The Term Structure of Interest Rates in the European Union

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Abstract

This paper uses cointegration and common trends techniques to investigate empirically the expectations hypothesis of the term structure of interest rates among the original 15 EU countries. By decomposing each term structure into its transitory and permanent components, we also examine whether the short or the long rate is weakly exogenous and thus determine the long run behavior of each term structure. The empirical results support the expectations theory of the term structure of interest rates for all the EU-15 countries. They also indicate that the long term interest rates are weakly exogenous for almost all the countries in our sample. Further, we investigate if the expectation theory of the term structure of interest rates is affected by other exogenous variables such as nominal and real exchange rates, inflation rates, inflation variance, money growth and its variance. Our evidence suggests that the inclusion of the other exogenous variables does not affect the expectations hypothesis for most of the EU-15 countries.

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1 Introduction

The term structure of interest rates, which gives the yield to maturity of all securities of all maturities at a given point in time, has been the focus among monetary economist and monetary policy officials for a long time. There are several reasons for this. First, the shape of the term structure or yield curve provides valuable information about the future movements of the long term interest rates, and hence the long term investment prospects and economic growth of a country. Second, the spread between the long and current short rates has been found to be a better predictor of a country's monetary policy stance than the level of the short term interest rates or the rate of monetary growth allowed by a central bank. Third, empirical studies have suggested that the interest rate spread has good predictive power about the future movement on economic activity, and hence the cyclical behavior of an economy (Estrella and Hardouvelis (1991), Lahiri and Wang (1996), Estrella and Mishkin (1998)).

Among the theories that have been developed in order to explain the term structure of interest rates and hence the yield curve, which in general, could be upward slopping, flat or even downward slopping, the most famous is the expectations theory of the term structure (ETTS). According to the ETTS, the interest rate on a long-term security is an average of the current short rate and the expected future rates on securities of shorter maturity. If future short rates are expected to be constant over time, then the yield curve will be flat or a horizontal line at the level of the current short rate. If on the other hand future short rates are expected to rise, then the yield curve will be upward sloping. Conversely, if the future short rates are expected to fall, the yield curve will be downward slopping. Thus, if the expectations theory of the term structure is correct, an upward slopping yield curve reflect expectations of rising future short rates. Such expectations could be caused by many factors, including increased uncertainty about future economic conditions, inflationary expectations or uncertainty about government policies.

The literature on the term structure of interest rates is large and growing; see Shiller (1990) for an excellent survey of theory and empirical studies. Among others, Hall, Anderson and Granger (1992) used monthly data from 1970:3 to 1988:12 to analyze the term structure of 12 yield series on US Treasury bills. Using multivariate cointegration methods and the vector error correction model approach (VECM), these authors found evidence supportive of the ETTS for the US. Hardouvelis (1994) used monthly data of different time spans to investigate empirically the ETTS for the G7 countries: Canada, France, Germany, Italy, Japan, the UK and the USA. Based on OLS regression and VAR techniques, he found that the ETTS holds for all countries except the USA. Gerlach and Smets (1997) studied the term srtuctures in a sample 17 countries with time spans between 10 and 30 years, and monthly data for 1-month, 3-month, 6-month and 12-month euro rates. Using cross-sectional regression analysis, they concluded that for most of the countries the ETTS is compatible with the data. Jondeau and Ricart (1999) adopted the VECM approach to test the ETTS on French, German, UK and US euro rates. Using monthly data for 1-month, 3-month, 6-month and 12-month euro rates from 1975:1 to 1997:12, they could not reject the ETTS for French and UK rates, but they rejected it for German and US rates.

Even though most of the studies to date have been concerned with testing the ETTS for a specific country or group of countries, the decomposition of the term structure into its transitory (i.e. the $I(0)$ cointegrating relations) and permanent (i.e. the $I(1)$ common trends) components can be equally useful and insightful. The cointegration relations, which capture the spreads, contain information about the effects of short run monetary policies, while the common trends contain information about long run macroeconomic conditions and expectations about the course of future government policies. 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 a sample of monthly observations from 1979:3 to 1995:6, they found that the ETTS holds for these countries. Also, by decomposing each term structure into its transitory and permanent components, these authors found that the long term interest rate is the source of the common trend in each country, and that 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 for 6 EU countries (Belgium, France, Germany, Italy, The Netherlands and the UK), using a sample of monthly observations from 1974:1 to 1996:3.

In the present paper we contribute to the existing literature in several ways. First, we use the most recent data available from the 1980s to the present and the VECM approach (Johansen (1988, 1991, 1994, 1995)) to test the ETTS of interest rates for the EU-15 countries. The evidence suggests that the ETTS holds for all countries of our sample.

Second, we use the Gonzalo-Granger methodology in order decompose each interest rate into its permanent and transitory components. Further, we identify and estimate the common trends that drive the cointegrating relations among the interest rates in each country's term structure. Hypothesis testing in this framework provides information as to which interest rates contain the common trend(s).

As mentioned above, future short rates are affected by many factors, including increased uncertainty about future economic conditions, inflationary expectations or uncertainty about government policies. Consequently, under the ETTS the long term rates are also affected. All the above studies concerning the ETTS do not include in the analysis any of the possibly non-stationary proxies mentioned above.

Inclusion of such exogenous non-stationary variables in the analysis necessitates estimation of different vector error-correction models (Pesaran, Shin and Smith (2000)). It also necessitates estimation of different critical values in order to evaluate the number of cointegrating vectors (MacKinnon, Haug and Michelis (1999),Pesaran, Shin and Smith (2000)). As a third contribution to the literature we test the validity of the expectations hypothesis in the context of having exogenous $I(1)$ variables into the model. Also, by testing the significance of the VECMs' adjustment coefficients, allows us to indicate which interest rates are weakly exogenous and thus, comprise together with the exogenous non stationary variables, the long run driving forces of the cointegrated systems. These results are then compared with the results of the model without the inclusion of the exogenous $I(1)$ variables. As exogenous variables we used nominal and real exchange rates, inflation rates, inflation variance, money growth and its variance. In brief, the results indicate that the inclusion of the exogenous variables does not affect the expectations hypothesis for almost all the EU-15 countries. Such analysis is useful to policy makers who wish to know where the short term or the long term interest rate is an exogenous variable.

The rest of the paper is organized as follows. In Section 2 we describe the ETTS of interest rates and outline the models for cointegration and common trends that we use in the paper. In Section 3 we describe the data and analyze the empirical results. In Section 4 we make some concluding remarks.

2 Theoretical Framework

2.1 The ETTS of Interest Rates

The ETTS of interest rates states that the yield to maturity of an $n-$period bond $R_{n,t}$ will equal an average of the current and future rates on a set of $m-$period short yields $r_{m,t}$, with $m < n$, plus the term premium. The relationship can be expressed in the following form

$$(1 + R_{n,t})^n = \varphi^*_{n,t} \prod_{i=0}^{n-1} (1 + E_t r_{m,t+i}), \tag{1}$$

where $\varphi^*_{n,t}$ is a possible non-zero but stationary $n-$period term premium and E_t is the expectations operator conditional on information up to and including time t. The equality in equation (1) is established by the condition of no arbitrage opportunities to investors willing to hold both short term and long term bonds. Log-linearizing equation (1) we get

$$R_{n,t} = \varphi_{n,t} + (1/n) \sum_{i=0}^{n-1} E_t r_{m,t+i}. \tag{2}$$

where $\varphi_{n,t} = \log(\varphi^*_{n,t})$. Equation (2) indicates that the yield of the $n-$period bond and the $m-$period short yields are functionally related. For the subsequent analysis it is convenient to re-express equation (2) as

$$R_{n,t} - r_{m,t} = \varphi_{n,t} + (1/n)\sum_{i=1}^{n} E_t\left(r_{m,t+i-1} - r_{m,t}\right). \tag{3}$$

The left hand side of equation (3) represents the spread between the $n-$period (long term) yield and the $m-$period (short term) yield. Assuming that the yields are $I(1)$ and cointegrated the right hand side of equation (3) is stationary. It follows that the left hand side of equation (3) is stationary and that $(1, -1)'$ is a cointegration vector linking the long term and short term interest rates.

In general, an implication of the ETTS of interest rates is that long term and short term yields in any maturity comparison for a given currency should be cointegrated, with cointegrating vector $(1, -1)'$. Cointegration between interest rates over the term structure of a currency is consistent with the idea that market forces continuously adjust to correct any temporary disequilibrium, so that yields on different maturities do not drift apart permanently, which would otherwise give rise to arbitrage opportunities. The above analysis can be replicated for each pair of short term and long term yields, so if the ETTS holds, there should be $p-1$ independent cointegrating vectors and a single shared common trend across the term structure of p yields. In what follows, we analyze the time series and cointegration properties of the bond yields on different maturities of the 15 original EU countries, given the insights of equation (3).

2.2 The Johansen Models for Cointegration and Common Trends

In this section we outline the models that we employ in the subsequent empirical analysis. The maximum likelihood theory of systems of potentially cointegrated stochastic variables assumes that the variables are integrated of order one, or $I(1)$, and that the data-generating process is a Gaussian[1] vector autoregressive model of finite order l, or $VAR(l)$ which may possibly include some deterministic components. If Z_t denotes a $p \times 1$ vector of $I(1)$ variables, the $VAR(l)$ model can be written as

$$\Phi(L)(Z_t - \mu - \gamma t) = \epsilon_t \ , \tag{4}$$

where $\Phi(L)$ is a $p \times p$ matrix polynomial of order l in the lag operator L, μ and γ are $p \times 1$ vectors of unknown coefficients and ϵ_t is a $p \times 1$ multivariate normal random error vector with mean vector zero and variance matrix Ω that is positive definite and independent across time periods. The $VAR(l)$ model

[1]The Gaussian assumption is not necessary, but it is convenient for the derivation of asymptotic results.

in equation (4) can be written in a vector error-correction model (VECM) form as

$$\Delta Z_t = \Pi Z_{t-1} + \sum_{i=1}^{l-1} \Gamma_i \Delta Z_{t-i} + \mu_0 + \mu_1 t + \epsilon_t, \qquad t = 1, ..., T \quad , \tag{5}$$

where Π and Γ_i are $p \times p$ matrices of coefficients and μ_0 and μ_1 are $p \times 1$ vectors of constant and trend coefficients, respectively. The hypothesis of cointegration can be stated in terms of the rank of the long run matrix Π in equation (5). Under the hypothesis of cointegration, this matrix can be written as

$$\Pi = \alpha\beta' \tag{6}$$

where α and β are $p \times r$ matrices of full rank. If $r = 0$, then $\Pi = 0$, which means that there is no linear combination of the elements of Z_t that is stationary. The other extreme case is when the rank of the Π matrix equals p. In this case Z_t is a stationary process. In the intermediate case, when $0 < r < p$ there are r stationary linear combinations of the elements of Z_t and $p - r$ non stationary common stochastic trends.

Under the hypothesis of cointegration $\Pi = \alpha\beta'$, where α and β are $p \times r$ matrices of full rank, the relation between α and the deterministic term $\mu_t \equiv \mu_0 + \mu_1 t$ is crucial for the properties of the process Y_t. To see this, first we decompose μ_0 and μ_1 in the directions of α and $\alpha_\perp$, where $\alpha_\perp$ is a $p \times (p - r)$ matrix that is the orthogonal complement to α:

$$\mu_i = \alpha\beta_i + \alpha_\perp\gamma_i, \qquad i = 0, 1 \tag{7}$$

where $\beta_i = (\alpha'\alpha)^{-1}\alpha'\mu_i$ and $\gamma_i = (\alpha'_\perp\alpha_\perp)^{-1}\alpha'_\perp\mu_i$. Next, following Johansen (1994), we consider the following five submodels, which are ordered from the most to the least restrictive:

Model 0: $\mu_t = 0$

Model 1*: $\mu_t = \alpha\beta_0$

Model 1: $\mu_t = \alpha\beta_0 + \alpha_\perp\gamma_0$

Model 2*: $\mu_t = \alpha\beta_0 + \alpha_\perp\gamma_0 + \alpha\beta_1 t$

Model 2: $\mu_t = \alpha\beta_0 + \alpha_\perp\gamma_0 + (\alpha\beta_1 + \alpha_\perp\gamma_1)t$

The interpretation of these models becomes clear in the context of the solution of Z_t in equation (5). The solution is given by

$$Z_t = C\sum_{i=1}^{t} \epsilon_t + \frac{1}{2}\tau_2 t^2 + \tau_1 t + \tau_0 + W_t + A \tag{8}$$

where W_t is a stationary process, A is a vector such that $\beta' A = 0$, $C = \beta_\perp(\alpha'_\perp \Gamma \beta_\perp)^{-1}\alpha'_\perp$, $\Gamma = I_p - \sum_{i=1}^{k-1}\Gamma_i$, $\beta_\perp$ is a $p \times (p-r)$ matrix of full rank that is orthogonal to β and $\tau_2 = C\mu_1$.

Using equation (8), Johansen (1994) shows that the five submodels imply different behavior for the process Z_t and the cointegrating relations $Z'Y_t$. Briefly, in Model 0, Z_t has no deterministic trend and all the stationary components have zero mean. In Model 1*, Z_t has neither quadratic or linear trend. However, both Z_t and the cointegrating relations $\beta' Z_t$ are allowed a constant term. In Model 1, Z_t has a linear trend, but the cointegrating relations $\beta' Z_t$ have no linear trend. In Model 2*, Z_t has no quadratic trend but Z_t has a linear trend that is present even in the cointegrating relations. In Model 2, Z_t has a quadratic trend but the cointegrating relations $\beta' Z_t$ have only a linear trend.

Because of the normality assumption, one can easily test for the reduced rank of the Π matrix using the maximum likelihood approach. This procedure gives at once the maximum likelihood estimators (MLE) of α and β and the eigenvalues needed in order to construct the likelihood ratio tests. Using the technique of the reduced rank regression, the MLE of α and β are obtained by regressing ΔZ_t and Z_{t-1} on $\Delta Z_{t-1} ... \Delta Z_{t-l}$ and μ_t (allowing for the restrictions imposed by each of the five models). These auxiliary regressions give residuals R_{0t} and R_{1t} respectively, and residual product matrices

$$S_{ij} = T^{-1}\sum_{t=1}^{T} R_{it}R'_{jt}, \qquad i,\ j = 0,\ 1 \tag{9}$$

Solving the eigenvalue problem

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

for eigenvalues $1 > \widehat{\lambda}_1 > ... > \widehat{\lambda}_p > 0$ and eigenvectors $\widehat{V} = (\widehat{v}_1 ... \widehat{v}_p)$, normalized such that $\widehat{V}' S_{11} \widehat{V} = I$, one gets the MLE of α and β as $\widehat{\alpha} = S_{01}\ \widehat{\beta}$ and $\widehat{\beta} = (\widehat{v}_1 ... \widehat{v}_r)$, where $(\widehat{v}_1 ... \widehat{v}_r)$ are the eigenvectors associated with the r largest eigenvalues of equation (10).

In testing the null hypothesis that $rank(\Pi) \leq r$ against the alternative hypothesis that $rank(\Pi) = p$, the likelihood ratio statistic, called also the Trace statistic by Johansen and Juselius (1990), is given by

$$Trace = -T\sum_{i=r+1}^{p} \ln(1 - \widehat{\lambda}_i) \tag{11}$$

The testing is performed sequentially for $r = 0, ..., p-1$ and it terminates when the null hypothesis is not rejected for the first time.

It is also possible to test the null hypothesis that $rank(\Pi) = r$ against the alternative that $rank(\Pi) = r + 1$. In this case, the likelihood ratio statistic, which is called the $\lambda_{\max}$ statistic, is given by

$$\lambda_{\max} = -T \ln(1 - \widehat{\lambda}_{r+1}). \tag{12}$$

Of course, the $\lambda_{\max}$ statistic is equal to the Trace statistic when $p - r = 1$.

MacKinnon, Haug and Michelis (1999) have computed highly accurate critical values for the Trace statistic in equation (11) and the $\lambda_{\max}$ statistic in equation (12), using the response surface methodology. These critical values differ substantially from those in the existing literature, especially when the dimension of the VECM is large; e.g., see Osterwald-Lenum (1992) or Johansen (1995). In this study, we use these new critical values for testing hypotheses[2].

