Π Α Ν Ε Π Ι Σ Τ Η Μ Ι Ο   Π Ε Ι Ρ Α Ι Ω Σ

Τμήμα Χρηματοοικονομικής και Τραπεζικής Διοικητικής
Μεταπτυχιακό Πρόγραμμα Σπουδών

ΣΥΓΚΛΙΣΗ ΠΛΗΘΩΡΙΣΜΟΥ ΚΑΙ ΕΠΙΤΟΚΙΩΝ: Η Περίπτωση των Νέων Μελών της ΕΕ

ΕΠΙΜΕΛΕΙΑ
Αθηνά Τσάκαλου
ΜΧΡΗ/0234

ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ
Κρίστης Χασάπης

- Ιούνιος 2004 -

IV. METHODOLOGY

A. UNIT ROOT TESTS

Before testing for cointegration, we shall test all time series for stationarity. Tests of stationarity are referred to as unit roots tests. The simplest approach to testing for stationarity is the **Dickey-Fuller test**. The hypothesis of a stationary series can be evaluated by testing for the value of a_1 in the following equations. The test takes the unit root as the null hypothesis, i.e. H_0: $a_1 = 1$, where the series is $I(1)$. Since explosive series do not make sense in finance, this hypothesis is tested against the one-sided alternative, i.e. H_1: $a_1 < 1$, where the series is $I(0)$. Re-specifying each equation in terms of changes in Y_t, the test is carried out on the value of $\beta = a_1 - 1$. If $\beta = 0$ ($a_1 = 1$), the series Y_t exhibits a unit root and is $I(1)$, while the series ΔY_t is stationary and if $\beta < 0$ ($a_1 < 1$), the series Y_t is itself stationary, $I(0)$. We distinguish the following cases concerning the form of the model being tested:

a) Zero mean, no time trend:

$Y_t = a_1 Y_{t-1} + e_t$, or in terms of changes in Y_t: $\Delta Y_t = \beta Y_{t-1} + e_t$. If the null hypothesis is accepted, the Y_t series is a random walk without drift.

b) Non-zero mean, no time trend:

$Y_t = a_0 + a_1 Y_{t-1} + e_t$, or equivalently: $\Delta Y_t = a_0 + \beta Y_{t-1} + e_t$.

c) Non-zero mean and time trend:

$Y_t = a_0 + a_1 Y_{t-1} + \gamma T + e_t$, or equivalently: $\Delta Y_t = a_0 + \beta Y_{t-1} + \gamma T + e_t$.

The simple unit root tests are robust against reasonable degrees of heteroscedasticity, but autocorrelation causes problems. The Dickey-Fuller test is valid only if the series is an autoregressive of order one [*AR(1)*] process. If the series is correlated at higher order lags, the assumption of white noise disturbances is violated. The **Augmented Dickey-Fuller test** solves the problem of testing for stationarity when there is autocorrelation in the residuals. This approach makes a parametric correction for higher-order correlation by assuming that the series follows an AR(k) process, i.e. it incorporates lagged values of the dependent variable in the regression equation, with the number of lags being chosen simply to be sufficient to remove the autocorrelation in the residuals. The selection of the appropriate lag length *k* can be based on various Information Criteria (IC) provided by E-Views. The corresponding forms of the model are now:

a) Zero mean, no time trend:

$$\Delta Y_t = \beta Y_{t-1} + \gamma_1 \Delta Y_{t-1} + \gamma_2 \Delta Y_{t-2} + \ldots + e_t$$

b) Non-zero mean, no time trend:

$$\Delta Y_t = a_0 + \beta Y_{t-1} + \gamma_1 \Delta Y_{t-1} + \gamma_2 \Delta Y_{t-2} + \ldots + e_t$$

c) Non-zero mean and time trend:

$$\Delta Y_t = a_0 + \beta Y_{t-1} + \gamma_1 \Delta Y_{t-1} + \gamma_2 \Delta Y_{t-2} + \ldots + \delta T + e_t$$

The exact form of the significance tests depends upon the form of the model being tested. In all cases, the null hypothesis of unit root will be rejected if the test statistic $\beta/SE(\beta)$ is smaller (has a larger negative value) than the reported critical values. However, as stated Hendry and Juselius (1999), when a variable is stationary but with a root close to unity, it is often a good idea to act as if there are unit roots to obtain robust statistical inference.

B. COINTEGRATION TESTS

Cointegration analysis is designed to find linear combinations of non-stationary variables (other than differencing) that remove unit roots. Specifically, cointegration vectors determine $I(0)$ relations (long-run equilibria) that hold between variables which are individually $I(1)$. These relations act as “attractors” towards which convergence occurs whenever there are departures therefrom.

The **maximum likelihood theory of multivariate cointegration** assumes that the stochastic variables are integrated of order one $I(1)$ and that the data generating process is a Gaussian vector autoregressive model of finite order k [*VAR(k)*] which may possibly include some deterministic components (intercept and trend). The lag length of the *VAR* is determined based on the sequential modified LR test statistic.

Let Y_t be a p-dimensional column vector of $I(1)$ variables:

$$Y_t = A_1 Y_{k-1} + \ldots + A_k Y_{t-k} + \mu_0 + \mu_1 t + \varepsilon_t, \qquad t = 1 \ldots \mathrm{T} \qquad (1)$$

where $A_1 \ldots A_k$ are $(p \times p)$ matrices of coefficients, μ_0 and μ_1 are $(p \times 1)$ vectors of constant and trend coefficients, respectively. The deterministic term is equal to $\mu_t \equiv \mu_0 + \mu_1 t$. Finally, ε_t is a $p \times 1$ multivariate normal random error vector with mean vector zero and covariance matrix Ω that is independent across time periods.

Following the **Granger Representation Theorem** [Engle and Granger (1987)], if two series are cointegrated, then there exists an error correction representation of the relationship between the first differences of the two series and the *VAR(k)* can be written in a **Vector Error-Correction Model (VECM)** form as:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \mu_0 + \mu_1 t + \varepsilon_t, \qquad t = 1 \ldots \mathrm{T} \qquad (2)$$

where $\Pi = \sum_{=1}^{k} A_i - I$ and $\Gamma_i = \sum_{=i+1}^{k} A_j$ are $(p \times p)$ matrices of coefficients. $\boldsymbol{\Pi}$ represents the **long-run relationship of the individual series**, while and $\boldsymbol{\Gamma_i}$ traces out the **short-run impact of shocks to the system**.

