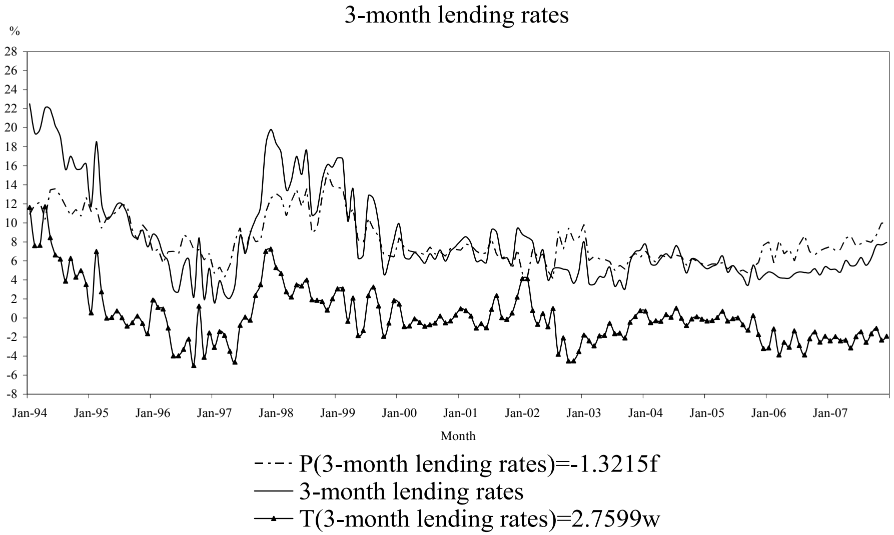
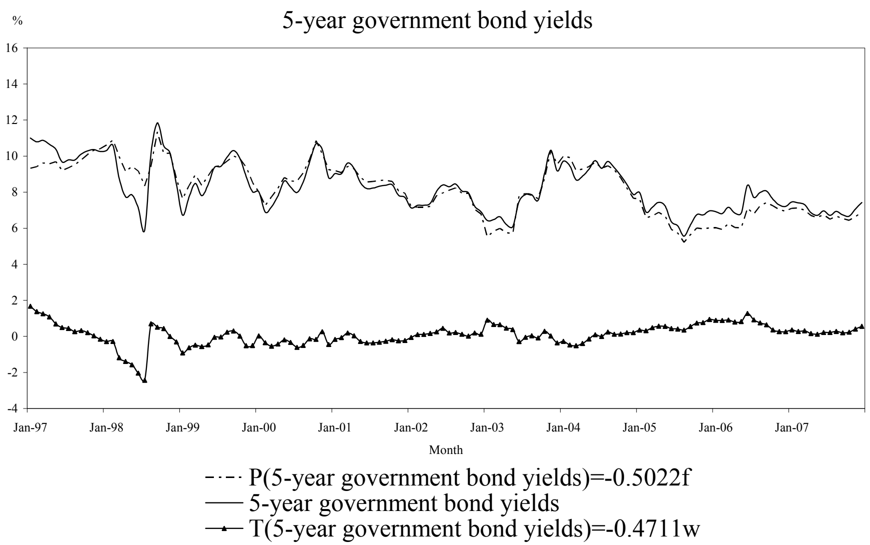