In respect to the common trends, it is clear from equation (8) that the common trends in Z_t are contained in the first term of that expression. Given the definition of C, Johansen (1995, p. 41) defines the common trends by the cumulated disturbances $\alpha'_{\perp} \sum_{i=1}^{t} \epsilon_t$. Assuming that the common trends are a linear combination of Z_t, in the form $f_t = \alpha'_{\perp} Z_t$, Gonzalo and Granger proposed the following decomposition of any cointegrating system into its permanent and transitory (P-T) components:

$$Z_t = A_1 f_t + A_2 z_t \quad , \tag{13}$$

where, in addition to f_t, $z_t = \beta' Z_t$, $A_1 = \beta_{\perp} \left(\alpha'_{\perp} \beta_{\perp}\right)^{-1}$ and $A_2 = \alpha \left(\beta' \alpha\right)^{-1}$. Assuming that $\mu_t = 0$, they also derived the MLE of $\alpha_{\perp}$ as the eigenvectors corresponding to the $(p - r)$ smallest eigenvalues of the problem

$$\left| \lambda S_{00} - S_{01} S_{11}^{-1} S_{10} \right| = 0. \tag{14}$$

Solving equation (14) for eigenvalues $1 > \widehat{\lambda}_1 > ... > \widehat{\lambda}_p > 0$ and eigenvectors $\widehat{M} = (\widehat{m}_1 ... \widehat{m}_p)$, normalized such that $\widehat{M}' S_{00} \widehat{M} = I$, one gets the MLE of $\alpha_{\perp}$ as $\widehat{\alpha}_{\perp} = (\widehat{m}_{r+1} ... \widehat{m}_p)$.

Given this framework, it is easy to test whether or not certain linear combinations of Z_t can be common trends. Null hypotheses on $\alpha_{\perp}$ have the following form

$$H_0 : \alpha_{\perp} = G\theta \tag{15}$$

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 $p - r \leq m \leq p$. To carry out the test, one solves the eigenvalue problem

$$\left| \lambda G' S_{00} G - G' S_{01} S_{11}^{-1} S_{10} G \right| = 0 \tag{16}$$

[2] The latest edition of EViews 5 has also adopted the MacKinnon et al.(1999) critical values.

for eigenvalues $1 > \widehat{\lambda}_1^* > ... > \widehat{\lambda}_m^* > 0$, and eigenvectors $\widehat{M}^* = (\widehat{m}_1^* ... \widehat{m}_m^*)$, normalized such that $\widehat{M}^{*\prime}(G'S_{00}G)\widehat{M}^* = I$. Choose $\widehat{\theta}_{m\times(p-r)} = (\widehat{m}_{(m+1)-(p-r)} ... \widehat{m}_m)$ and $\widehat{\alpha}_\perp = G\widehat{\theta}$. The likelihood ratio test statistic for testing H_0 is given by

$$L = -T \sum_{i=r+1}^{p} \ln \left[(1 - \widehat{\lambda}_{i+(m-p)}^*)/(1 - \widehat{\lambda}_i) \right]. \tag{17}$$

In the Section 3, we use the $L-$statistic in (17) to test the statistical significance of the $\alpha_\perp$'s of the long term and the short term interest rate of the bond yields on different maturities of the 15 original EU countries. A significant $\alpha_\perp$ implies that the respective interest rate is weakly exogenous and dominates the common trend in the cointegrating system.

Gonzalo and Granger have derived their results assuming that $\mu_t = 0$ in the VECM. In the present study, our model selection tests indicated that this is a restrictive assumption and Model 1* describes best some variables in our data set. For this reason, we extent the VECM by the inclusion of a constant term. This extension does not invalidate the asymptotic distributions of $\widehat{\alpha}_\perp$ and the $L-$statistic in (17). This follows from the fact that in computing these statistics, we obtain the residual matrices R_{0t} and R_{1t} by reduced rank regression of ΔZ_t and $(Z_{t-1}, 1)$ on the lagged differences $\Delta Z_{t-1} ... \Delta Z_{t-k}$. Then, the χ^2-distribution of the $L-$statistic follows from the results in Johansen (1995); (see Corollary 11. 2, p. 161) and the duality of $\widehat{\alpha}_\perp$ and $\widehat{\beta}$ (p. 128).

2.3 The Pesaran-Shin-Smith (PSS) Models for Cointegration, with Exogenous $I(1)$ Variables in the VECMs

In this section, we briefly describe the models that arise in the PSS framework. Based on equation (5), let Z_t be partitioned into an $m-$vector Y_t and a $k-$vector X_t, where $p \equiv m + k$, and X_t is assumed to be weakly exogenous with respect to Π. By partitioning the error term ϵ_t conformably with $Z_t = (Y_t', X_t')'$, as $\epsilon_t = (\epsilon_{yt}', \epsilon_{xt}')'$ and its variance matrix as $\Omega = \begin{bmatrix} \Omega_{yy} & \Omega_{yx} \\ \Omega_{xy} & \Omega_{xx} \end{bmatrix}$, we can express ϵ_{yt} conditionally in terms of ϵ_{xt} as

$$\epsilon_{yt} = \Omega_{yx}\Omega_{xx}^{-1}\epsilon_{xt} + u_t \quad , \tag{18}$$

where $u_t \sim N(0, \Omega_{uu})$, $\Omega_{uu} \equiv \Omega_{yy} - \Omega_{yx}\Omega_{xx}^{-1}\Omega_{xy}$ and u_t is independent of ϵ_{xt}. Substituting (18) into (5) together with a similar partitioning of the parameters $\Pi = (\Pi_y', \Pi_x')'$, $\Gamma_i = (\Gamma_{yi}', \Gamma_{xi}')'$ with $i = 1, ..., l-1$, $\mu_0 = (\mu_{y0}', \mu_{x0}')'$ and $\mu_1 = (\mu_{y1}', \mu_{x1}')'$, we can easily derive the following conditional VECM for Y_t:

$$\Delta Y_t = \Pi_{y.x} Z_{t-1} + \sum_{i=1}^{l-1} \Psi_i \Delta Z_{t-i} + \Lambda \Delta X_t + c_0 + c_1 t + u_t, \qquad t = 1, ..., T \quad , \tag{19}$$

where $\Pi_{y.x} \equiv \Pi_y - \Omega_{yx}\Omega_{xx}^{-1}\Pi_x$, $\Psi_i \equiv \Gamma_{yi} - \Omega_{yx}\Omega_{xx}^{-1}\Gamma_{xi}$ with $i = 1, ..., l-1$, $\Lambda \equiv \Omega_{yx}\Omega_{xx}^{-1}$, $c_0 \equiv \mu_{y0} - \Omega_{yx}\Omega_{xx}^{-1}\mu_{x0}$ and $c_1 \equiv \mu_{y1} - \Omega_{yx}\Omega_{xx}^{-1}\mu_{x1}$.

Furthermore, under the assumption that the vector X_t is weakly exogenous with respect to Π, which requires $\Pi_x = 0$ and consequently $\Pi_{y.x} = \Pi_y$, equation (19) can be expressed as the following system of equations:

$$\Delta Y_t = \Pi_y Z_{t-1} + \sum_{i=1}^{l-1} \Psi_i \Delta Z_{t-i} + \Lambda \Delta X_t + c_0 + c_1 t + u_t \tag{20}$$

$$\Delta X_t = \sum_{i=1}^{l-1} \Gamma_{xi} \Delta Z_{t-i} + \mu_{x0} + \epsilon_{xt}, \qquad t = 1, ..., T \quad , \tag{21}$$

where $\mu_{x1} = 0$, $c_1 \equiv \mu_{y1}$and thus, $c_0 = -\Pi_y\mu + (\Gamma_y - \Omega_{yx}\Omega_{xx}^{-1}\Gamma_x + \Pi_y)\gamma$ and $c_1 = -\Pi_y\gamma$. It is clear from equation (21) that the elements of the vector X_t are not cointegrated among themselves. Also, we may regard X_t as the long run driving force for Y_t. Therefore, in the above framework, the cointegration analysis is based on the assumption that there are at most m cointegrating vectors and that $rank(\Pi) \equiv rank(\Pi_y)$.

The hypothesis of cointegration can be stated be stated in terms of the conditional long run impact matrix Π_y, which can be written as

$$\Pi_y = \alpha_y \beta_*' \tag{22}$$

where α_y and β_* are respectively $m \times r$ and $p \times r$ matrices of full rank. Again, if $r = 0$, then $\Pi_y = 0$, which means that there is no linear combination of the elements of Y_t that is stationary. The other extreme case is when the rank of the Π_y matrix equals m. In this case Y_t is a stationary process, if $k = 0$, but will in general be non stationary if X_t is $I(1)$. In the intermediate case, when $0 < r < m$ there are r stationary linear combinations of the elements of Y_t and $p - r$ common stochastic trends.

Under the hypothesis of equation (22), different restrictions on c_0 and c_1 are crucial in determining the properties of the process Y_t. Pesaran et al. (2000) derive the following five submodels of the general model of equation (19), which are ordered from the most to the least restrictive:

Case I: $c_0 = 0$ and $c_1 = 0$. That is $\mu = 0$ and $\gamma = 0$, which means that there are no intercepts and no trends in the VECM.

Case II: $c_0 = -\Pi_y \mu$ and $c_1 = 0$. Here $\gamma = 0$ and there are restricted intercepts and no trends in the VECM.

Case III: $c_0 \neq 0$ and $c_1 = 0$. Again $\gamma = 0$ and there are unrestricted intercepts and no trends in the VECM.

Case IV: $c_0 \neq 0$ and $c_1 = -\Pi_y \gamma$. In this case there are unrestricted intercepts and restricted trends in the VECM.

Case V: $c_0 \neq 0$ and $c_1 \neq 0$. In this case there are unrestricted intercepts and unrestricted trends in the VECM.

Since the PSS framework introduces exogenous $I(1)$ variables into the analysis, the five cases I to V above are not directly comparable to the five cases 0, 1*, 1, 2*, and 2 in Section 2.2 However, in the special case in which $k = 0$, when there are no exogenous variables in the VAR, cases I, II and IV of the PSS framework are the same as cases 0, 1*, and 2* of Section 2.2. However, cases III and V of the PSS framework, are different from cases 1 and 2 of Section 2.2, because the former do not allow for a linear and quadratic trend, respectively, in the level of the process Y_t, whereas the latter do allow for them (see McKinnon et al. (1999)).

As in the previous section, due to the normality assumption, one can easily test for the reduced rank of the Π_y matrix using the maximum likelihood approach. This procedure gives at once the maximum likelihood estimators (MLE) of α_y and β_* and the eigenvalues needed in order to construct the likelihood ratio tests. Using the technique of the reduced rank regression, the MLE of α_y and β_* are obtained by regressing ΔY_t and Z_{t-1} on $(\Delta X_t, \Delta Z_{t-1} ... \Delta Z_{t-l})$ and allowing for the restrictions on the deterministic components that imposed by each of the models I to V. These auxiliary regressions give residuals R_{Yt} and R_{Zt} respectively, and residual product matrices

$$S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R'_{jt}, \qquad i,\ j = Y,\ Z \tag{23}$$

The MLE of β_* is given by the eigenvectors corresponding to the r largest eigenvalues $1 > \tilde{\lambda}_1^* > ... > \tilde{\lambda}_m^* > 0$ of the eigenvalue problem

$$\left| \lambda^* S_{ZZ} - S_{ZY} S_{YY}^{-1} S_{YZ} \right| = 0 \quad , \tag{24}$$

while $\alpha_y = S_{YZ} \widehat{\beta}_*$

In the PSS framework, the null hypothesis that $rank(\Pi_y) \leq r$ against the alternative hypothesis that $rank(\Pi_y) = m$, can be tested by using the Trace statistic in equation (11). Again, the testing is performed sequentially for $r = 0, ..., m-1$ and it terminates when the null hypothesis is not rejected for the first time. The null hypothesis that $rank(\Pi_y) = r$ against the alternative that $rank(\Pi_y) = r+1$, can be tested by using the $\lambda_{\max}$ statistic in equation (12). Also in the PSS framework, the $\lambda_{\max}$ statistic is equal to the Trace statistic when $m - r = 1$. Critical values for the Trace statistic in equation (11) and the $\lambda_{\max}$ statistic in equation (12), in the context of having exogenous $I(1)$ variables in the VECM, have been computed by McKinnon et al. (1999) and Pesaran et al. (2000). These critical values will be used in the Section 3.4 for testing hypotheses.

3 Data and Empirical Results

3.1 Data

We collected data for 14 of the 15 original EU members. We excluded Luxembourg, for which data about the term structure of interest rates are not available. We worked on four interest rates for most of the countries of our sample: one short term treasury bill yield (either 3-month or 12-month), one medium term government bond yield (either 2-year or 3-year) and two long term government bond yields (5-year and 10-year). The countries, for which were available data only for three interest rates will be indicated below. Our sample consists of monthly data of varying time spans for different countries determined by data availability. All interest rates are expressed in natural logarithms.

For Austria the time span is 1981:1 to 2004:12. Monthly end-of-period 12-month treasury bill rates and 2-year, 5-year and 10-year government bond yields were obtained from the Austrian Kontrollbank. For Belgium the time span is 1987:6 to 2004:12 and data for 3-month treasury bill rates and 3-year, 5-year, 10-year government bond yields were taken from the National Bank of Belgium. For Denmark the time span is 1984:1 to 2004:12. Danish National Bank provided us data only for 2-year, 5-year and 10-year government bond yields, since data for treasury bill yields were not available. For Finland we collected data for three interest rates (3-month treasury bills, 5-year and 10-year government bonds). The time span is 1991:8 to 2004:12 and the data were obtained from the Bank of Finland.

For France the time span 1986:7 to 2004:12. Data for 12-month treasury bill rates and 2-year, 5-year and 10-year government bond yields were obtained from the Bank of France. For Germany the time span 1979:1 to 2004:12, while data for 12-month treasury bill rates and 2-year, 5-year and 10-year government bond yields were obtained from the Bundesbank. For Greece the time span is 1993:9 to 2004:12. Data for 12-month treasury bill rates and 3-year, 5-year and 7-year government bond yields were collected from the Bank of Greece. We used the 7-year government bond yields instead of the 10-year, because the time span for the latter is quite small, since the country issued 10-year government bonds for the first time in 1997:6. For Ireland the time span is 1984:4 to 2004:12. Data for 2-year, 5-year and 10-year government bond yields were taken from the Central Bank of Ireland.

For Italy the time span is 1991:3 to 2004:12. Data for 12-month treasury bill rates and 3-year, 5-year and 10-year government bond yields were obtained from the Bank of Italy. The time span for The Netherlands is 1986:5 to 2004:12, while The Netherlands Bank provided us data for 12-month treasury bill rates and 5-year and 10-year government bond yields. For Portugal the time span is 1993:7 to 2004:12. Data for 12-month treasury bill rates and 2-year, 5-year and 10-year government bond yields were taken from the Bank of Portugal. The time span for Spain is 1989:7 to 2004:12 and the data for 12-month treasury bill rates and 3-year, 5-year and 10-year government bond yields were obtained from the Bank of Spain.

For Sweden the time span is 1990:1 to 2004:12. Data for 2-year, 5-year and 10-year government bond yields were obtained from the Central Bank of Sweden. Finally, for the United Kingdom the time span is 1982:6 to 2004:12. Data for 12-month treasury bill rates and 2-year, 5-year and 10-year government bond yields were provided to us by the Bank of England.

As mentioned above, we used nominal and real exchange rates, inflation rates, inflation variance, money growth and its variance as exogenous variables. All nominal and real exchange rates are expressed in natural logarithms. Monthly end-of-period nominal exchange rates (units of domestic currency per US dollars) for all the countries were obtained for the respective period of each country using line ae of the IFS. For the United Kingdom we used line ag of the IFS, which is the inverse of line ae. Monthly real exchange rates for all the countries were calculated for the same periods using the expression $(e * P^{US})/P$, where e is the nominal US dollar exchange rate of the country, P^{US} the US consumer price index (CPI) and P the domestic CPI[3]. Monthly CPI figures for all the countries were obtained from line 64 of the IFS. The CPI figures were also used to calculate monthly inflation rates. Inflation variance for each country was calculated using the expression $(\pi_t - \overline{\pi})^2$, where π is each country's inflation and $\overline{\pi}$ its mean. Real exchange rates, inflation rates and inflation variance were not calculated for Ireland due to lack of monthly data availability for the CPI.