The hypothesis of cointegration can be stated in terms of the long run matrix Π in (2). Under the hypothesis of cointegration, this matrix can always be written as:

$$\Pi = \alpha\beta' \qquad (3)$$

where α and β are $(p \times r)$ matrices of full rank. $\boldsymbol{\alpha}$ is the matrix of the **rate of adjustment of the process towards equilibrium** and $\boldsymbol{\beta}$ is the matrix of **cointegrating vectors** (each column of β is a cointegrating vector), which describe the long-run equilibrium relationships between the variables.[1] The rows of β' are such that for each row: $\beta'_i * Y_{t-1}$ is $I(0)$.

Regardless of the normalization chosen, the rank of Π (the number of linearly independent rows) is still related to the number of cointegrating vectors. There are three possibilities to consider:

- If the <u>rank of Π is 0</u>, then Π = Ø, which means that there is no linear combination of the elements of Y_t that is stationary and that there are p stochastic trends. The variables of Y_t do not have any cointegration relations and hence cannot move together in the long run. In this case, the equation in (2) reduces to a standard *VAR* in first differences.
- The other extreme case is when <u>Π matrix is of full rank</u>, i.e. the rank of the Π equals p. In this case, the assumed stationarity of the error term requires that the levels of the Y_t process themselves be stationary.
- In the intermediate case, when <u>Π is of rank $0 < r < p$</u>, Y_t is $I(1)$ and there exist r stationary linear combinations of the elements of Y_t (r cointegrating vectors) and p - r common trends.

Due to the normality assumption, we can test for the reduced rank of the Π matrix using likelihood ratio tests. The procedure of **Johansen** (1988, 1991) and **Johansen and Juselius** (1990) uses the technique of reduced rank regression and gives at once the *maximum likelihood estimators* (*MLE*) of α and β and the eigenvalues needed in order to construct the likelihood ratio test. The MLE of α and β are obtained by regressing ΔY_t and Y_{t-1} on $\Delta Y_{t-1} \ldots \Delta Y_{t-k}$ and μ_t. These regressions give residuals R_{0t} and R_{it}, respectively. Solving the eigenvalue problem:[2]

---

[1] We may impose restrictions on both coefficients. To impose restrictions on the adjustment coefficients we refer to the (i, j)-th element of the α matrix, for i, j = 1,…, p. One restriction of particular interest is whether the i^{th} row of the α matrix is zero. In this case, the i^{th} endogenous variable is said to be exogenous with respect to the β parameters.

[2] Where $S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R'_{jt}$, for i, j = 0, 1.

$$\left|\lambda S_{11} - S_{10} S_{00}^{-1} S_{01}\right| = 0 \qquad (4)$$

for eigenvalues 1 > $\hat{\lambda}_1$ > ... > $\hat{\lambda}_p$ > 0 and eigenvectors $\hat{V}$ = ($\hat{v}_1$ ... $\hat{v}_p$), normalized such that $\hat{V}' S_{11} \hat{V}$ = I, we get the *MLE* of α and β as $\hat{\alpha}$ = $S_{01}\hat{\beta}$ and $\hat{\beta}$ = ($\hat{v}_1$ ... $\hat{v}_r$) respectively, where ($\hat{v}_1$ ... $\hat{v}_r$) are the eigenvectors associated with the r largest eigenvalues of (4). The choice of $\hat{\beta}$ is equivalent to the choice of the r linear combinations of Y_{t-1} that have the largest squared correlation with the stationary part (ΔY_t). The eigenvalues $\hat{\lambda}_i$ are the squared canonical correlations of R_{it} with respect to R_{0t}. Therefore, they measure how strongly the linear combination $\hat{\beta}'_i{*}Y_{t-1}$ is correlated with the stationary part ΔY_t. If $\hat{\beta}'_i{*}Y_{t-1}$ is non-stationary, this correlation tends to 0 and asymptotically $\hat{\lambda}_i$ = 0, for i = r + 1,…, p. This analysis allows us to calculate all p eigenvalues and eigenvectors and then make inference about the number of important cointegration relations, by testing how many of the λ's are zero. The statistical problem is to derive a test procedure to discriminate between the $\hat{\lambda}_i$, i = 1,…, r, which are large enough to correspond to stationary $\beta' Y_{t-1}$ and those $\hat{\lambda}_i$, i = r + 1,…, p, which are small enough to correspond to non-stationary eigenvectors. The procedure of Johansen (19988, 1991) and Johansen and Juselius (1990) involves two likelihood ratio statistics for testing for r cointegrating relations:

(a) Trace Statistic:

The Trace statistic tests the null hypothesis of r, at most, cointegrating vectors against the alternative hypothesis of p cointegrating vectors.

H_0: $rank(\Pi)$ = r < p (r cointegrating relations)

H_1: $rank(\Pi)$ = p (full rank, so $Y_t \sim I(0)$)

The likelihood ratio statistic is given by:

$$Trace(r|\,p) = -T\ \ln[(1 - \hat{\lambda}_{r+1})...(1 - \hat{\lambda}_p)] = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i) \qquad (5)$$

where $\hat{\lambda}_i$ is the i^{th} smallest eigenvalue to equation (4), for $i = r + 1,..., p$. The testing is performed sequentially for $r = 0,..., p - 1$ and it terminates when the null hypothesis is not rejected for the first time.

The asymptotic distribution of the trace statistic is non-standard and depends on whether there is a constant and/or a trend; and whether these are unrestricted or not in the model.

(b) Maximum Eigenvalue Statistic:

The Maximum Eigenvalue statistic tests the hypothesis of *r* cointegrating vectors against the alternative hypothesis of *r* + 1 cointegrating vectors.

H_0: $rank(\Pi) = r < p$ (r cointegrating relations)

H_1: $rank(\Pi) = r + 1$

The test statistic is computed as:

$$Maximum\ Eigenvalue\ (\lambda_{max}) = -T\ \ln[(1 - \lambda_{r+1}) = Trace(r|\,p) - Trace(r+1|\,p) \qquad (6)$$

for $r = 0,..., p - 1$.