Figure 4: P-T Decomposition of Interest rates: Hungary



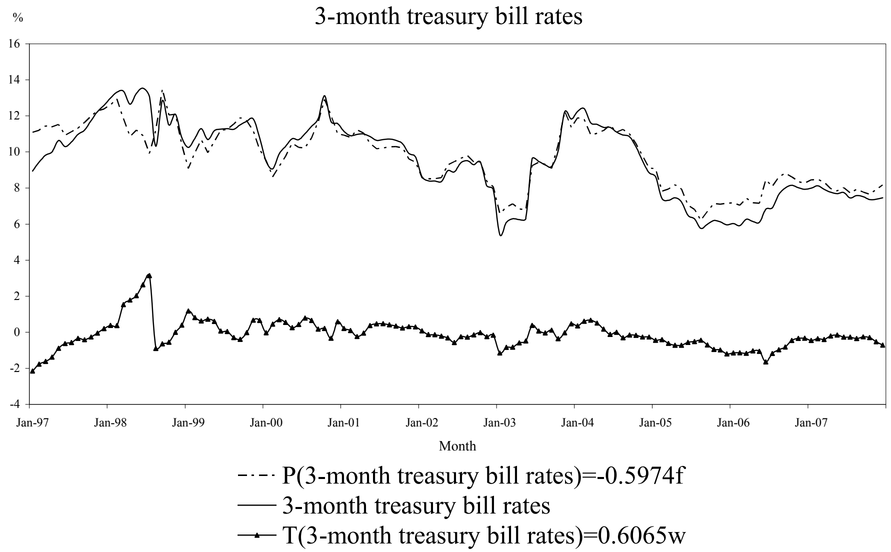


Figure 5: P-T Decomposition of Interest rates: Lithuania

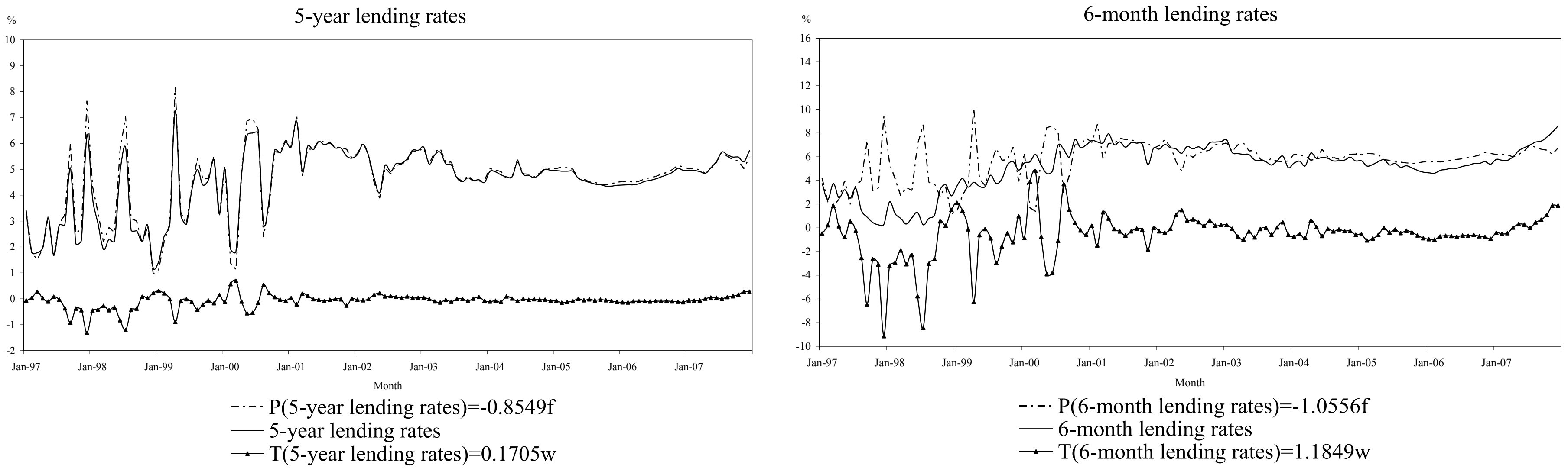


Figure 6: P-T Decomposition of Interest rates: Slovakia