For money we used M3 for all the countries, except for the United Kingdom for which we used M4. All money data were obtained from the respective central banks of the countries of our sample. Money

[3]Since the introduction of euro in 1/1/1999, the real exchange rate of each Eurozone member was calculated from the expression P^{US}/P, which is the PPP exchange rate.

growths were calculated for the respective period of each country using the expression $[(M_{t+1}/M_t) - 1] * 100$, where M is each country's money. Variance of money growth for each country was calculated using the expression $\left[M_t - \overline{M}\right]^2$, where $\overline{M}$ is the mean of each country's money growth.

3.2 Testing for the ETTS

In this section we report and analyze the unit root and cointegration results among the interest rates for each country. Before testing for cointegration, we tested each time series for unit roots using the Augmented Dickey-Fuller test at the 5 percent level of significance. The results are presented in the first panel of Table 1. To select the appropriate lag length for the ADF test regression, we used the Akaike's information criterion. As shown in Table 1, we fail to reject the unit root hypothesis in the interest rates for all countries. In all the cases we also tested for a second unit root. Based on these results we proceeded with cointegration analysis using the VECM in equation (5) above for each country, where Z_t contains the respective interest rates.

To select the appropriate lag length, l, in equation (5), we set up a separate VECM for each country and used the likelihood ratio test. Under the hypothesis $\Gamma_l = 0$, the likelihood ratio test is asymptotically distributed as χ^2 with p^2 degrees of freedom (see Johansen 1995, p. 21). Further, to determine which submodel describes best each set of variables, we tested the submodels 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:

$$0 \underset{r}{\subset} 1^* \underset{p-r}{\subset} 1 \underset{r}{\subset} 2^* \underset{p-r}{\subset} 2 .$$

Table 2 reports the cointegration results among the interest rates for each of the original 14 EU countries. Based on the Trace and the $\lambda_{\max}$ statistics at the 10 percent level of significance[4], we find evidence of $p-1$ cointegrating relations and a single shared common trend for Austria, Belgium, Denmark, Finland, Greece, The Netherlands, Sweden and the United Kingdom, in full consistency with the ETTS. The evidence of two cointegrating relations and two common trends among the four interest rates for France, Germany, Italy, Portugal and Spain, and of just one cointegrating relation for Ireland, goes against a strict interpretation of the ETTS. The results for Germany are in line with Wolters (1998), who showed that the strong form of the ETTS does not hold for the German bond market. Before we

[4]In the cases where the Trace and the $\lambda_{\max}$ statistics do not indicate the same number of cointegrating relations, our analysis was based on the statistic that indicated the highest number of cointegrating relations.

move to a more detailed analysis, it seems safe to conclude that Table 2 provides evidence in favor of the ETTS. The possibility of no cointegration is strongly rejected for all the countries of our sample.

Table 3 reports the likelihood ratio test statistics for the parameter estimates of the cointegrating vectors (β's). Each likelihood ratio test statistic is distributed as χ_1^2 asymptotically, under the null hypothesis that the respective component of the cointegrating vectors equals zero. As shown in Table 3, the parameters of the cointegrating vectors are statistically significant in all cases, which means that the interest rates enter significantly the cointegration vectors.

Further we tested if each single spread $S(i, j)$ between any two different yields of maturities i and j, belongs in the cointegration space of the term structure, as suggested by the ETTS. Equivalently, we tested the hypothesis $H_0 : \beta_i + \beta_j = 0$, when $(\beta_i, \beta_j)' = (1, -1)'$. Using the likelihood ratio test statistic at the 5 percent level of significance, the evidence indicate that for Belgium, Finland, France, Germany, Ireland, Italy, Sweden and the United Kingdom, the null hypothesis cannot be rejected. This implies that the spreads of these countries belong in the cointegration space. For Portugal, only the spread between the 12-month treasury bill rate and the 2-year government bond yield belongs in the cointegration space. On the contrary, the null hypothesis is rejected for Austria, Denmark, Greece, The Netherlands and Spain. Consequently, the results only for the first group of countries are in favor of the ETTS.

3.3 Common Trends Results

In this section we decomposed each VECM into its permanent and transitory components, in order to see which interest rate(s), if any, contributes significantly to the common trends. This is potentially useful information for the design and adjustment of the monetary policy within each EU member.

Consider, for instance, the four yields of one EU country, and suppose that this 4-dimensional system has three cointegrating vectors and a single shared common trend, dominated by the 10-year government bond yield. Then, in this hypothetical scenario, the 10-year government bond yield is an exogenous variable, determined, possibly, by that country's current and expected future monetary policy and by fundamental real factors of that economy. The other three yields are endogenous and changes in the 10-year government bond yield will affect both their transitory (stationary) and permanent components. Alternatively, changes in the other three yields, except the 10-year, will have only a temporary impact on the long run equilibrium relationships of the four yields without being able to alter them in a permanent way. Consequently, the driving force in this system of yields is the 10-year government bond yield.

Figures 1 to 14 show examples of the P-T decomposition, based on equation (13), in each country's system of yields. Notice that the plots in each figure are informative in two useful ways. First, they point to the same number of common trends as identified by the cointegration tests. Second, they reveal information as to which yields' permanent components are important. For example, as seen from Figure 6, the two permanent components in the system of German yields correspond to the 2-year and the 10-year government bond yields.

Furthermore, for each country we tested if any of its yields has a common permanent component in the $I(1)$ common factor(s) of the respective system. To accomplish this objective, we estimated the $\alpha_{\perp}$'s, which are the orthogonal complements of adjustment coefficients of the VECM, using the Gonzalo-Granger methodology. To test their statistical significance, we computed the $L-$statistic in equation (17) for specific choices of the G matrix. A significant $\alpha_{\perp}$ implies that the respective interest rate is weakly exogenous and contains the common trend in the cointegrating system. In other words, it is affected by changes in the fundamental factors of the economy and not by short run domestic policy actions.

For Austria, Belgium, Greece, and the United Kingdom that exist 3 cointegrating relations and a single shared common trend among the 4 yields, to test the null hypothesis that the 10-year government bond yield has a permanent component in the single common factor, we set the G matrix to

$$G = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}.$$

For Denmark, Finland, The Netherlands and Sweden that exist 2 cointegrating relations and a single shared common trend among the 3 yields, to test the same null hypothesis as above, we set the G matrix to

$$G = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}.$$

For France, Germany, Italy, Portugal and Spain, the results indicate two cointegrating relations and two common trends among the 4 yields. In that case, we can only test if a combination of two (or more) interest rates has a common permanent component between the two non stationary common factors. To test the null hypothesis that the combination of 5-year and 10-year government bond yields have a permanent component in the two common trends, we set the G matrix to

$$G = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}.$$

Finally, for Ireland that exist one cointegrating relation and two common trends among the 3 yields, the G matrix for the same null hypothesis as above, has the following form:

$$G = \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}.$$

In all the G matrices, the first row corresponds to the shorter yield, the second row to the successive longer yield and so on. The number of columns is determined by the number of common trends. By modifying the position of the constants in the above matrices, we can test each interest rate for weak exogeneity.

The computed $L-$statistics for each country's interest rates are presented in Table 4. The results indicate that for Belgium, Denmark, Finland and The Netherlands all the yields with maturity two years or more are weakly exogenous (i.e. contain the single shared common trend). For Austria and the United Kingdom all the yields enter significantly the shared common trend, while for Greece only the 7-year government bond yield is weakly exogenous. For France, Germany, Ireland, Italy and Spain our evidence suggests that the combination of the longer yields (i.e. the 5-year and the 10-year government bond yields) determines the two common trends. Finally, we could not find evidence of weak exogeneity for the interest rates of Portugal and Sweden. Overall, our results indicate that for almost all of the original EU members, the yields with maturity of one year or less adjust to deviations from the long run equilibrium, while the longer yields are not affected by past disequilibria and thus determine the $I(1)$ common factors of the respective systems.

3.4 Testing for the ETTS, with Exogenous $I(1)$ Variables in the VECMs

In the present section we test the ETTS of interest rates in the context of having exogenous $I(1)$ variables, based on the methodology proposed by Pesaran et al. (2000) and described in Section 2.3. As mentioned above, the reason is that future short rates are affected by many factors, including increased uncertainty about future economic conditions, inflationary expectations or uncertainty about government policies.

This implies that under the ETTS the long term rates are also affected. As proxies for the above factors we used nominal exchanges rates, real exchanges rates, inflation rates, inflation variance, money growth and its variance for each country of our sample.

Before testing for ETTS, we tested each of these proxies for unit root, using the Augmented Dickey-Fuller test at the 5 percent level of significance. The results are presented in the second panel of Table 1. Again, to select the appropriate lag length for the ADF test regression, we used the Akaike's information criterion. As shown in Table 1, we fail to reject the unit root hypothesis for these proxies, for most of the cases. In all the cases we also tested for a second unit root[5]. The variables that were found to be stationary were dropped out from further analysis. Based on these results we proceeded with testing for the ETTS, including the exogenous $I(1)$ variables in the VECMs.

For comparability purposes, the lag length l in each of the new VECMs is the same with the previous section. Further, to choose among submodels I to V, we tested the submodels against each other using likelihood ratio test statistics (Pesaran et al. 2000, Theorems 4.3 to 4.6). These tests are distributed as χ^2 with degrees of freedom determined by the pairs of models being tested as follows:

$$I \underset{r}{\subset} II \underset{m-r}{\subset} III \underset{r}{\subset} IV \underset{m-r}{\subset} V \ .$$

Using the Trace and the $\lambda_{\max}$ statistics at the 10 percent level of significance[6], we test if the number of cointegrating relations remains unchanged for each country[7]. If this is the case, it can be interpreted as evidence that the ETTS of interest rates remains unaffected. On the contrary, if the number of cointegrating relations has been increased (decreased), it implies that the ETTS strengthens (weakens) because of the inclusion of the uncertainty factors.

The results are presented in Table 5 and show that the inclusion of the uncertainty variables does not affect the ETTS of interest rates for Denmark (except for the case of inflation rate), Finland (in the cases of nominal and real exchange rates), France, Germany, Greece (except for the cases of nominal exchange rate and money growth), Ireland, Italy, The Netherlands (in the cases of money growth and money growth variance), Portugal, Spain and Sweden. In all other cases our evidence suggests a decrease in the number of cointegrating relations. Thus, we can conclude that the inclusion of variables concerning

[5]The second unit roots test results for the interest rates and the proxies are not presented here but are available under request.

[6]As in the previous section, in the cases where the Trace and the $\lambda_{\max}$ statistics do not indicate the same number of cointegrating relations, our analysis was based on the statistic that indicated the highest number of cointegrating relations.

[7]To test for the cointegration rank in each case, we used the critical values of MacKinnon et al. (1999) and the critical values of Pesaran et al. (2000). Both sets of critical values gave the same results. The 10 percent critical values of MacKinnon et al. (1999) have been computed using the computer program that developed by MacKinnon and is available in http://www.econ.queensu.ca/jae/ .

uncertainty and inflationary expectations gives evidence that are in favor of the ETTS, for most of the EU-15 members.

Further, we test if the inclusion of the exogenous non stationary variables affects the number of spreads that belong in the cointegration space. The results are presented in Table 5, in row $S(i, j)$'s for each country, and are based on likelihood ratio tests at the 5 percent level of significance. Overall, the results are similar with those obtained by testing for the ETTS without the inclusion of the exogenous variables. Only in a few cases the results differ substantially than those of the previous section. More specifically, for Belgium, in the case of nominal exchange rate only two spreads (i.e. between 3-month and 3-year yields and between 3-month and 5-year yields) enter the cointegration space. For Germany, in the case of inflation rate none of the spreads belongs in the cointegration space. For Italy, in the case of inflation variance none of the spreads belongs in the cointegration space. For Sweden, in the cases of nominal exchange rate none of the spreads belongs in the cointegration space, while in the case of real exchange rate only the spread between the 5-year and the 10-year government bond yields enters the cointegration space.

Also, for Greece, in the cases of nominal and real exchange rates, and for Portugal, in the case of inflation variance, all the spreads enter the cointegration space. Note that when testing the ETTS without the inclusion of exogenous $I(1)$ variables for these two countries, none of spreads enters the cointegration space in the case of Greece, and only the spread between the12-month treasury bill yield and the 2-year government bond yield enters the cointegration space in the case of Portugal.

Finally in this section, we test the statistical significance of the adjustment coefficients (α_i's) in each of the new VECMs, in order to investigate if the inclusion of the exogenous $I(1)$ affects the results about weak exogeneity that presented in Table 4. A statistically significant α_i implies a statistically insignificant $\alpha_{\perp}^i$ (i.e. the orthogonal complement of α_i) and thus, endogeneity of the variable i. Table 6 reports the Wald test statistics for the parameter estimates of the adjustment coefficients. Each Wald test statistic is distributed as χ^2 asymptotically, under the null hypothesis that the respective adjustment coefficient(s) equals zero. The degrees of freedom of the $\chi^2 - statistic$ are determined by the number of cointegrating relations in the respective VECM.

As shown in Table 6, most of the results are the same with those presented in Table 4, when testing for weak exogeneity with the absence of exogenous $I(1)$ variables. More Specifically, for Belgium, Finland (except for the case of inflation variance), France, Germany, Ireland, Italy, The Netherlands (in the cases of inflation rate and money growth variance) and Spain, the short term rates are endogenous, while the medium and the long rates are weakly exogenous and thus, comprise (together with the respective exogenous $I(1)$ variables) the long run driving forces of the cointegrated systems. For Greece, in the cases of nominal and real exchange rates and money growth, the 7-year government bond yield is weakly exogenous. Also for the United Kingdom, in the cases of nominal and real exchange rates and inflation rate, all the yields remain weakly exogenous. The results for Sweden are also the same with those of Table 4, and imply endogeneity for all the interest rates of the country.

The results for the rest of the cases presented in Table 6, are also in the same direction with those presented in Table 4, but with slight differences. For Austria, the 12-month treasury bill yield becomes endogenous, if we include the nominal exchange rate of the country as exogenous variable in the VECM. All the other interest rates remain weakly exogenous. For Denmark, most of the interest rates remain weakly exogenous. For Finland, when we include the inflation variance in the VECM, even the 3-month yield turns out to be weakly exogenous. For Greece, when we include the inflation rate in the VECM, the 12-month yield becomes weakly exogenous, while in the case of money growth variance, even the 7-year government bond yield becomes endogenous. For The Netherlands, in the cases of nominal and real exchange rates, inflation variance and money growth, the 5-year yield becomes endogenous, while the 12-month and the 10-year yields remain endogenous and weakly exogenous, respectively.

For Portugal, when we include exogenous variables in the VECMs, the 12-month treasury bill yield becomes weakly exogenous and comprise (together with the respective exogenous $I(1)$ variables) the long run driving forces of the cointegrated systems. All the other interest rates of the country remain endogenous. The endogeneity for almost all the interest rates of this country can be explained by the fact that its financial market was not fully developed during the major part of our sample period and thus, the domestic monetary authorities, with their short run policy actions, could affect and determine the short and long yields. Only the recent years, the financial market of Portugal has been full developed. Finally, for the United Kingdom, when we include the inflation variance in the VECM, only the 5-year and the 10-year government bond yields remain weakly exogenous.

In brief, the evidence of the present section suggest that the inclusion of uncertainty factors does not affect the power of the ETTS of interest rates for most of the original 15 EU members. Also, for most of them, the yields with the longer maturities remain weakly endogenous. This implies that for most of the EU-15 countries, their medium and long run interest rates are determined by changes in the fundamental economic factors, and not affected by short run domestic policy actions.

4 Concluding Remarks

In this paper we investigated empirically the term structure of interest rates for the 15 original EU countries. Since the interest rates follow random walks, we evaluated the expectations hypothesis of the term structure using cointegration analysis and common trends techniques. Also we investigated if the spreads between any two yields belong in the cointegration space and tested each yield for weak exogeneity. Furthermore, in order to capture the increased uncertainty about future economic conditions, we incorporated exogenous non stationary variables in our systems and evaluated the ETTS again.