As noted by Kasa (1992) the Trace statistic will tend to have greater power than λ_{max} when the λ_i are evenly distributed, as it takes account of all $p - r$ of the smallest eigenvalues. On the other hand, λ_{max} will tend to give better results when the λ_i are either large or small. In practice the value of r is best chosen by a judicious consideration of both statistics, along with an inspection of the eigenvalues themselves.

C. FIVE CASES FOR TRENDS AND INTERCEPTS

Reconsider the VEC representation (2):

$$\Delta Y_t = \alpha\beta' Y_{t-1} + \sum_{=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \mu_0 + \mu_1 t + \varepsilon_t, \qquad t = 1 \ldots T \tag{7}$$

$\Delta Y_t \sim I(0)$ and $\varepsilon_t \sim I(0)$, thereby $\beta' Y_{t-1}$ must be $I(0)$ also. Since all the above are stationary, they have constant means:

- $E(\Delta Y_t) = \gamma$, describing a $(p \times 1)$ vector of growth rates.
- $E(\beta' Y_{t-1}) = \delta$, describing a $(r \times 1)$ vector of intercepts in the cointegrating relations.

Under the hypothesis $\Pi = \alpha\beta'$, 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, we first decompose the two ($p \times 1$) vectors μ_0 and μ_1 in the directions of α and $\alpha\perp$, where $\alpha\perp$ is a $p \times (p - r)$ matrix of full rank consisting of vectors orthogonal to the vectors in α:

$$\mu_0 = \alpha\delta + \alpha\perp\gamma$$
$$\mu_1 = \alpha\zeta + \alpha\perp\eta$$

The vector in the $\alpha\perp$ directions is related to the mean value of the cointegrating relations $[\beta' Y_{t-1}]$ and the vector in the $\alpha\perp$ is related to growth rates $[\Delta Y_t]$. Hence, the constant term μ_0 and the deterministic linear trend μ_1 play a dual role in the cointegrated model:

- In the α directions, they describe an intercept (δ) and a linear trend (ζ) in the steady-state relations.
- In the $\alpha\perp$ directions, they describe linear (γ) and quadratic (η) trends[3] in the data.

We now discuss five of the most frequently used models arising from restricting the deterministic components in (7):

[3] Linear trends in growth and thus quadratic trends in the variables.

Case 1 **$\mu_1 = 0$, $\mu_0 = 0$**:

The model excludes all deterministic components in the data ($\zeta = \eta = \gamma = \delta = 0$).

Case 2 **$\mu_1 = 0$, $\gamma = 0$**, but **$\delta \neq 0$**:

The constant term is *restricted* in the cointegration space. There are no linear trends in the cointegrating relations ($\zeta = 0$) and no linear ($\gamma = 0$) or quadratic trends ($\eta = 0$) in the data. The only deterministic components in the model are the intercepts (δ) in any cointegrating relations (i.e. some or all equilibrium means are non-zero).

Case 3 **$\mu_1 = 0$**:

There are no linear trends in (8). This means that there are no quadratic trends in the data ($\eta = 0$) or linear trends in any cointegration relations ($\zeta = 0$). But since the constant term is unrestricted $\mu_0 \neq 0$, there are still linear trends in the data ($\gamma \neq 0$) and a non-zero intercept in the cointegration relations ($\delta \neq 0$).

Case 4 **$\eta = 0$:**

The trend is *restricted* in the cointegration space, but the constant is unrestricted. There are linear ($\gamma \neq 0$) but no quadratic trends in the data ($\eta = 0$). These linear trends in the variables do not cancel in the cointegration space ($\zeta \neq 0$). There is also a non-zero intercept in the cointegration relations ($\delta \neq 0$).

Case 5 **No restrictions:**

The trend and the intercept are *unrestricted* in the VAR model.

These five cases correspond to the following representations of the deterministic term μ_t:

Model 1 **(H_2)** $\mu_t = 0$

Model 2 **(H_1^*)** $\mu_t = \alpha\delta$

Model 3 **(H_1)** $\mu_t \equiv \mu_0 = \alpha\delta + \alpha_\perp\gamma$

Model 4 **(H_0^*)** $\mu_t = \alpha\delta + \alpha_\perp\gamma + \alpha\zeta t$

Model 5 **(H_0)** $\mu_t \equiv \mu_0 + \mu_1 t = \alpha\delta + \alpha_\perp\gamma + (\alpha\zeta + \alpha_\perp\eta)t$

The above models are each a subset of the other:

$$H_2 \subset H_1^* \subset H_1 \subset H_0^* \subset H_0$$

Johansen constructed likelihood ratio (LR) statistics for determining the correct model for a given number of r cointegrating vectors. These statistics are the following:

$$-2\ln(Q;H_0^*|H_0) = T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i^*)/(1-\hat{\lambda}_i) \sim \chi^2(p-r)$$

$$-2\ln(Q;H_1|H_0^*) = T\sum_{i=1}^{r}\ln(1-\hat{\lambda}_i)/(1-\hat{\lambda}_i^*) \sim \chi^2(r)$$

$$-2\ln(Q;H_1^*|H_1) = T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i^*)/(1-\hat{\lambda}_i) \sim \chi^2(p-r)$$

$$-2\ln(Q;H_2|H_1^*) = T\sum_{i=1}^{r}\ln(1-\hat{\lambda}_i)/(1-\hat{\lambda}_i^*) \sim \chi^2(r)$$

where $\hat{\lambda}_i$ and $\hat{\lambda}_i^*$ are the i^{th} largest eigenvalue under the hypothesis H and H^*, respectively. As indicated above, the statistics follow a χ^2 distribution with r or $p - r$ degrees of freedom. The null hypothesis corresponds to the case that the more restrictive model is more suitable than the less restrictive one. The testing is performed sequentially, starting form the most restrictive model and moving to the less restrictive and it terminates when a hypothesis is not rejected for the first time.