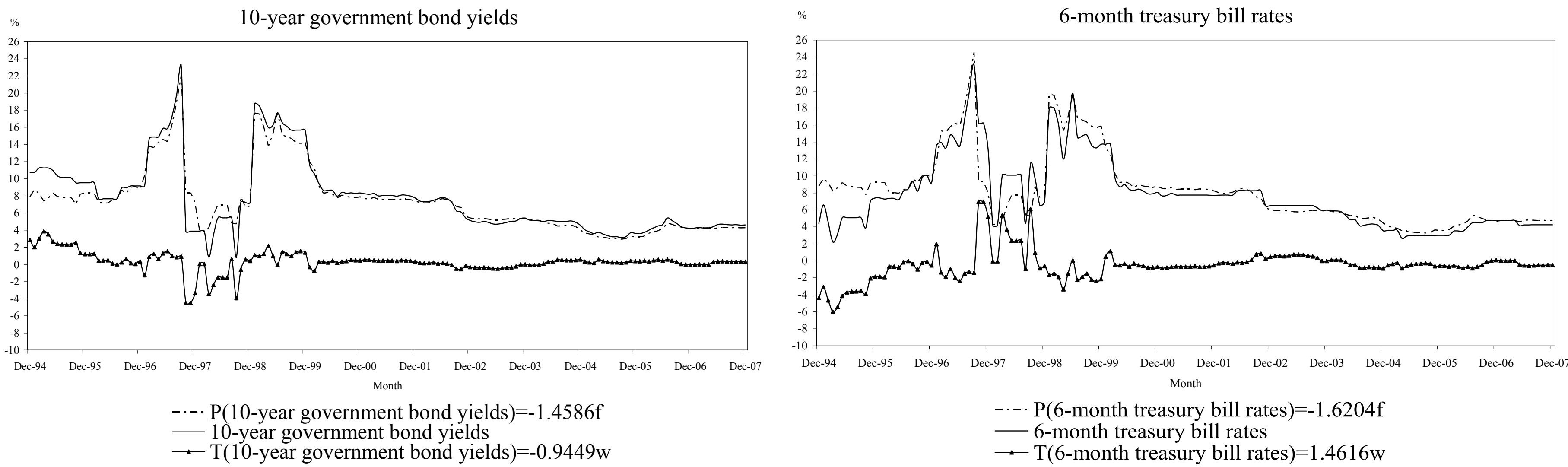


Figure 7: P-T Decomposition of Interest rates: Slovenia

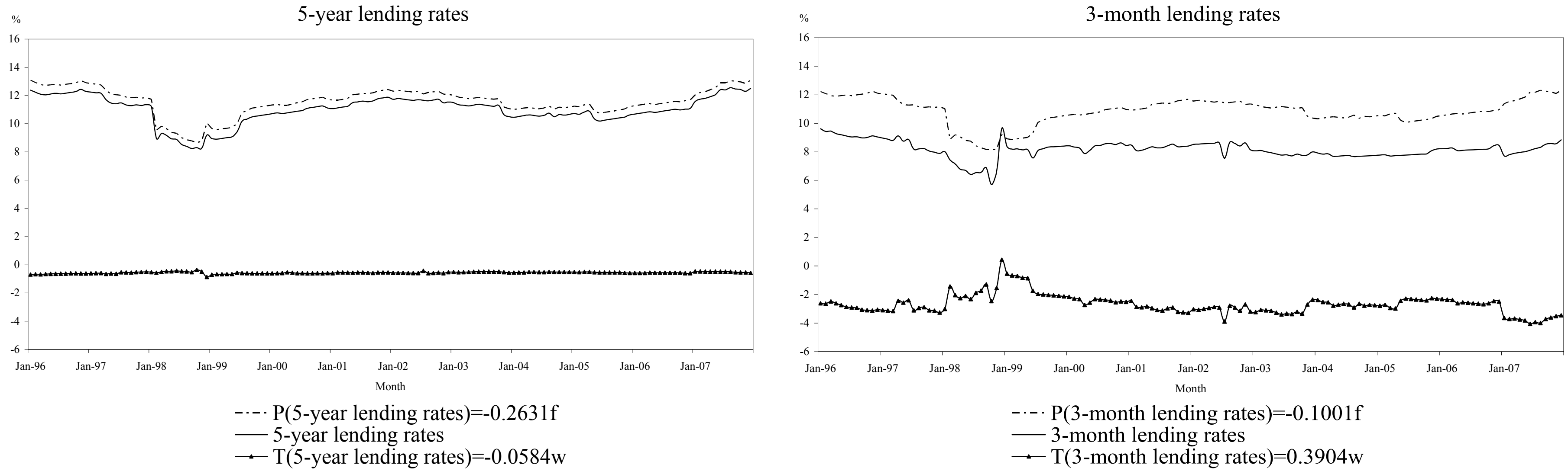


Figure 8: P-T Decomposition of Interest rates: France

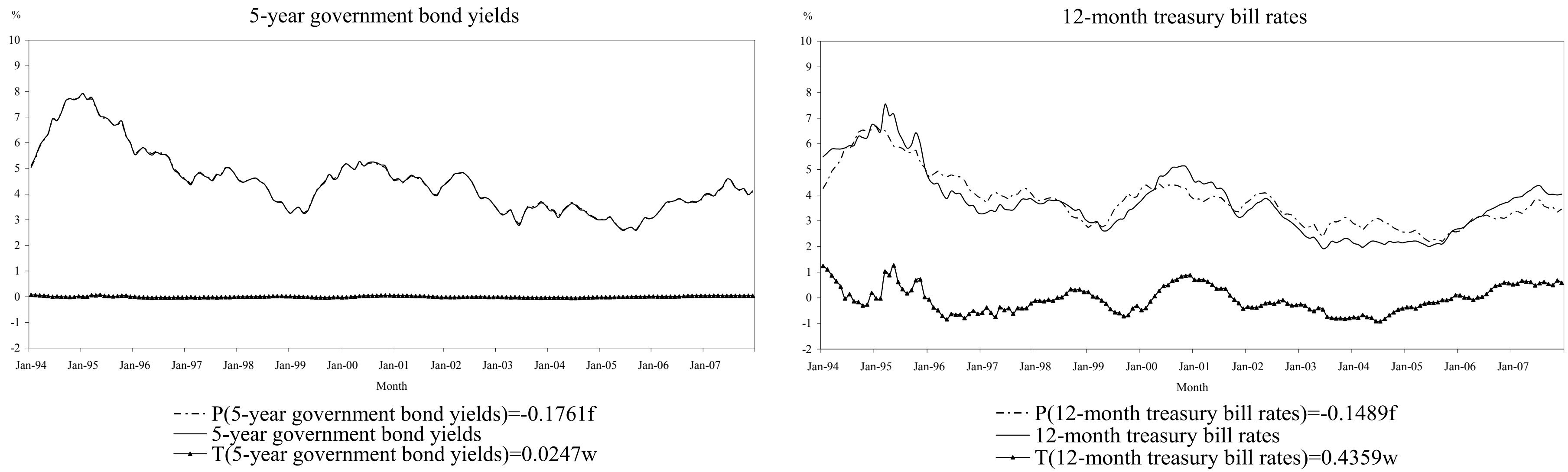


Figure 9: P-T Decomposition of Interest rates: Germany