In general, our empirical findings provide evidence in favor of the ETTS, since the possibility of no cointegration is strongly rejected for all the countries of our sample. But for France, Germany, Ireland, Italy, Portugal and Spain, our results are against a strict interpretation of the ETTS, since they indicate more than one common trends. Also, for most of the countries of our sample (i.e. Belgium, Finland, France, Germany, Ireland, Italy, Sweden and the United Kingdom) the spreads between any two interest rates belong in the cointegration space, as suggested by the ETTS. Furthermore, the decomposition of each system into each transitory and permanent components, indicates that for almost all of the EU-15 members, except for Portugal and Sweden, the long term interest rates are weakly exogenous and have a permanent component in the non stationary common factors.

The ETTS is not affected by the inclusion of uncertainty factors, for the most of the EU-15 countries. Also, the number of spreads that belong in the cointegration space is not affected, in almost all the cases. The tests for the significance of the adjustment coefficients provide evidence, which are in the same direction with those that arose from the estimation of the ETTS without the exogenous variables. Our evidence suggests that for the majority of the EU-15 countries the long term interest rates remain weakly exogenous. For Sweden and Portugal, the inclusion of the exogenous non stationary variables has not affected the endogeneity of their long term interest rates.

Overall, our analysis has been focused on the evaluation of the ETTS for the 15 original EU countries and how it is affected by the uncertainty about future economic conditions, government policies or inflationary expectations. This is a useful study as it provides valuable knowledge about the patterns and the characteristics of monetary policies in the EU.

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Table 1
Augmented Dickey - Fuller tests for a unit root[a]

Country	3-month treasury bill rates	12-month treasury bill rates	2-year government bond yields	3-year government bond yields	5-year government bond yields	10-year government bond yields
Austria		-0.87	-0.97		-0.80	-1.08
Belgium	-0.34			-0.32	-0.70	-0.37
Denmark			-0.53		-0.68	-0.76
Finland	-2.06				-1.54	-1.11
France		-0.26	-0.39		-0.37	-0.24
Germany		-0.80	-0.97		-1.11	-0.61
Greece		-0.10		-0.55	-0.80	-0.97[b]
Ireland			-1.22		-1.11	-1.34
Italy		-0.36		-0.80	-0.82	-0.85
The Netherlands		-1.42			-0.78	-0.71
Portugal		-0.89	-0.75		-0.59	-0.64
Spain		-0.73		-0.73	-0.78	-0.69
Sweden			-1.11		-1.46	-1.35
United Kingdom		-1.04	-1.00		-0.62	-0.61

Country	Nominal exchange rates	Real exchange rates	Inflation rates	Inflation variance	Money growth	Variance of money growth
Austria	-1.35	-1.55	-1.12	-1.15	-1.33	-1.21
Belgium	-1.87	-1.71	-0.95	-2.24*	-1.71	-1.02
Denmark	-1.72	-3.51*	-1.38	-6.29*	-2.89*	-0.15
Finland	-2.03	-2.14	-1.32	-0.71	-4.86*	-3.41*
France	-2.03	-1.69	-0.71	-2.83*	-1.33	-2.02*
Germany	-1.30	-2.12	-1.67	-1.26	-1.17	-2.02*
Greece	-1.17	-0.95	-1.57	-7.81*	-1.87	-1.79
Ireland	-3.09*				-1.70	-10.66*
Italy	-1.77	-1.68	-1.67	-1.56	-1.27	-1.09
The Netherlands	-2.30	-2.06	-0.79	-0.12	-0.55	-0.93
Portugal	-0.94	-0.85	-1.09	0.01	-1.90	-1.97*
Spain	-1.25	-1.67	-1.39	-0.39	-1.39	-1.06
Sweden	-1.67	-1.46	-2.66*	-5.98*	-1.34	-6.17*
United Kingdom	-2.52	-1.75	-0.88	-1.24	-3.31*	-10.78*

[a] The entry in each cell is the ADF test statistic. [b] 7-year government bond yield. * denotes rejection of the unit root hypothesis at the 5% level of significance. All interest rates, nominal exchange rates and real exchange rates are expressed in natural logarithms. For the countries of the table, the sample sizes are 285 for Austria, 211 for Belgium, 252 for Denmark, 161 for Finland, 222 for France, 312 for Germany, 136 for Greece, 240 for Ireland, 166 for Italy, 224 for The Netherlands, 138 for Portugal, 186 for Spain, 180 for Sweden and 271 for the United Kingdom. We also tested the null hypothesis of a second unit root. This hypothesis was rejected in all cases.

Table 2
Trace and λ_{max} statistics

	Austria		Belgium		Denmark	
$(p-r)$	Trace	λ_{max}	Trace	λ_{max}	Trace	λ_{max}
4	83.98** (.000)	38.93** (.002)	50.90** (.003)	26.49** (.024)		
3	45.05** (.003)	27.58** (.008)	24.41** (.048)	12.28 (.278)	52.36** (.000)	34.14** (.001)
2	17.47 (.116)	14.64* (.078)	12.13* (.054)	10.43* (.069)	18.22* (.093)	14.84* (.073)
1	2.83 (.613)	2.83 (.613)	1.70 (.226)	1.70 (.226)	3.38 (.512)	3.38 (.512)
l^{a}	9		5		10	
Model	1*		0		1*	
	Finland		**France**		**Germany**	
$(p-r)$	Trace	λ_{max}	Trace	λ_{max}	Trace	λ_{max}
4			60.94** (.000)	34.51** (.001)	58.02** (.000)	32.66** (.003)
3	42.81** (.006)	23.83** (.030)	26.44** (.026)	21.17** (.015)	25.36** (.036)	20.72** (.018)
2	18.98* (.074)	12.61 (.153)	5.28 (.529)	3.39 (.726)	4.65 (.618)	3.63 (.688)
1	6.37 (.164)	6.37 (.164)	1.89 (.200)	1.89 (.200)	1.02 (.364)	1.02 (.364)
l	8		2		1	
Model	1*		0		0	
	Greece		**Ireland**		**Italy**	
$(p-r)$	Trace	λ_{max}	Trace	λ_{max}	Trace	λ_{max}
4	82.76** (.000)	51.26** (.006)			60.74** (.000)	35.49** (.001)
3	31.51** (.005)	20.11** (.022)	24.47** (.047)	19.19** (.031)	25.25** (.038)	20.95** (.016)
2	11.40* (.071)	10.96* (.056)	5.28 (.529)	4.58 (.538)	4.30 (.667)	3.57 (.697)
1	0.44 (.570)	0.44 (.570)	0.70 (.462)	0.70 (.462)	0.73 (.450)	0.73 (.450)
l	1		7		3	
Model	0		0		0	
	The Netherlands		**Portugal**		**Spain**	
$(p-r)$	Trace	λ_{max}	Trace	λ_{max}	Trace	λ_{max}
4			87.69** (.000)	48.55** (.000)	75.31** (.000)	33.01** (.013)
3	44.23** (.004)	26.20** (.013)	39.14** (.018)	24.30** (.026)	42.30** (.007)	27.64** (.008)
2	18.03* (.098)	16.04** (.047)	14.84 (.236)	11.21 (.236)	14.67 (.246)	11.02 (.251)
1	1.99 (.780)	1.99 (.780)	3.62 (.471)	3.62 (.471)	3.65 (.467)	3.65 (.467)
l	7		4		4	
Model	1*		1*		1*	
	Sweden		**United Kingdom**			
$(p-r)$	Trace	λ_{max}	Trace	λ_{max}		
4			45.84** (.012)	17.71 (.292)		
3	35.23** (.001)	20.19** (.021)	28.12** (.016)	14.47 (.148)		
2	15.04** (.017)	13.41** (.020)	13.65** (.030)	10.98* (.055)		
1	1.63 (.237)	1.63 (.237)	2.67 (.121)	2.67 (.121)		
l	3		12			
Model	0		0			

The value reported at the top of each column is for $r = 0$, so that $p - r = p$, where $p = 4$ (i.e. the number of interest rates included). The values reported in parentheses are the P-values. ** (*) denotes rejection of the null hypothesis of at most r cointegrating relations at the 5% (10%) level of significance.
[a] l indicates the lag length.

Table 3
Testing for the term structure of interest rates

$H_0: \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df[a]	$H_0: (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
				Austria			
β_{12m}	25.66*	7.81	3	$12m, 2y$	7.42*	3.84	1
β_{2y}	28.00*	7.81	3	$12m, 5y$	7.61*	3.84	1
β_{5y}	33.87*	7.81	3	$12m, 10y$	8.86*	3.84	1
β_{10y}	33.53*	7.81	3	$2y, 5y$	7.31*	3.84	1
				$2y, 10y$	8.91*	3.84	1
				$5y, 10y$	11.39*	3.84	1
				Belgium			
$H_0: \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0: (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{3m}	22.53*	7.81	3	$3m, 3y$	0.40	3.84	1
β_{3y}	15.32*	7.81	3	$3m, 5y$	0.32	3.84	1
β_{5y}	12.39*	7.81	3	$3m, 10y$	0.34	3.84	1
β_{10y}	10.82*	7.81	3	$3y, 5y$	0.12	3.84	1
				$3y, 10y$	0.26	3.84	1
				$5y, 10y$	0.40	3.84	1
				Denmark			
$H_0: \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0: (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{2y}	30.69*	5.99	2	$2y, 5y$	6.71*	3.84	1
β_{5y}	29.90*	5.99	2	$2y, 10y$	7.40*	3.84	1
β_{10y}	27.60*	5.99	2	$5y, 10y$	8.18*	3.84	1
				Finland			
$H_0: \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0: (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{3m}	13.75*	5.99	2	$3m, 5y$	0.01	3.84	1
β_{5y}	14.69*	5.99	2	$3m, 10y$	0.38	3.84	1
β_{10y}	14.63*	5.99	2	$5y, 10y$	3.04	3.84	1
				France			
$H_0: \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0: (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	24.31*	5.99	2	$12m, 2y$	0.07	3.84	1
β_{2y}	19.56*	5.99	2	$12m, 5y$	0.02	3.84	1
β_{5y}	18.32*	5.99	2	$12m, 10y$	0.01	3.84	1
β_{10y}	19.71*	5.99	2	$2y, 5y$	0.01	3.84	1
				$2y, 10y$	0.01	3.84	1
				$5y, 10y$	0.01	3.84	1
				Germany			
$H_0: \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0: (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	24.98*	5.99	2	$12m, 2y$	2.21	3.84	1
β_{2y}	18.59*	5.99	2	$12m, 5y$	1.63	3.84	1
β_{5y}	19.23*	5.99	2	$12m, 10y$	1.46	3.84	1
β_{10y}	20.92*	5.99	2	$2y, 5y$	0.88	3.84	1
				$2y, 10y$	0.91	3.84	1
				$5y, 10y$	0.94	3.84	1
				Greece			
$H_0: \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0: (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	26.75*	7.81	3	$12m, 3y$	10.28*	3.84	1
β_{3y}	38.01*	7.81	3	$12m, 5y$	10.30*	3.84	1
β_{5y}	41.61*	7.81	3	$12m, 7y$	10.24*	3.84	1
β_{7y}	21.95*	7.81	3	$3y, 5y$	10.30*	3.84	1
				$3y, 7y$	10.16*	3.84	1
				$5y, 7y$	9.66*	3.84	1

Table 3 *(continued)*

$H_0 : \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0 : (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
				Ireland			
β_{2y}	13.93*	3.84	1	$2y, 5y$	1.97	3.84	1
β_{5y}	12.44*	3.84	1	$2y, 10y$	2.70	3.84	1
β_{10y}	7.49*	3.84	1	$5y, 10y$	3.40	3.84	1
				Italy			
$H_0 : \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0 : (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	31.04*	5.99	2	$12m, 3y$	2.03	3.84	1
β_{3y}	23.84*	5.99	2	$12m, 5y$	2.12	3.84	1
β_{5y}	19.64*	5.99	2	$12m, 10y$	2.21	3.84	1
β_{10y}	17.39*	5.99	2	$3y, 5y$	2.25	3.84	1
				$3y, 10y$	2.32	3.84	1
				$5y, 10y$	2.37	3.84	1
				The Netherlands			
$H_0 : \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0 : (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	23.71*	5.99	2	$12m, 5y$	12.36*	3.84	1
β_{5y}	17.75*	5.99	2	$12m, 10y$	11.25*	3.84	1
β_{10y}	13.94*	5.99	2	$5y, 10y$	6.33*	3.84	1
				Portugal			
$H_0 : \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0 : (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	31.07*	5.99	2	$12m, 2y$	3.54	3.84	1
β_{2y}	30.59*	5.99	2	$12m, 5y$	5.04*	3.84	1
β_{5y}	19.55*	5.99	2	$12m, 10y$	5.21*	3.84	1
β_{10y}	28.46*	5.99	2	$2y, 5y$	5.29*	3.84	1
				$2y, 10y$	5.28*	3.84	1
				$5y, 10y$	5.29*	3.84	1
				Spain			
$H_0 : \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0 : (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	20.93*	5.99	2	$12m, 3y$	7.37*	3.84	1
β_{3y}	20.23*	5.99	2	$12m, 5y$	7.36*	3.84	1
β_{5y}	18.13*	5.99	2	$12m, 10y$	7.35*	3.84	1
β_{10y}	15.32*	5.99	2	$3y, 5y$	7.35*	3.84	1
				$3y, 10y$	7.33*	3.84	1
				$5y, 10y$	7.32*	3.84	1
				Sweden			
$H_0 : \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0 : (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{2y}	14.80*	5.99	2	$2y, 5y$	1.29	3.84	1
β_{5y}	17.31*	5.99	2	$2y, 10y$	0.45	3.84	1
β_{10y}	17.81*	5.99	2	$5y, 10y$	0.01	3.84	1
				United Kingdom			
$H_0 : \beta_i = 0$	Test statistic	$\chi^2_{(5\%)}$	df	$H_0 : (\beta_i, \beta_j)' = (1, -1)'$	Test statistic	$\chi^2_{(5\%)}$	df
β_{12m}	10.75*	7.81	3	$12m, 2y$	0.01	3.84	1
β_{2y}	11.70*	7.81	3	$12m, 5y$	0.12	3.84	1
β_{5y}	12.47*	7.81	3	$12m, 10y$	0.05	3.84	1
β_{10y}	12.14*	7.81	3	$2y, 5y$	0.26	3.84	1
				$2y, 10y$	0.07	3.84	1
				$5y, 10y$	0.01	3.84	1

[a] df stands for the degrees of freedom. The β's are the parameters of the cointegrating vectors. The test statistics are likelihood ratio test statistics. * denotes rejection of the null hypothesis at the 5% level of significance.