V. DATA - GROUPS

The countries in question, as mentioned above, are the new EU members: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. Various authors [see Kocenda (2001), Kutan and Yigit (2002)] separate the countries according to the starting dates of negotiations. On 31 March 1998 negotiations started with Cyprus, the Czech Republic, Estonia, Hungary, Poland and Slovenia (*"1998 group")* and on 13 October 1999 the Commission recommended the opening of negotiations with Latvia, Lithuania, Malta, the Slovak Republic (*"1999 group"*).[1] However, the "wave" approach has been left behind and each country's accession prospects depend on its progress with negotiations through the acquis. Thereby, a segmentation according the type of the economies of the candidates could seem useful. In that case, the first group consists of the *transition-economy candidates* (Czech Republic, Estonia, Hungary, Poland, Slovenia, Latvia, Lithuania and the Slovak Republic) and the second of the *market-economy candidates* (Cyprus and Malta). The former group is further separated into two groups. The first reflects the institutional aspects of transition reforms with respect to the international trade arrangement between the Central and Eastern European Countries (CEEC). Such an arrangement was institutionalised in March 1993 in the form of the *CEFTA*, comprised of the Czech and the Slovak Republic, Hungary, Poland, and Slovenia. The final group consists of the *Baltic* countries (Estonia, Latvia, Lithuania). EMU is represented by three countries: Germany, France and the Netherlands. The decision not to include Germany alone arises from the doubts expressed about its dominant role and from two of the criteria proposed by the Maastricht Treaty.[2]

The research in the field of inflation and interest rates convergence of the new EU members is likely to be more reliable in the future, since – as stated by Eurostat (2003) – the accession process has led to the construction of more appropriate indices, like the harmonised long-term interest rates series for convergence

[1] Bulgaria and Romania were also included in this group, but the negotiations did not close in 2002, as happened with the other countries.

[2] In order to qualify for joining the EMU, a country must have: (a) an inflation rate not higher than 1.5% above the average of the three countries with the lowest inflation rates, (b) a long-term interest rate not higher than 2% above the average of the three countries with the lowest inflation rates.
However, the construction of a series that includes such data would generate stationary processes, not appropriate for cointegration analysis. We, thereby, use data from the countries included in Koukouritakis and Michelis (2003).

assessment purposes since 2001 and the harmonised index of consumer prices (HICP).[3]

The Consumer Price Index (CPI) and interest rates data used in the analysis were obtained by the DATASTREAM, IMF Statistics (IFS) and EcoWIn Pro Databases, as well as by the ECB, EUROSTAT and the National Banks for the post-1993 period. We excluded data from the pre-1993 period both to avoid the early transition period and its financial chaos and to be able to include the Czech and Slovak Republics in the analysis. In some cases, after all, data availability forced us to truncate the data set somewhat. For CPI we use data for the period from January 1993 to December 2003, that produces a total of 120 observations. For the calculation of inflation we used the twelfth differences of the logs of the monthly CPI series (i.e. the growth rate of each month relative to the same month of the previous year) so the reference period is reduced from January 1994 to December 2003, equivalent to a total of 120 monthly observations. For interest rates we use the logs of the monthly long-term government bond yields for most of the countries for the period spanning from January 1995 to December 2003 (a total of 108 observations) for the CEFTA members and the Baltic countries and from January 1996 to December 2003 for the market economies. As Estonia has a very limited government debt, there are currently no suitable long-term government bonds available on the financial market. Furthermore, since government bond yields data for Latvia and Slovenia are limited to the post-2001 period, the indicators for these countries represent the interest rates on loans to non-financial corporations and households with maturities over five years[4]. In this case, however, Lithuania was removed from the sample due to data unavailability for the entire period. In the following table, we report the type of long-term interest rates used in the analysis.

TABLE 1. Interest Rates Groups

Countries	Type of Interest Rate
Czech and Slovak Republics, EMU Members	10-year government bond yield
Cyprus, Malta, Hungary	5-year government bond yield
Poland	4-year government bond yield
Estonia, Latvia, Slovenia	Interest rates on long-term loans

[3] The first stage to harmonization is the interim HICP (or proxy HICP), based largely on existing national CPIs, adapted to the HICP coverage and methodology. For the acceding countries, they are expected to be fully compliant with the HICPs of the Member States by 2004.

[4] However, a large part of the underlying claims is linked to variable interest rates and the claims are subject to a different credit risk than government bonds.

VI. ECONOMETRIC RESULTS

A. UNIT ROOT TESTS

First of all, we have to determine the time-series characteristics of the data. All time series under consideration are tested for stationarity. As explained previously, the ADF unit root test is employed. The appropriate lag length k is automatically selected, based on the Akaike Information Criterion (AIC). The results of the unit root tests on the inflation and interest rates series are reported in Table 2.

TABLE 2. ADF Unit Root Tests Results.*

	Inflation		**Interest Rates**	
Country	**Sample**	**Result**	**Sample**	**Result**
Baltic Countries				
Estonia	1994:01-2003:12	*I*(1)**	1995:01-2003:12	*I*(1)
Latvia	1994:01-2003:12	*I*(1)**	1995:01–2003:12	*I*(1)
Lithuania	1994:01-2003:12	*I*(1)**	-	
CEFTA Members				
Czech Republic	1994:01-2003:12	*I*(1)	1995:01-2003:12	
Hungary	1994:01-2003:12	*I*(1)	1995:01-2003:12	*I*(1)
Poland	1994:01-2003:12	*I*(1)	1995:01-2003:12	*I*(1)
Slovak Republic	1994:01-2003:12	*I*(1)	1995:01-2003:12	*I*(1)
Slovenia	1994:01-2003:12	*I*(1)	1995:01-2003:12	
Market Economies				
Cyprus	1994:01-2003:12	*I*(1)	1996:01-2003:12	
Malta	1994:01-2003:12	*I*(1)	1996:01-2003:12	*I*(1)
EMU Members				
Germany	1994:01-2003:12	*I*(1)**	1995:01-2003:12	*I*(1)
France	1994:01-2003:12	*I*(1)	1995:01-2003:12	*I*(1)
Netherlands	1994:01-2003:12	*I*(1)	1995:01-2003:12	*I*(1)

* All results are reported at 1% significance level.
** These series are sensitive to the unit root test specification.

As illustrated above, we are unable to reject the unit root hypothesis for all the inflation and interest rates series. Since they are non-stationary, they are appropriate for a cointegration analysis.

B. COINTEGRATION TESTS

In this section, we report the results of the cointegration tests of the inflation and interest rates series. One prior step in constructing the suitable model for cointegration testing is to determine the number of lags that it should include. For that reason, we estimate a VAR model in differences and then take under consideration the various lag length criteria reported by E-Views. We pay special attention to the sequential modified LR test statistic[5]. We then consider the VECM cases 1 to 5 as described in Section IV. First, we test the suitability of the various submodels by using the likelihood ratio (LR) tests introduced by Johansen (see pp. 28), distributed as χ^2 and then determine the number of cointegrating vectors based on the Trace and Maximum Eigenvalue statistics.

The Johansen procedure also permits hypothesis testing of the cointegrating relations and adjustment coefficients. So, as next step we impose restrictions on the α and β parameters and test the validity of the assumptions. Here, it is important to note that the E-Views program is able to test this kind of hypothesis only under the assumption of one cointegrating vector. At first, we test whether a country adjusts to the long-run relationship by testing the hypothesis that the α parameter corresponding to the country is significantly different from 0. If the parameter is 0 the country does not adjust to (but rather leads) the long-run relation, i.e. the country actually dominates the common trend. If this is the case, then the corresponding endogenous variable is said to be *weakly exogenous* with respect to the β parameters.

We further test if the cointegrating coefficients, under the assumption of one cointegrating relation, are significantly different from 0. If a coefficient is found to be 0, then it is removed from the cointegrating equation, as it does not participate in the equilibrium relation.

---

[5] The sequential modified likelihood ratio (LR) test is carried out as follows. Starting from the maximum lag, test the hypothesis that the coefficients on lag l are jointly zero using the χ^2 statistics:

$$LR = (T - m)\{\log|\Omega l\text{-}1| - \log|\Omega l|\} \sim \chi^2(k^2)$$

where m is the number of parameters per equation under the alternative. We employ Sims' (1980) small sample modification, which uses $(T - m)$ rather than T. The modified LR statistics is compared to the 5% critical values starting from the maximum lag, and decreasing the lag one at a time until the first rejection. The alternative lag order from the first rejected test is marked with an asterisk (if no test rejects, the minimum lag will be marked with an asterisk).

Finally, we apply Granger causality tests. The Granger approach to the question of whether X causes Y is to see how much of the current Y can be explained by past values of Y and then to see whether adding lagged values of X can improve the explanation. Y is said to be Granger-caused by X if X helps in the prediction of Y, or equivalently if the coefficients on the lagged X's are statistically significant. Note that two-way causation is frequently the case: X Granger causes Y and Y Granger causes X. In the VAR environment, we carry out pairwise Granger causality tests and tests whether an endogenous variable can be treated as exogenous. For each equation in the VAR, the output displays χ^2 (Wald) statistics for the joint significance of each of the other lagged endogenous variables in that equation. The statistic in the last row (All) is the χ^2 statistic for joint significance of all other lagged endogenous variables in the equation (C(1,1)=…=C(1,p) = 0). The C's are the coefficients of the Γ matrix are 0. We remind that the Γ matrix captures the short-run impact of shocks to the system, the short-run dynamics. If the null hypothesis is accepted, the changes in the inflation or interest rates of the dependent variable are not explained by past changes in the corresponding variables of the independent variable. This has the interpretation of lack of short-run dynamics.

1. INFLATION

1.1. Baltic Countries

(a) Cointegration Results:

The number of lags indicated by the sequential modified LR test statistic (as well as the Final Prediction Error and the Akaike Information Criteria) for the inflation rates of the Baltic countries alongside with the EMU is 7.

Table 3. Lag selection.

Lag	LR	FPE	AIC	SC	HQ
0	N/A	1.37E-28	-47.13346	-46.98864*	-47.07469*
1	99.63103	1.01E-28	-47.43621	-46.42249	-47.02485
2	60.33910	1.05E-28	-47.40243	-45.51981	-46.63848
3	80.71747	8.53E-29	-47.62396	-44.87243	-46.50742
4	77.83029	6.83E-29	-47.87122	-44.25080	-46.40209
5	52.50237	7.10E-29	-47.87433	-43.38500	-46.05261
6	54.43543	6.99E-29	-47.95342	-42.59519	-45.77910
7	61.44577*	6.02E-29*	-48.19405*	-41.96691	-45.66714

* Lag order selected by the criterion.

For the selection of the appropriate model we employ the likelihood ratio tests, under the assumption of 3 cointegrating vectors. We start from the less restrictive model and we move to the more restrictive one. The log Likelihood by rank and model is reported below.

Table 4. Log Likelihood by Rank (rows) and Model (columns).

	Model				
Rank	1	2	3	4	5
0	3107.610	3107.610	3110.729	3110.729	3117.244
1	3130.985	3131.477	3133.782	3142.389	3147.615
2	3147.905	3152.055	3153.865	3162.544	3167.771
3	3159.345	3165.146	3166.776	3176.918	3181.915
4	3167.583	3173.925	3174.344	3185.968	3190.946
5	3170.304	3178.256	3178.304	3191.341	3192.615
6	3170.306	3179.237	3179.237	3192.842	3192.842

In testing for model 4 in model 5, we reject the null hypothesis that model four is more suitable, as LR = -2*(3176.918 – 3181.915) = 9.994 ~ $\chi^2(3)$ and Probability ≈

0.02 < 0.05. The analysis, thus, indicates model 5 as the more appropriate one. Thereby, we estimate model 5, which assumes quadratic trend in the data and intercept and trend in the cointegrating equations. Table 5 reports the number of cointegrating vectors according to the Trace and Maximum Eigenvalue statistics, presented in Section IV (B).

Table 5. Unrestricted Cointegration Rank Test.

Hypothesized No. of CE(s)	Trace Statistic	Critical Value 5%	Critical Value 1%	Max-Eigen Statistic	Critical Value 5%	Critical Value 1%
None	151.1963**	104.94	114.36	60,74353**	42.48	48.17
At most 1	90.45279**	77.74	85.78	40,31083*	36.41	41.58
At most 2	50.14195	54.64	61.24	28,28883	30.33	35.68
At most 3	21.85312	34.55	40.49	18,06136	23.78	28.83
At most 4	3.791761	18.17	23.46	3,338472	16.87	21.47
At most 5	0.453289	3.74	6.40	0,453289	3.74	6.40

* Rejection of the hypothesis at the 5% level.
** Rejection of the hypothesis at the 1% level.

The Trace statistic indicates two cointegrating vectors at both the 1% and the 5% level, while the Maximum Eigenvalue indicates one cointegrating vector at the 1% level and two cointegrating vectors at the 5% level. We therefore accept that there are **two (2)** cointegrating vectors. The existence of two cointegrating vectors in six variables is supportive of "partial" convergence in the inflation rates of the Baltic countries with the three EMU members.