Table 4
Testing for weak exogeneity

	Austria				Belgium		
H_0 [a]	$L-statistic$	$\chi^2_{(5\%)}$	df[b]	H_0	$L-statistic$	$\chi^2_{(5\%)}$	df
$\alpha_\perp^{12m}$	4.64	7.81	3	$\alpha_\perp^{3m}$	15.24*	7.81	3
$\alpha_\perp^{2y}$	1.38	7.81	3	$\alpha_\perp^{3y}$	2.18	7.81	3
$\alpha_\perp^{5y}$	4.54	7.81	3	$\alpha_\perp^{5y}$	4.68	7.81	3
$\alpha_\perp^{10y}$	6.28	7.81	3	$\alpha_\perp^{10y}$	5.92	7.81	3
	Denmark				Finland		
H_0	$L-statistic$	$\chi^2_{(5\%)}$	df	H_0	$L-statistic$	$\chi^2_{(5\%)}$	df
$\alpha_\perp^{2y}$	0.22	5.99	2	$\alpha_\perp^{3m}$	7.37*	5.99	2
$\alpha_\perp^{5y}$	4.42	5.99	2	$\alpha_\perp^{5y}$	0.01	5.99	2
$\alpha_\perp^{10y}$	3.28	5.99	2	$\alpha_\perp^{10y}$	1.83	5.99	2
	France				Germany		
H_0	$L-statistic$	$\chi^2_{(5\%)}$	df	H_0	$L-statistic$	$\chi^2_{(5\%)}$	df
$\alpha_\perp^{12m}, \alpha_\perp^{2y}$	30.26*	9.49	4	$\alpha_\perp^{12m}, \alpha_\perp^{2y}$	23.22*	9.49	4
$\alpha_\perp^{5y}, \alpha_\perp^{10y}$	2.83	9.49	4	$\alpha_\perp^{5y}, \alpha_\perp^{10y}$	7.29	9.49	4
	Greece				Ireland		
H_0	$L-statistic$	$\chi^2_{(5\%)}$	df	H_0	$L-statistic$	$\chi^2_{(5\%)}$	df
$\alpha_\perp^{12m}$	8.92*	7.81	3	$\alpha_\perp^{2y}, \alpha_\perp^{5y}$	12.53*	5.99	2
$\alpha_\perp^{3y}$	14.14*	7.81	3	$\alpha_\perp^{5y}, \alpha_\perp^{10y}$	3.60	5.99	2
$\alpha_\perp^{5y}$	32.35*	7.81	3				
$\alpha_\perp^{7y}$	7.66	7.81	3				
	Italy				The Netherlands		
H_0	$L-statistic$	$\chi^2_{(5\%)}$	df	H_0	$L-statistic$	$\chi^2_{(5\%)}$	df
$\alpha_\perp^{12m}, \alpha_\perp^{3y}$	32.46*	9.49	4	$\alpha_\perp^{12m}$	14.72*	5.99	2
$\alpha_\perp^{5y}, \alpha_\perp^{10y}$	5.09	9.49	4	$\alpha_\perp^{5y}$	4.36	5.99	2
				$\alpha_\perp^{10y}$	3.10	5.99	2
	Portugal				Spain		
H_0	$L-statistic$	$\chi^2_{(5\%)}$	df	H_0	$L-statistic$	$\chi^2_{(5\%)}$	df
$\alpha_\perp^{12m}, \alpha_\perp^{2y}$	33.08*	9.49	4	$\alpha_\perp^{12m}, \alpha_\perp^{3y}$	15.83*	9.49	4
$\alpha_\perp^{5y}, \alpha_\perp^{10y}$	30.80*	9.49	4	$\alpha_\perp^{5y}, \alpha_\perp^{10y}$	8.71	9.49	4
	Sweden				United Kingdom		
H_0	$L-statistic$	$\chi^2_{(5\%)}$	df	H_0	$L-statistic$	$\chi^2_{(5\%)}$	df
$\alpha_\perp^{2y}$	8.86*	5.99	2	$\alpha_\perp^{12m}$	7.16	7.81	3
$\alpha_\perp^{5y}$	15.46*	5.99	2	$\alpha_\perp^{2y}$	6.76	7.81	3
$\alpha_\perp^{10y}$	16.98*	5.99	2	$\alpha_\perp^{5y}$	3.35	7.81	3
				$\alpha_\perp^{10y}$	1.29	7.81	3

[a] The null hypothesis is that the respective interest rate(s) determines the common trend(s). [b] df stands for the degrees of freedom. The $\alpha_\perp$'s are the orthogonal complements of the adjustment coefficients. The degrees of freedom for the $L-$statistic are df $= (p - r) \times (p - m)$. * denotes rejection of the null hypothesis at the 5% level of significance.

Table 5
Testing for the term structure of interest rates, with exogenous $I(1)$ variables in the VECMs

Country		Exogenous $I(1)$ variable in the VECM: Nominal exchange rate	Real exchange rate	Inflation rate	Inflation variance	Money growth	Money growth variance
Austria	CEs[a] (Trace)	2	2	2	2	2	2
	CEs ($\lambda_{\max}$)	2	2	2	2	2	2
	$S(i,j)$'s[b]	0	0	1	0	0	0
	Model	II	II	II	II	II	II
Belgium	CEs (Trace)	2	2	2		1	1
	CEs ($\lambda_{\max}$)	1	1	1		1	1
	$S(i,j)$'s	2	4	6		6	6
	Model	I	I	I		I	I
Denmark	CEs (Trace)	2		1			2
	CEs ($\lambda_{\max}$)	2		1			2
	$S(i,j)$'s	0		0			0
	Model	II		II			II
Finland	CEs (Trace)	2	2	1	1		
	CEs ($\lambda_{\max}$)	2	2	1	1		
	$S(i,j)$'s	2	2	2	2		
	Model	II	II	II	II		
France	CEs (Trace)	2	2	1		1	
	CEs ($\lambda_{\max}$)	2	2	2		2	
	$S(i,j)$'s	6	6	6		6	
	Model	I	I	I		I	
Germany	CEs (Trace)	1	1	2	1	1	
	CEs ($\lambda_{\max}$)	2	2	2	2	2	
	$S(i,j)$'s	6	6	0	6	6	
	Model	I	I	I	I	I	
Greece	CEs (Trace)	2	3	3		2	2
	CEs ($\lambda_{\max}$)	2	2	3		2	3
	$S(i,j)$'s	6	6	0		0	0
	Model	I	I	I		I	I
Ireland	CEs (Trace)					0	
	CEs ($\lambda_{\max}$)					1	
	$S(i,j)$'s					3	
	Model					I	
Italy	CEs (Trace)	2	2	1	1	1	1
	CEs ($\lambda_{\max}$)	2	2	2	2	2	2
	$S(i,j)$'s	6	6	6	0	6	6
	Model	I	I	I	I	I	I
The Netherlands	CEs (Trace)	1	1	1	1	2	1
	CEs ($\lambda_{\max}$)	1	1	1	1	2	2
	$S(i,j)$'s	0	0	0	0	0	0
	Model	II	II	II	II	II	II
Portugal	CEs (Trace)	2	2	2	2	2	
	CEs ($\lambda_{\max}$)	2	2	2	2	1	
	$S(i,j)$'s	0	0	0	6	0	
	Model	II	II	II	II	II	

Table 5 *(continued)*

Country		Exogenous $I(1)$ variable in the VECM: Nominal exchange rate	Real exchange rate	Inflation rate	Inflation variance	Money growth	Money growth variance
Spain	CEs (Trace)	2	2	2	2	2	2
	CEs ($\lambda_{\max}$)	2	2	2	2	2	2
	$S(i,j)$'s	0	0	0	0	0	0
	Model	II	II	II	II	II	II
Sweden	CEs (Trace)	2	2			2	
	CEs ($\lambda_{\max}$)	2	2			2	
	$S(i,j)$'s	0	1			3	
	Model	I	I			I	
United Kingdom	CEs (Trace)	2	2	1	1		
	CEs ($\lambda_{\max}$)	0	0	0	1		
	$S(i,j)$'s	5	5	5	4		
	Model	I	I	I	I		

[a] CEs stands for the number of cointegrating relations, which is indicated by the Trace and the $\lambda_{\max}$ statistics at the 10% level of significance. [b] $S(i,j)$'s indicates the number of spreads that belong in the cointegration space.

Table 6
Testing the significance of the adjustment coefficients (a_i's), with exogenous $I(1)$ variables in the VECMs

		Exogenous $I(1)$ variable in the VECM					
Country	$H_0 : a_i = 0$	Nominal exchange rate	Real exchange rate	Inflation rate	Inflation variance	Money growth	Money growth variance
Austria	α_{12m}	6.20*	5.93	5.52	4.63	1.89	3.69
	α_{2y}	0.33	0.39	1.54	0.91	3.20	1.24
	α_{5y}	1.58	1.46	2.11	2.24	3.17	2.51
	α_{10y}	4.06	4.14	3.54	2.95	4.39	2.81
	df[a]	2	2	2	2	2	2
	$\chi^2_{(0.05)}$	5.99	5.99	5.99	5.99	5.99	5.99
Belgium	α_{3m}	13.45*	13.20*	17.11*		16.74*	14.36*
	α_{3y}	0.77	0.72	0.58		0.07	0.24
	α_{5y}	0.04	0.08	0.18		0.08	0.01
	α_{10y}	2.10	1.67	1.30		0.15	0.01
	df	2	2	2		1	1
	$\chi^2_{(0.05)}$	5.99	5.99	5.99		3.84	3.84
Denmark	α_{2y}	0.31		0.04			0.86
	α_{5y}	4.56		4.49*			4.52
	α_{10y}	3.60		0.49			7.13*
	df	2		1			2
	$\chi^2_{(0.05)}$	5.99		3.84			5.99
Finland	α_{3m}	13.58*	13.34*	7.68*	3.27		
	α_{5y}	0.36	0.27	0.00	0.06		
	α_{10y}	1.91	2.20	1.23	1.37		
	df	2	2	1	1		
	$\chi^2_{(0.05)}$	5.99	5.99	3.84	3.84		
France	α_{12m}	15.81*	15.61*	16.44*		16.17*	
	α_{2y}	0.48	0.49	0.65		0.68	
	α_{5y}	2.49	2.83	3.07		2.74	
	α_{10y}	0.69	0.87	1.83		1.70	
	df	2	2	2		2	
	$\chi^2_{(0.05)}$	5.99	5.99	5.99		5.99	
Germany	α_{12m}	29.53*	26.39*	22.57*	16.64*	16.08*	
	α_{2y}	2.66	2.77	1.76	0.27	1.00	
	α_{5y}	3.40	3.09	5.02	4.58	5.55	
	α_{10y}	2.40	2.39	3.53	2.40	2.08	
	df	2	2	2	2	2	
	$\chi^2_{(0.05)}$	5.99	5.99	5.99	5.99	5.99	
Greece	α_{12m}	6.06*	12.59*	6.42		6.08*	9.05*
	α_{3y}	16.20*	20.69*	17.05*		7.80*	15.73*
	α_{5y}	34.70*	35.59*	36.89*		31.08*	38.32*
	α_{7y}	0.10	6.89	27.74*		0.04	10.01*
	df	2	3	3		2	3
	$\chi^2_{(0.05)}$	5.99	7.81	7.81		5.99	7.81

Table 6 *(continued)*

Country	$H_0 : a_i = 0$	Nominal exchange rate	Real exchange rate	Inflation rate	Inflation variance	Money growth	Money growth variance
		Exogenous $I(1)$ variable in the VECM					
Ireland	α_{2y}					6.29*	
	α_{5y}					0.04	
	α_{10y}					0.90	
	df					1	
	$\chi^2_{(0.05)}$					3.84	
Italy	α_{12m}	18.61*	19.02*	17.25*	16.44*	18.50*	16.95*
	α_{3y}	1.18	1.33	0.42	0.59	0.36	0.37
	α_{5y}	2.06	2.32	1.40	2.28	1.16	1.07
	α_{10y}	1.63	1.81	0.96	1.45	0.79	0.76
	df	2	2	2	2	2	2
	$\chi^2_{(0.05)}$	5.99	5.99	5.99	5.99	5.99	5.99
The Netherlands	α_{12m}	11.56*	12.36*	11.29*	9.61*	15.76*	14.48*
	α_{5y}	5.28*	4.97*	3.80	4.58*	6.48*	3.55
	α_{10y}	1.98	1.74	0.61	1.03	2.99	3.97
	df	1	1	1	1	2	2
	$\chi^2_{(0.05)}$	3.84	3.84	3.84	3.84	5.99	5.99
Portugal	α_{12m}	1.20	1.09	3.85	3.33	3.21	
	α_{2y}	28.84*	28.51*	37.22*	36.34*	37.50*	
	α_{5y}	26.12*	26.09*	29.89*	29.19*	26.45*	
	α_{10y}	6.40*	6.39*	10.09*	9.50*	11.28*	
	df	2	2	2	2	2	
	$\chi^2_{(0.05)}$	5.99	5.99	5.99	5.99	5.99	
Spain	α_{12m}	10.97*	10.40*	8.06*	6.70*	7.43*	6.42*
	α_{3y}	0.38	0.32	0.47	0.41	0.32	0.62
	α_{5y}	1.22	1.19	0.60	0.54	0.51	0.36
	α_{10y}	3.49	3.52	1.27	1.69	1.59	2.03
	df	2	2	2	2	2	2
	$\chi^2_{(0.05)}$	5.99	5.99	5.99	5.99	5.99	5.99
Sweden	α_{2y}	9.12*	9.01*			9.56*	
	α_{5y}	17.03*	17.11*			16.69*	
	α_{10y}	21.60*	21.74*			18.66*	
	df	2	2			2	
	$\chi^2_{(0.05)}$	5.99	5.99			5.99	
United Kingdom	α_{12m}	3.12	3.24	2.23	6.06*		
	α_{2y}	4.77	4.90	2.72	5.34*		
	α_{5y}	3.22	3.28	1.21	2.58		
	α_{10y}	1.16	1.37	1.14	2.82		
	df	2	2	1	1		
	$\chi^2_{(0.05)}$	5.99	5.99	3.84	3.84		

The numbers in each row of α_i's are Wald test statistics. [a] df stands for the degrees of freedom. * denotes rejection of the null hypothesis at the 5% level of significance.