(b) Restriction Results:

We now impose restrictions on the α and β parameters and test their validity, under the assumption of one cointegrating vector.

Table 6. Normalized Cointegrating Coefficients.*

Estonia	Latvia	Lithuania	Germany	France	Netherlands
1	0.133536	-0.617492	1.333223	-2.983642	-0.602493
	(0.26320)	(0.14696)	(0.59638)	(0.71028)	(0.47731)

* Standard Error in parentheses.

The corresponding adjustment coefficients are reported in the next table.

Table 7. Adjustment Coefficients.

Country	A(i, j)
Estonia	-0.185833
	(0.07031)
Latvia	0.040642
	(0.05541)
Lithuania	0.287368
	(0.07436)
Germany	0.012251
	(0.02285)
France	0.025261
	(0.02127)
Netherlands	-0.005508
	(0.01889)

* Standard Error in parentheses.

Firstly, we test whether a country participates in and whether it adjusts to the long-run relationship, by imposing restrictions on the parameters A(i,j) and B(j,i) under the assumption of one cointegrating relation. Next, we check the validity of these restrictions. The results are reported below.

Table 8. LR tests for restrictions on α and β matrices.

	Cointegration Restrictions					
	Estonia	**Latvia**	**Lithuania**	**Germany**	**France**	**Netherlands**
	A(1,1)=0	**A(2,1)=0**	**A(3,1)=0**	**A(4,1)=0**	**A(5,1)=0**	**A(6,1)=0**
χ^2(1)	6.595595	0.712400	12.29239	0.260736	1.640698	0.117727
Prob.	0.010223	0.398648*	0.000455	0.609615*	0.200230*	0.731513*
	B(1,1)=0	**B(1,2)=0**	**B(1,3)=0**	**B(1,4)=0**	**B(1,5)=0**	**B(1,6)=0**
χ^2(1)	19.59955	0.141089	7.917276	4.560402	13.54416	1.747087
Prob.	0.000010	0.707201*	0.004896	0.032719*	0.000233	0.186243*

A(i,j), B(j,i), where i: the country and j: the cointegrating equation, i.e. 1.
* Acceptance of the hypothesis at the 5% level.

As shown above, the adjustment coefficients of Latvia, Germany, France and the Netherlands are 0, i.e. these countries do not adjust to the changes of the long-run relation. The greatest rate of adjustment is observed in the case of Lithuania. As far as the restrictions on the cointegrating coefficients are concerned, we accept that Latvia, Germany and the Netherlands are 0; that is they do not participate in the equilibrium relation and thereby can be removed from the cointegrating equation. Consistent with the previous analysis, we conclude that the common trend is dominated by France.

(c) Causality Results:

In this final section, we carry out pairwise Granger causality tests. Table 9 displays χ^2 (Wald) statistics for the individual and joint significance of each of the other lagged endogenous variables. We remind that the null hypothesis is that of Granger non-causality, i.e. rejection of the hypothesis means that the specific independent variable Granger causes the dependent.

Table 9. VEC Pairwise Granger Causality / Block Exogeneity Wald Tests.

Variable: Δ(Inflation Rate)							
Independent Variable		**Dependent Variable**					
		Estonia	**Latvia**	**Lithuania**	**Germany**	**France**	**Netherlands**
Estonia	$\chi^2(7)$	-	22.2339*	59.24306*	0.373645	8.926737	8.872054
Latvia	$\chi^2(7)$	27.832*	-	69.41078*	5.644254	3.944342	10.88160
Lithuania	$\chi^2(7)$	14.676*	65.2993*	-	4.036064	7.541265	10.28637
Germany	$\chi^2(7)$	4.3952	5.52398	5.148794	-	5.442505	17.10205*
France	$\chi^2(7)$	12.1123	6.39013	31.23841*	10.59250	-	16.63640*
Netherlands	$\chi^2(7)$	9.50952	1.76499	15.40235*	9.386601	5.987642	-
ALL	$\chi^2(35)$	57.947*	134.352*	274.7156*	41.91484	27.11959	66.54432*

* Rejection of the hypothesis at the 5% level.

According to the results reported in Table 9, the inflation rates of Germany and France are the only that can be treated as exogenous, as the coefficients of lagged independent variables are zero. In this case, the changes in the inflation rates of Germany and France are not explained by the history of changes in the other countries. Except for the joint hypothesis of Granger non-causality, we are in position to test the statistical significance of the individual C's. Table 10 shows briefly the results. The table is read horizontally, e.g. Estonia Granger causes Latvia*, Germany does not Granger cause France, etc.

Table 10. Direction of Causality.

	Estonia*	**Latvia***	**Lithuania***	**Germany***	**France***	**Netherlands***
Estonia	-	Yes	Yes	No	No	No
Latvia	Yes	-	Yes	No	No	No
Lithuania	Yes	Yes	-	No	No	No
Germany	No	No	No	-	No	Yes
France	No	No	Yes	No	-	Yes
Netherlands	No	No	Yes	No	No	-
All	Yes	Yes	Yes	No	No	Yes

Yes: Granger causes.
No: Does not Granger cause.

1.2. CEFTA Members

(a) Cointegration Results:

The number of lags indicated by the sequential modified LR test statistic (as well as the Akaike Information Criteria) for the CEFTA group is 6, as shown in Table 11.

Table 11. Lag selection.

Lag	LR	FPE	AIC	SC	HQ
0	N/A	3.10E-38	-63.66539	-63.47230*	-63.58704*
1	140.7250	2.49E-38*	-63.88577	-62.14797	-63.18059
2	89.15292	3.10E-38	-63.68171	-60.39919	-62.34969
3	66.54050	4.71E-38	-63.30510	-58.47787	-61.34626
4	103.7172	4.33E-38	-63.46883	-57.09688	-60.88315
5	75.60675	5.40E-38	-63.38618	-55.46951	-60.17368
6	130.3476*	2.71E-38	-64.29011*	-54.82873	-60.45078

* Lag order selected by the criterion.

In order to select the appropriate model, we test the various submodels against each other using the Johansen likelihood ratio (LR) tests. We choose among the alternative models, under the assumption of 7 cointegrating vectors. (We select 7 cointegrating vectors as this is the number reported by the Trace and Maximum Eigenvalue statistics for all of the five models that is closer to the desired one). We start from the less restrictive model and we move to the more restrictive one. The following table reports the log likelihood by rank and by model.

Table 12. Log Likelihood by Rank (rows) and Model (columns).

	Model				
Rank	1	2	3	4	5
0	4013.720	4013.720	4024.391	4024.391	4026.211
1	4055.736	4058.287	4067.800	4079.175	4080.936
2	4086.523	4093.761	4102.898	4118.520	4120.025
3	4111.883	4119.709	4128.813	4144.442	4145.738
4	4125.163	4137.861	4146.737	4167.253	4168.525
5	4137.696	4150.412	4159.269	4183.822	4184.955
6	4146.477	4162.276	4170.691	4196.118	4197.043
7	4153.124	4171.056	4177.214	4207.316	4207.525
8	4153.125	4177.310	4177.310	4212.036	4212.036

In testing for model 4 in model 5, we accept the null hypothesis that model 4 is more suitable, as LR = 0.418 ~ $\chi^2(1)$ and Probability ≈ 0.52 > 0.05. In testing for model 3 in model 4, we reject the null hypothesis that model 3 is more suitable, as LR = 60.204 ~ $\chi^2(7)$ and Probability ≈ 0 < 0.05. The analysis indicates model 4 as the most appropriate one. Consequently, we estimate the 4th model, which assumes linear trend in data and intercept and trend in the cointegrating equations. The table below reports the number of cointegrating vectors according to the Trace and Maximum Eigenvalue Statistics.

Table 13. Unrestricted Cointegration Rank Test.

Hypothesized No. of CE(s)	Trace Statistic	Critical Value 5%	Critical Value 1%	Max-Eigen Statistic	Critical Value 5%	Critical Value 1%
None	375.2880**	182.82	196.08	109.5670**	55.50	62.46
At most 1	265.7211**	146.76	158.49	78.69085**	49.42	54.71
At most 2	187.0302**	114.90	124.75	51.84343**	43.97	49.51
At most 3	135.1868**	87.31	96.58	45.62259**	37.52	42.36
At most 4	89.56422**	62.99	70.05	33.13722*	31.46	36.65
At most 5	56.42701**	42.44	48.45	24.59277	25.54	30.34
At most 6	31.83424**	25.32	30.45	22.39485	18.96	23.65
At most 7	9.439391	12.25	16.26	9.439391	12.25	16.26

* Rejection of the hypothesis at the 5% level.
** Rejection of the hypothesis at the 1% level.

The Trace statistic indicates seven cointegrating vectors at both levels (1% and 5%), while the Maximum Eigenvalue statistic indicates four cointegrating vectors at the 1% level and five cointegrating vectors at the 5% level. We accept that there are **five (5)** cointegrating vectors.

Following, Koukouritakis and Michelis (2003) definition, the fact that the inflation rates of the CEFTA countries and the three EMU members have five cointegrating vectors and therefore share three common stochastic trend is indicative of "partial" convergence. We confirm, however, that the cointegrating vectors are far from the [1, -1] form required by the definition of Bernard and Durlauf (1995) developed earlier, by admitting in the same time that this is a very restrictive hypothesis.

(b) Restriction Results:

As next step we impose restrictions on the α and β parameters and test the validity of the assumptions, under the assumption of one cointegrating vector.

Table 14. Normalized Cointegrating Coefficients.*

Czech	Hungary	Poland	Slovakia	Slovenia	Germany	France	Netherlands	Trend
1	2.356664	-6.841522	1.168048	3.962179	6.786980	5.608426	-3.434250	-0.007825
	(0.41737)	(0.78606)	(0.18785)	(0.68250)	(1.74714)	(1.27612)	(1.01978)	(0.00115)

* Standard Error in parentheses.

The corresponding adjustment coefficients are shown in Table 15.

Table 15. Adjustment Coefficients.

Country	A(i, j)
Czech	0.046559
	(0.02454)
Hungary	-0.145781
	(0.02226)
Poland	-0.014905
	(0.03084)
Slovakia	0.023181
	(0.05004)
Slovenia	0.003171
	(0.02670)
Germany	-0.019326
	(0.01173)
France	-0.017724
	(0.01119)
Netherlands	-0.007372
	(0.01045)

* Standard Error in parentheses.

At first, we test whether a country adjusts to the long-run relationship by testing the hypothesis that the parameter A(i,j) (where i: the country and j: the cointegrating equation, i.e. 1) is significantly different from 0. We further test if the cointegrating coefficients B(j,i) under the assumption of one cointegrating relation, are significantly different from 0. The results are reported below.

Table 16. LR tests for restrictions on a and β matrices.

	Cointegration Restrictions							
	Czech	**Hungary**	**Poland**	**Slovakia**	**Slovenia**	**Germany**	**France**	**Netherlands**
	A(1,1)=0	**A(2,1)=0**	**A(3,1)=0**	**A(4,1)=0**	**A(5,1)=0**	**A(6,1)=0**	**A(7,1)=0**	**A(8,1)=0**
$\chi^2(1)$	4.441647	28.76993	0.291344	0.196472	0.018694	3.716546	2.968648	0.565387
Prob.	0.035072	0	0.589360*	0.657583*	0.891247*	0.053876*	0.084893*	0.452098*
	B(1,1)=0	**B(1,2)=0**	**B(1,3)=0**	**B(1,4)=0**	**B(1,5)=0**	**B(1,6)=0**	**B(1,7)=0**	**B(1,8)=0**
$\chi^2(1)$	4.518915	12.51021	29.68608	9.770630	15.50067	7.481809	3.567377	5.411534
Prob.	0.033522	0.000405	0	0.001773	0.000082	0.006233	0.058925*	0.020004

A(i,j), B(j,i), where i: the country and j: the cointegrating equation, i.e. 1.
* Acceptance of the hypothesis at the 5% level.

As shown above, only the adjustment coefficients of Czech and Hungary are significantly different from zero. Out of these two, Hungary performs the greatest adjustment to deviations from the long-run equilibrium. Poland, Slovakia, and Slovenia do not seem to adjust, but rather lead the trend, as do Germany, France and the Netherlands. As far as the restrictions on the cointegrating coefficients are concerned, we accept that only France does not participate in the equilibrium relation and thereby can be removed from the cointegrating equation. From the previous analysis, we deduce that the common trends are dominated by Poland, Slovakia, Slovenia, Germany and the Netherlands.