Figure 1
P-T decomposition of the interest rates: Austria

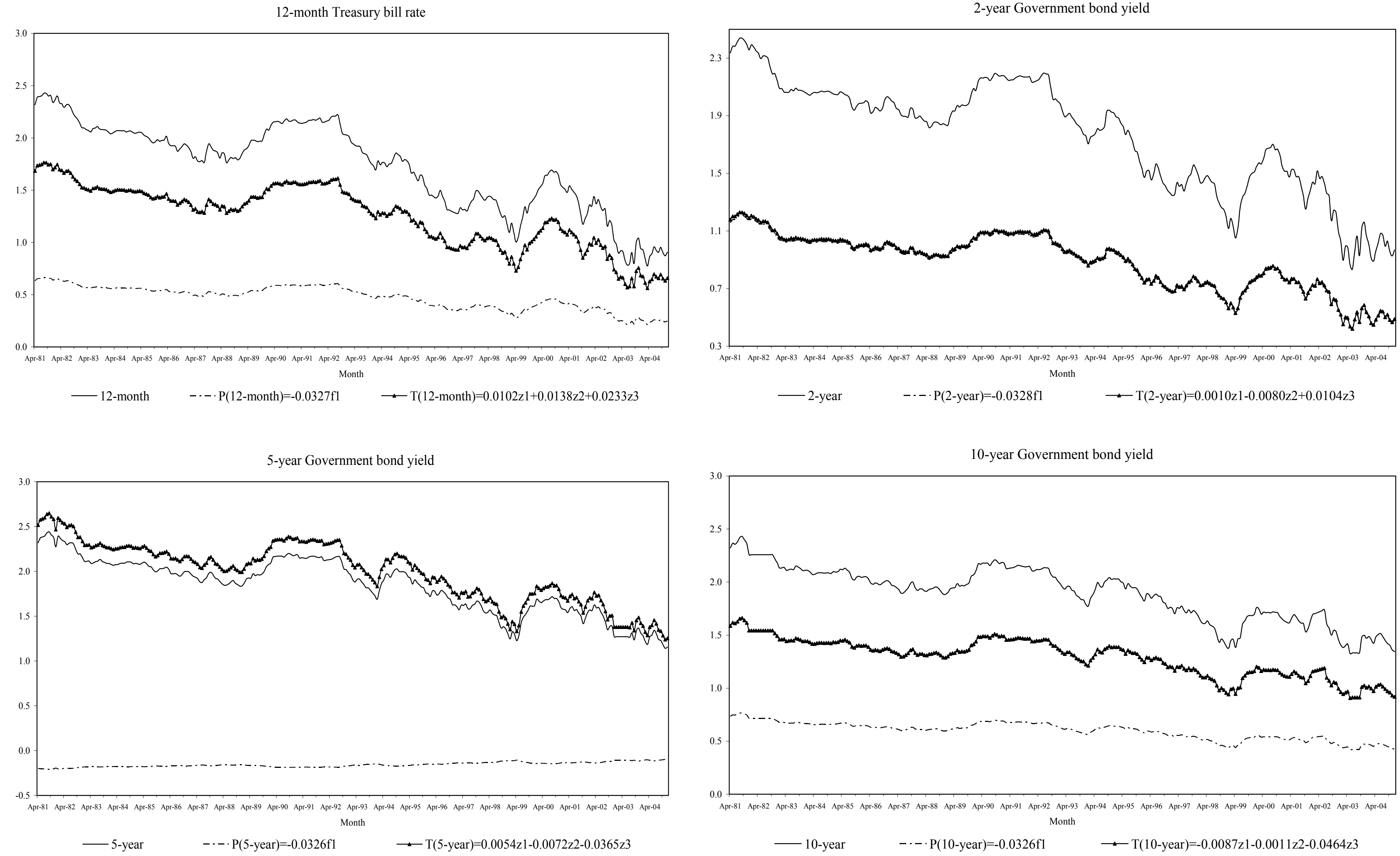


Figure 2
P-T decomposition of the interest rates: Belgium

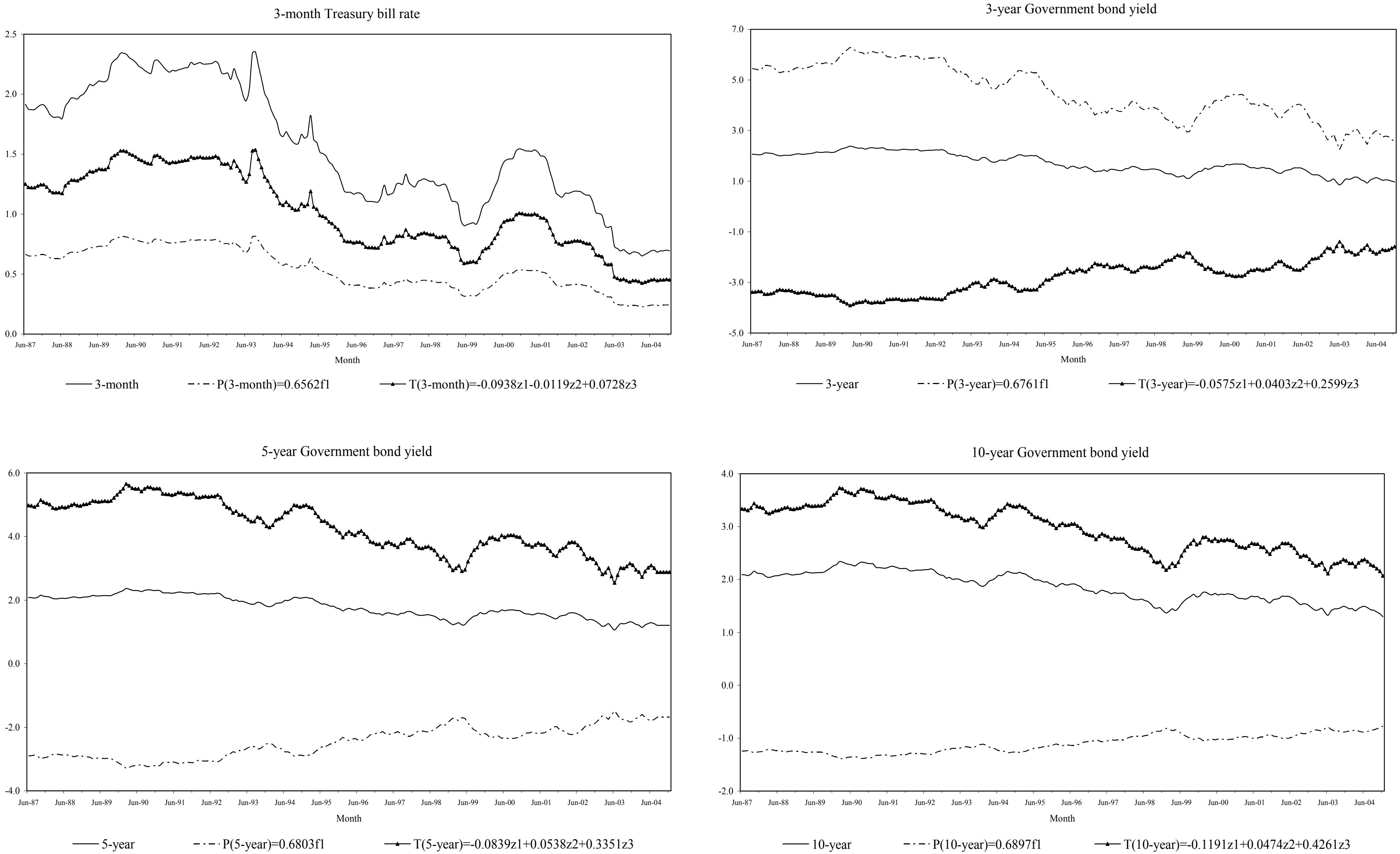
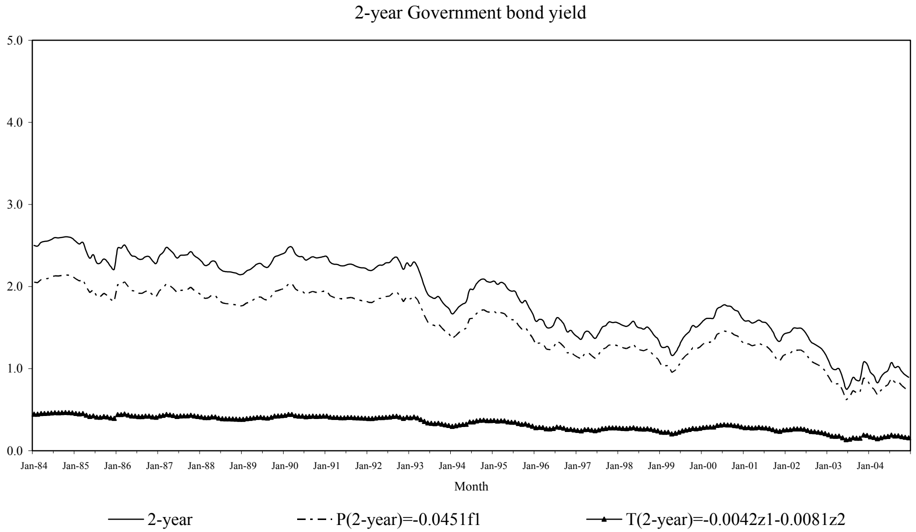
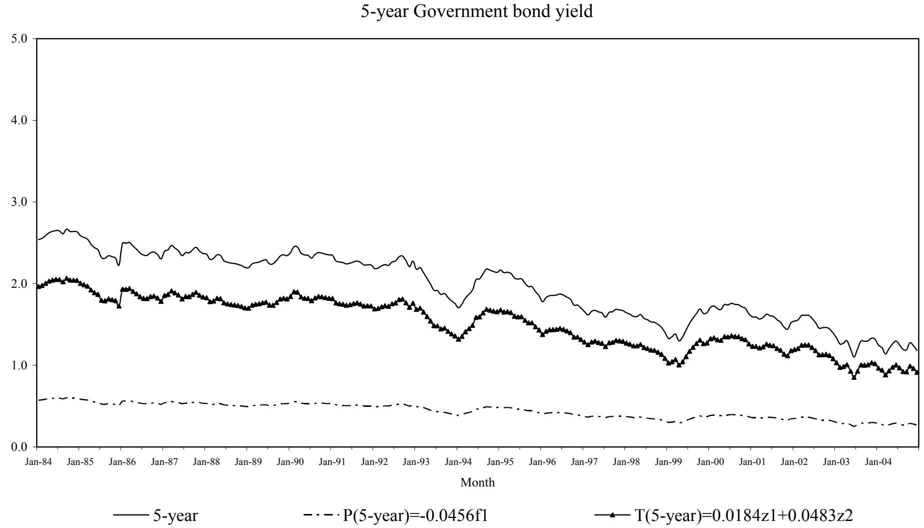


Figure 3
P-T decomposition of the interest rates: Denmark





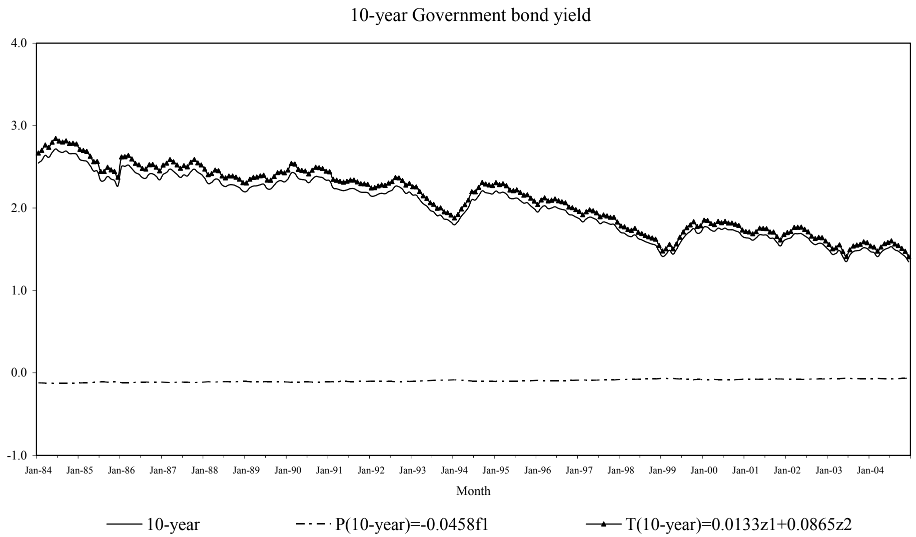
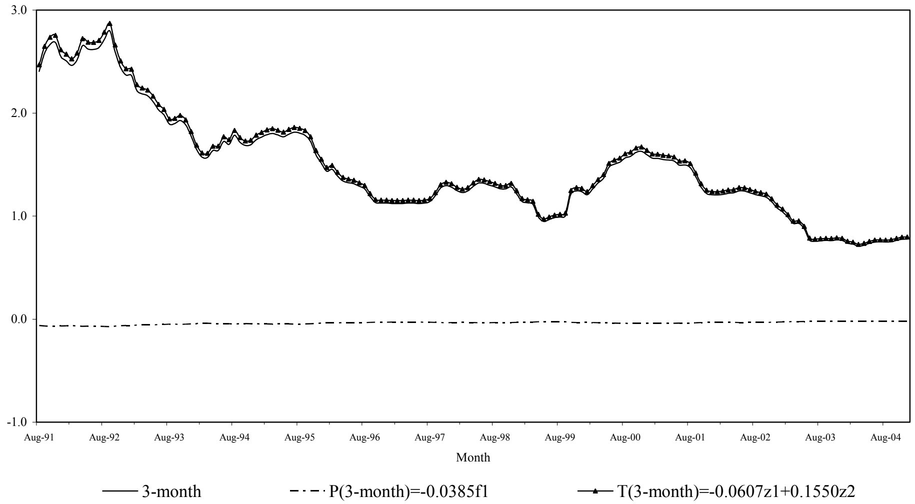
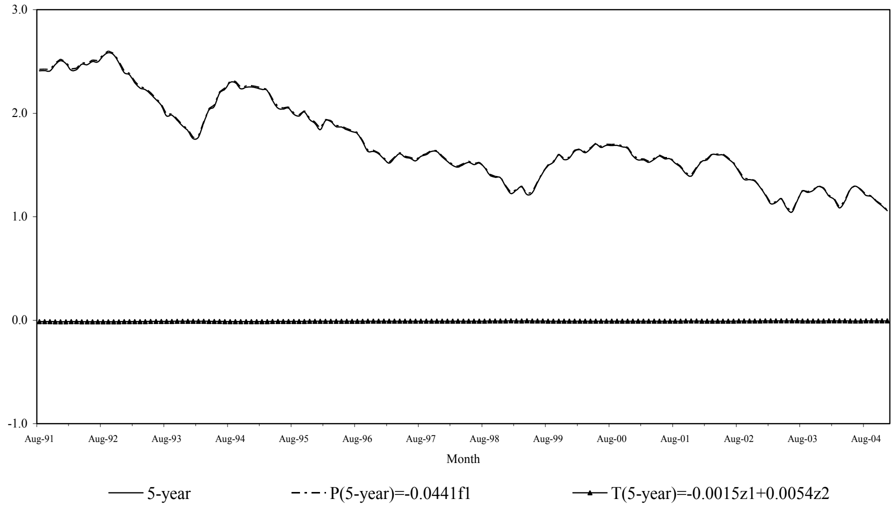


Figure 4
P-T decomposition of the interest rates: Finland

3-month Treasury bill rate



5-year Government bond yield



10-year Government bond yield

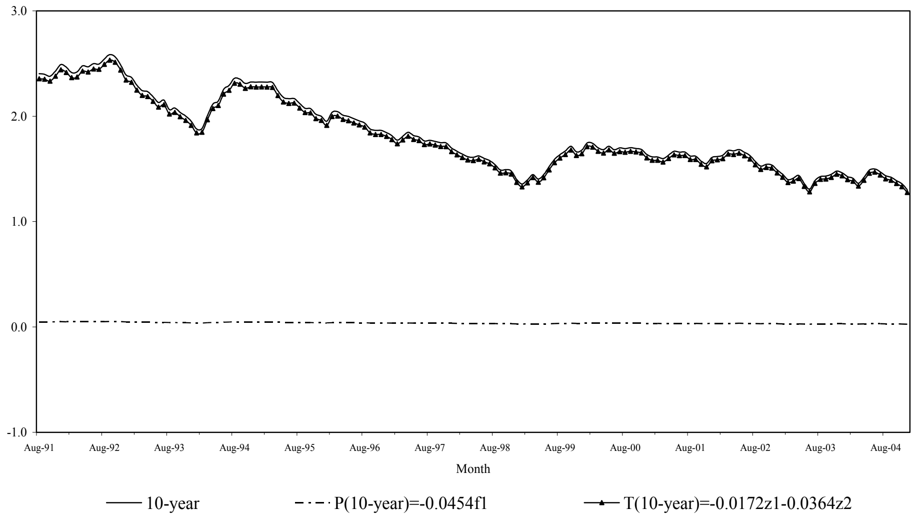


Figure 5
P-T decomposition of the interest rates: France

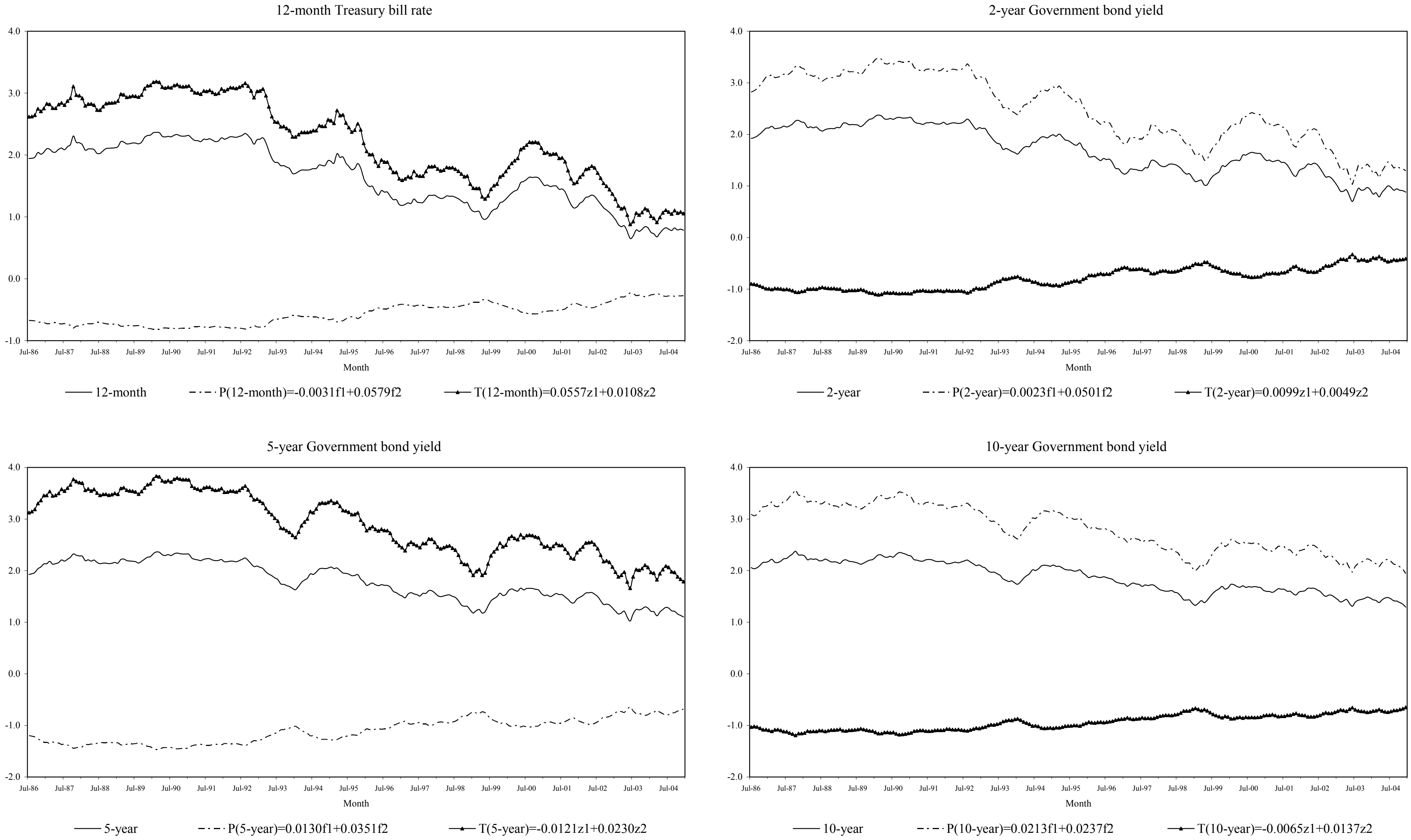


Figure 6
P-T decomposition of the interest rates: Germany

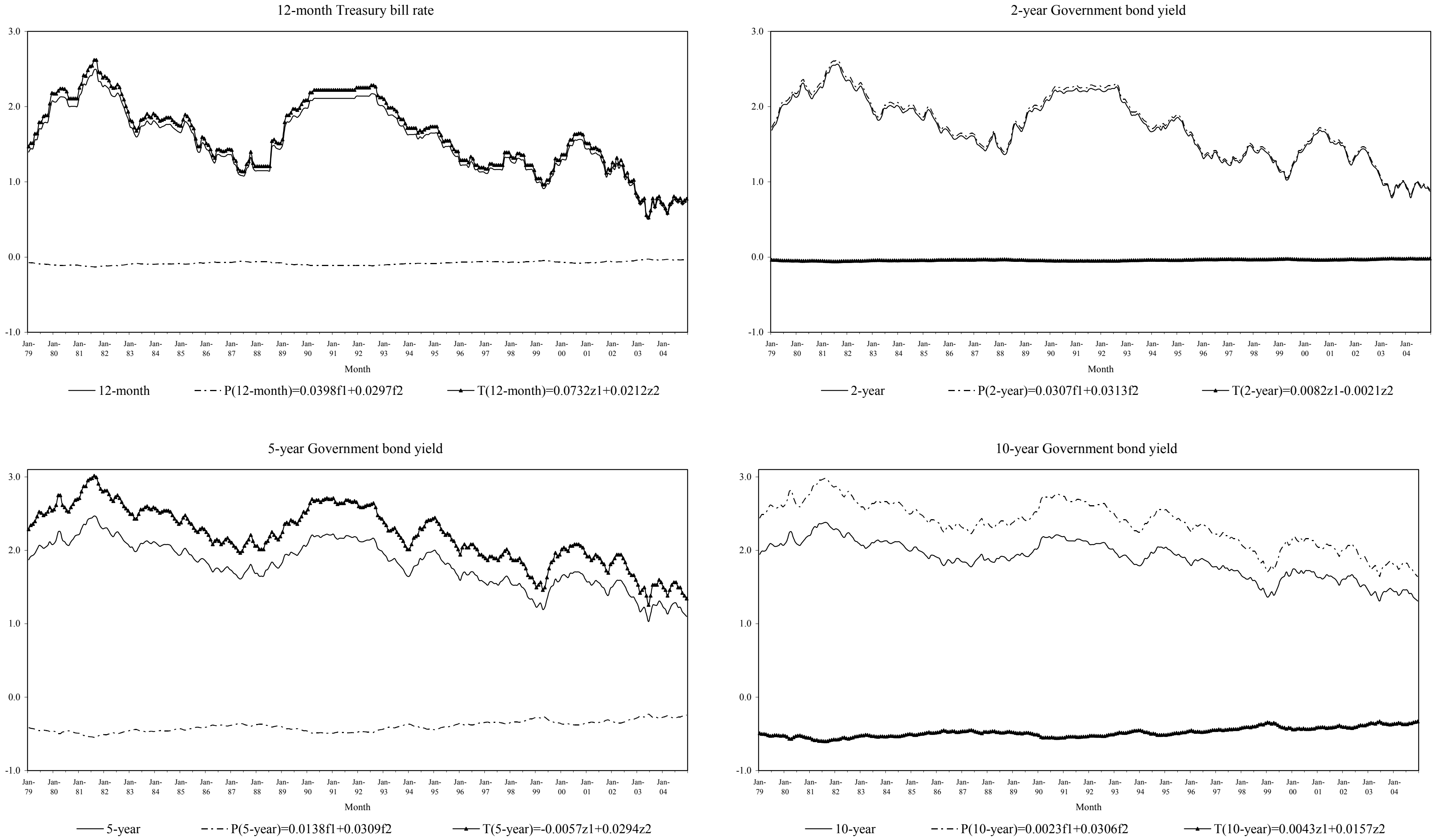


Figure 7
P-T decomposition of the interest rates: Greece

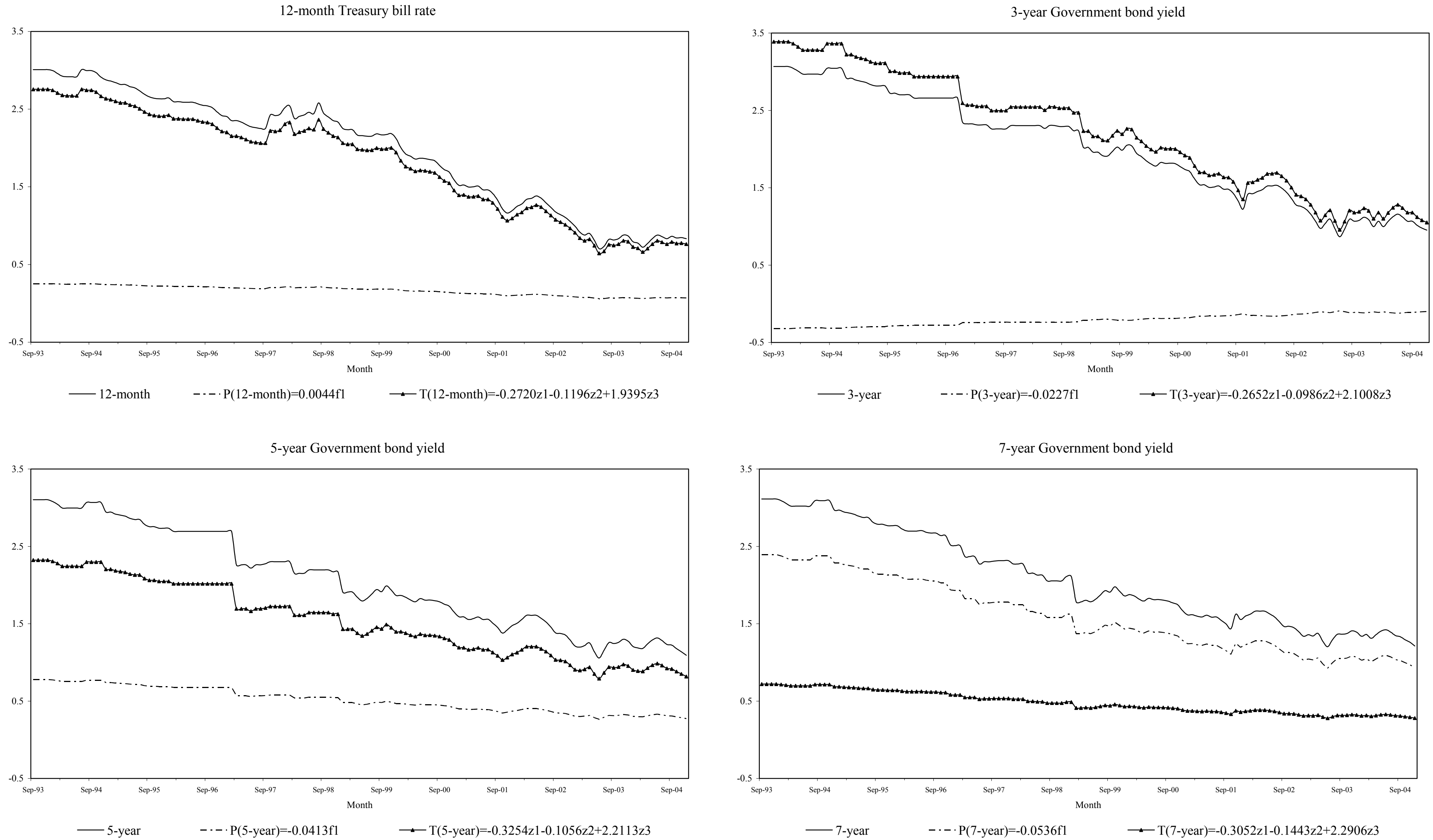
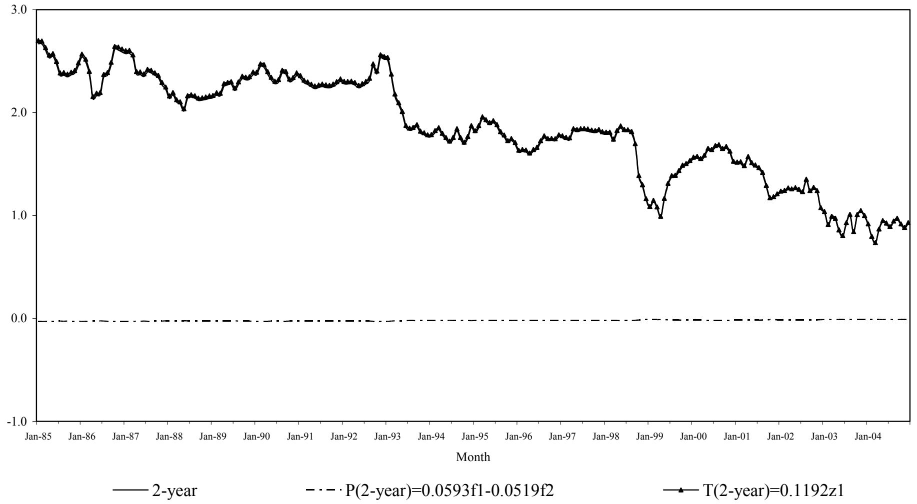
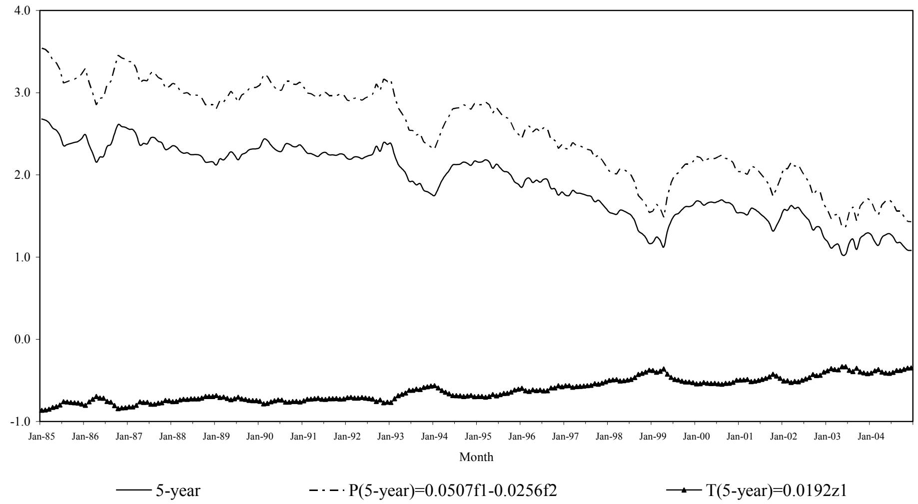


Figure 8
P-T decomposition of the interest rates: Ireland

2-year Government bond yield



5-year Government bond yield



10-year Government bond yield

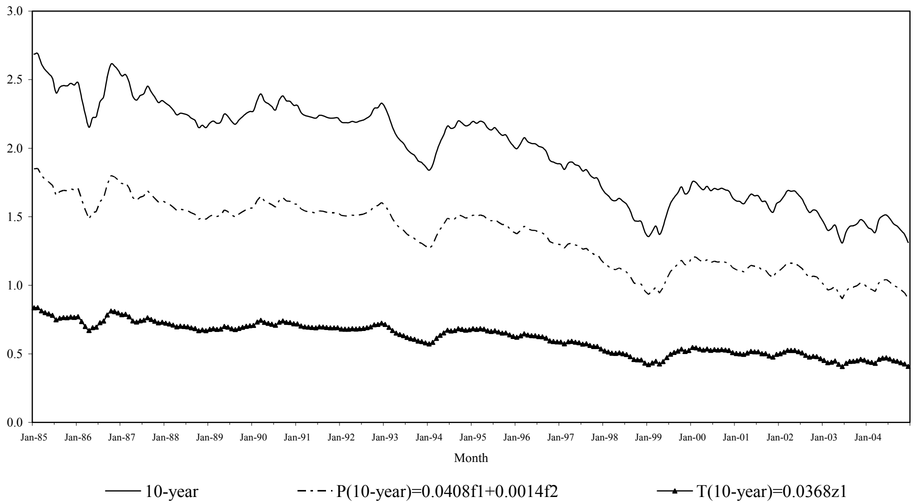


Figure 9
P-T decomposition of the interest rates: Italy

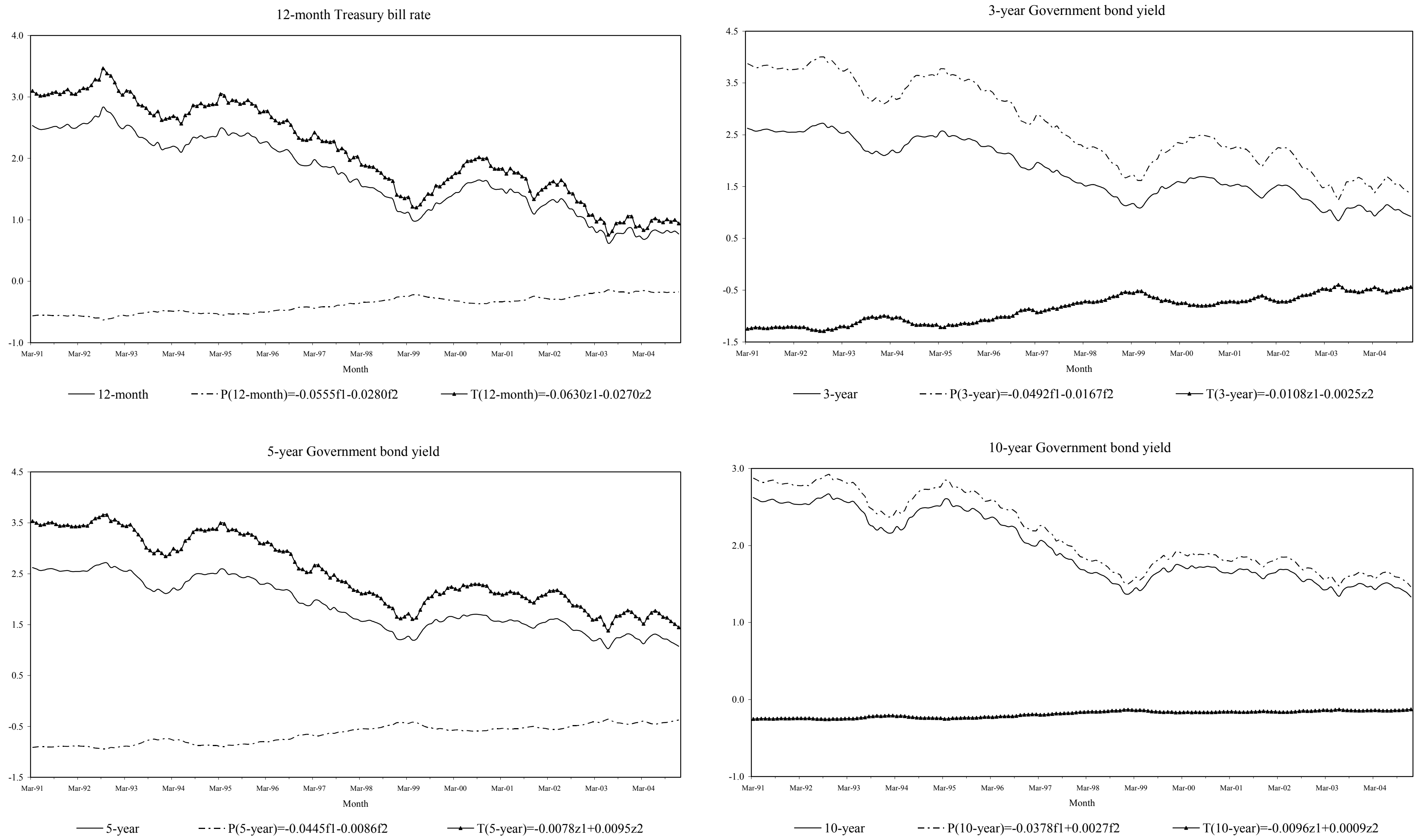
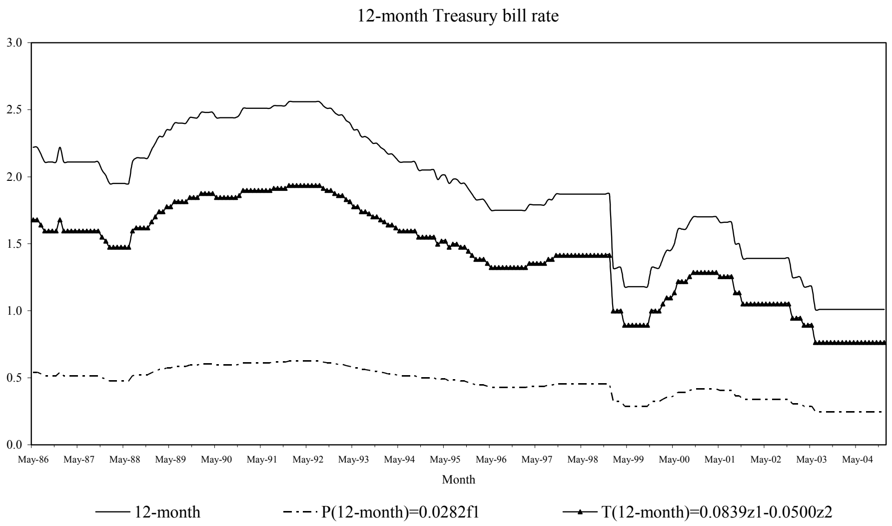
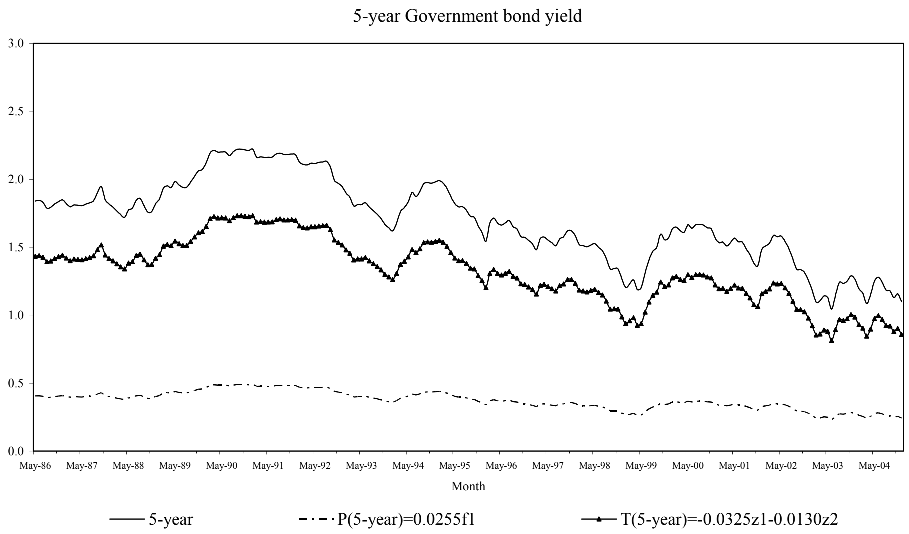


Figure 10
P-T decomposition of the interest rates: The Netherlands





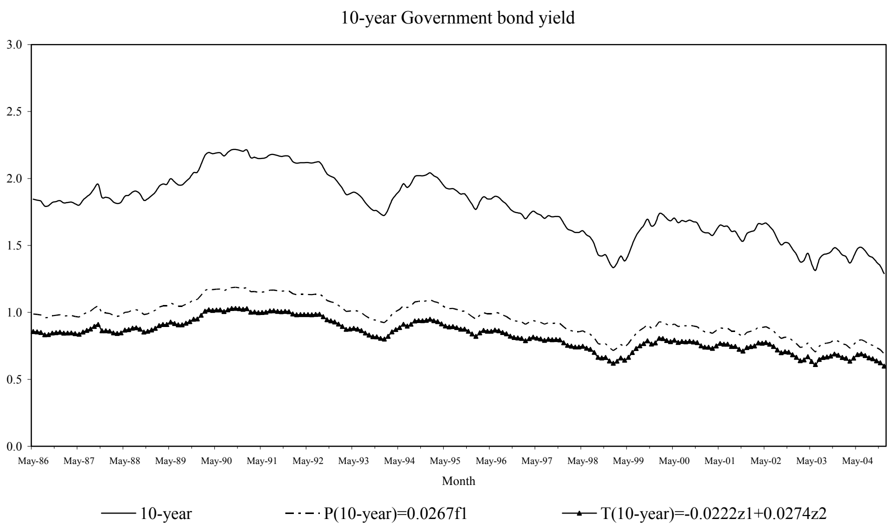


Figure 11
P-T decomposition of the interest rates: Portugal

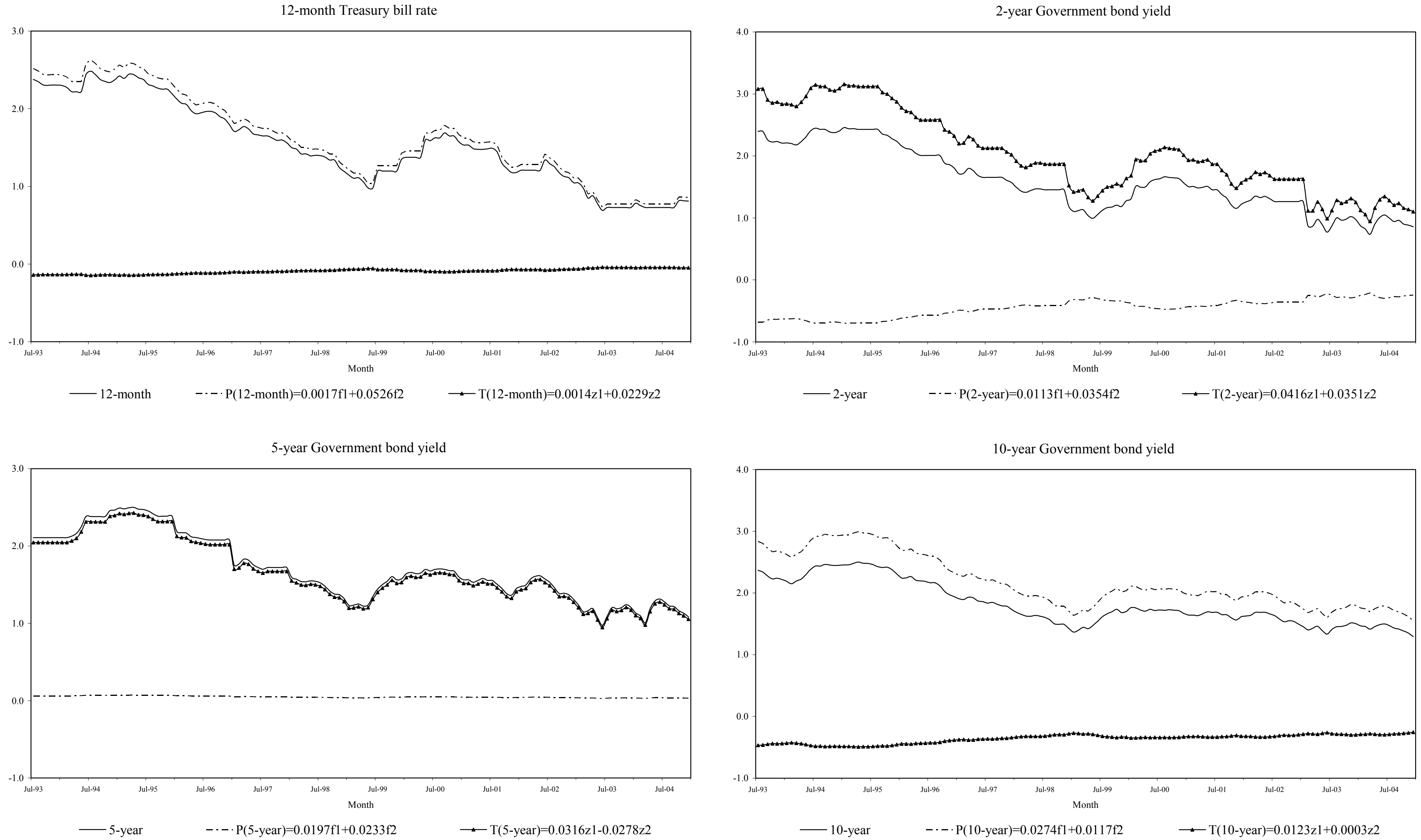


Figure 12
P-T decomposition of the interest rates: Spain

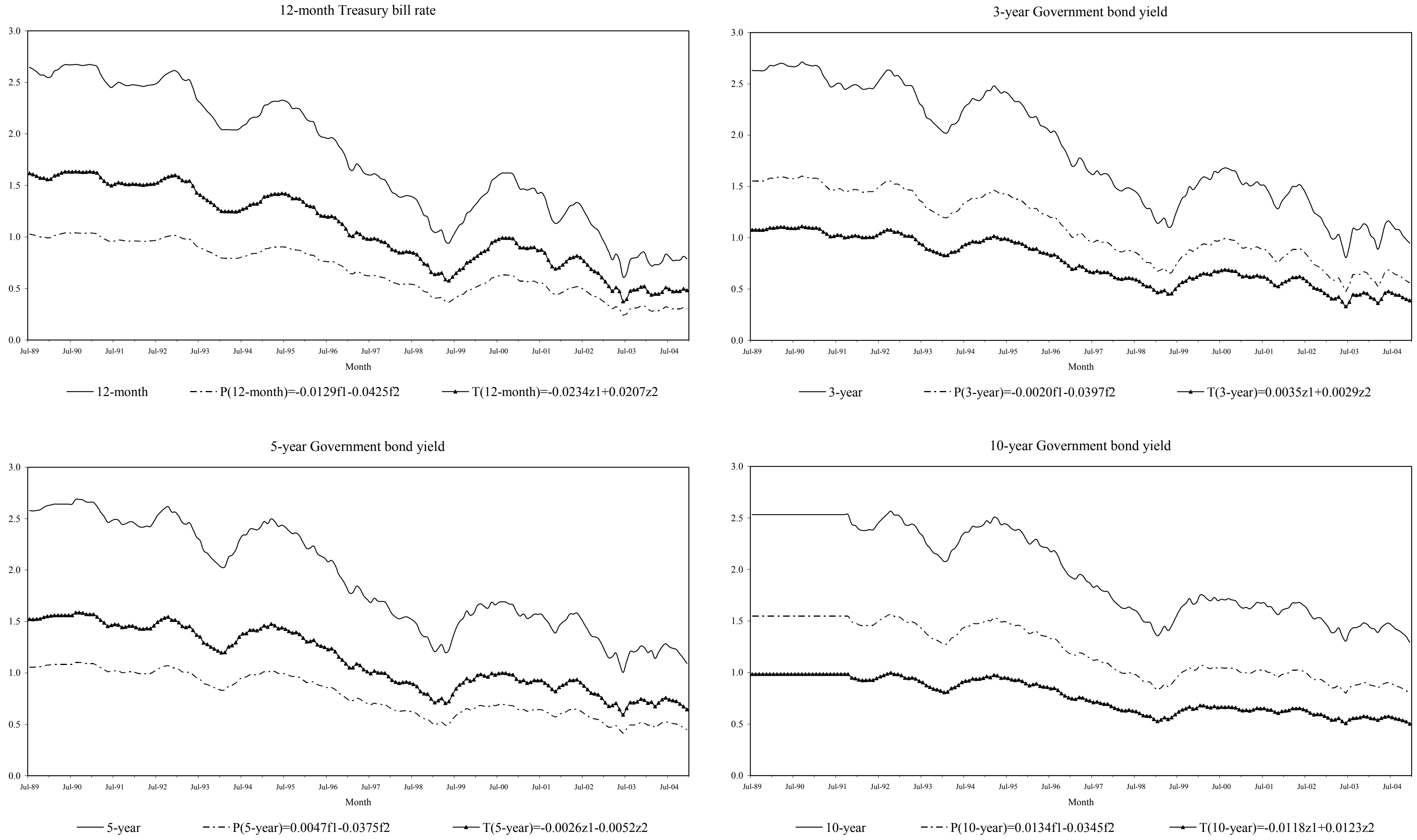
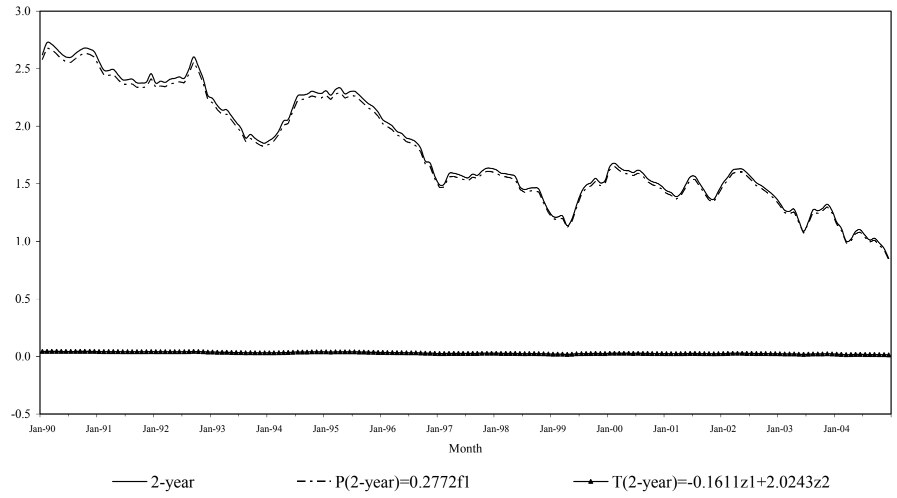


Figure 13
P-T decomposition of the interest rates: Sweden

2-year Government bond yield



5-year Government bond yield

10-year Government bond yield

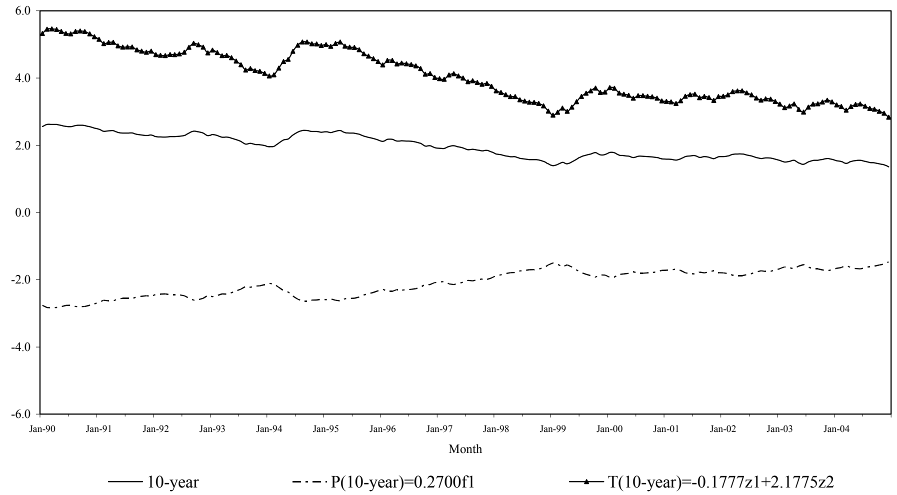


Figure 14
P-T decomposition of the interest rates: United Kingdom