(c) Causality Results:

In this section we carry out pairwise Granger causality tests, in order to decide about the direction of causality. Table 17 displays χ^2 (Wald) statistics for the individual and joint significance of each of the independent variables.

Table 17. VEC Pairwise Granger Causality / Block Exogeneity Wald Tests.

Variable: Δ(Inflation Rate)									
Independent Variable		Dependent Variable							
		Czech	**Hungary**	**Poland**	**Slovakia**	**Slovenia**	**Germany**	**France**	**Netherlands**
Czech	$\chi^2(6)$	-	46.93364*	2.64522	11.31256	13.645*	6.654716	6.18899	8.160578
Hungary	$\chi^2(6)$	16.164*	-	13.598*	2.039485	11.57722	3.919498	5.39466	9.217331
Poland	$\chi^2(6)$	13.83*	39.8486*	-	3.280059	18.7792*	6.799436	11.9497	3.916915
Slovakia	$\chi^2(6)$	15.37*	36.4183*	11.1657	-	1.420423	10.26620	15.7267	19.30895
Slovenia	$\chi^2(6)$	12.974*	28.0273*	10.1174	5.300576	-	10.05127	9.1545*	8.635239*
Germany	$\chi^2(6)$	25.334*	15.526*	5.7111	7.439894	4.404339	-	11.5246	11.65695
France	$\chi^2(6)$	25.305*	26.7653*	4.61693	5.918644	15.2373*	2.99721*	-	13.99994*
Netherlands	$\chi^2(6)$	7.09734	6.303692	1.57137	6.488640	1.474946	8.768179	6.50888	-
ALL	$\chi^2(42)$	112.77*	107.413*	67.838*	44.76040	78.6862*	73.047*	61.844*	90.55332*

* Rejection of the hypothesis at the 5% level.

According to the results reported in Table 17, only the inflation rates of Slovakia can be treated as exogenous, as the coefficients of lagged independent variables are zero. In this case, the changes in the inflation rates of Slovakia are not affected by the history of the changes in the inflation rates of the other countries.

Except for the joint hypothesis of Granger non-causality, we also tested the statistical significance of the C's individually. Table 18 shows more clearly the results. The table is read horizontally, e.g. Poland Granger causes Czech*, the Netherlands does not Granger cause Germany, etc.

Table 18. Direction of Causality.

	Czech*	**Hungary***	**Poland***	**Slovakia***	**Slovenia***	**Germany***	**France***	**Netherlands***
Czech	**-**	Yes	No	No	Yes	No	No	No
Hungary	Yes	-	Yes	No	No	No	No	No
Poland	Yes	Yes	-	No	Yes	No	No	No
Slovakia	Yes	Yes	No	-	No	No	No	No
Slovenia	Yes	Yes	No	No	-	No	Yes	Yes
Germany	Yes	Yes	No	No	No	-	No	No
France	Yes	Yes	No	No	Yes	Yes	-	Yes
Netherlands	No	No	No	No	No	No	No	-
All	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes

Yes: Granger causes.
No: Does not Granger cause.

1.3. Market-Economy Candidates

(a) Cointegration Results:

As shown below, the number of lags indicated by the sequential modified LR test statistic for the inflation series of the market economies (Cyprus and Malta) along with the EMU countries is 7.

Table 19. Lag selection.

Lag	LR	FPE	AIC	SC	HQ
0	N/A	5.17E-25*	-41.73206*	-41.61001*	-41.68254*
1	43.18366	5.38E-25	-41.69288	-40.96057	-41.39580
2	24.74247	6.61E-25	-41.48985	-40.14729	-40.94522
3	43.85911	6.58E-25	-41.50108	-39.54826	-40.70888
4	38.89386	6.79E-25	-41.48278	-38.91971	-40.44302
5	31.05687	7.55E-25	-41.39771	-38.22438	-40.11038
6	21.98630	9.29E-25	-41.22208	-37.43851	-39.68720
7	39.00805*	9.07E-25	-41.29174	-36.89791	-39.50929
8	31.14869	9.70E-25	-41.28627	-36.28218	-39.25626
9	28.59808	1.06E-24	-41.27579	-35.66145	-38.99822

* Lag order selected by the criterion.

For the selection of the appropriate model we employ the likelihood ratio tests, under the assumption of 1 cointegrating vector. The log Likelihood by rank and model is reported below.

Table 20. Log Likelihood by Rank (rows) and Model (columns).

	Model				
Rank	1	2	3	4	5
0	2642.159	2642.159	2643.005	2643.005	2645.389
1	2660.728	2663.403	2664.071	2667.530	2668.525
2	2669.919	2674.579	2675.073	2680.312	2681.298
3	2673.548	2681.992	2682.047	2687.315	2688.269
4	2676.092	2685.549	2685.582	2692.464	2692.741
5	2676.112	2686.515	2686.515	2693.984	2693.984

In testing for model 4 in model 5, we accept the null hypothesis that model 4 is more suitable, as LR = 1.990 ~ $\chi^2(4)$ and Probability ≈ 0.46 > 0.05. Continuing to test for model 3 in model 4, we reject the null hypothesis that model 3 is more suitable. In this case, LR = 6.918 ~ $\chi^2(1)$ and Probability ≈ 0.01 < 0.05. According to the results, we estimate the 4th model, which assumes linear trend in the data and intercept and trend in the cointegrating equations. Table 21 reports the number of cointegrating vectors according to the Trace and Maximum Eigenvalue statistics.

Table 21. Unrestricted Cointegration Rank Test.

Hypothesized No. of CE(s)	Trace Statistic	Critical Value 5%	Critical Value 1%	Max-Eigen Statistic	Critical Value 5%	Critical Value 1%
None	101.9586**	87.31	96.58	49.04995**	37.52	42.36
At most 1	52.90860	62.99	70.05	25.56360	31.46	36.65
At most 2	27.34500	42.44	48.45	14.00667	25.54	30.34
At most 3	13.33833	25.32	30.45	10.29695	18.96	23.65
At most 4	3.041375	12.25	16.26	3.041375	12.25	16.26

* Rejection of the hypothesis at the 5% level.
** Rejection of the hypothesis at the 1% level.

Both statistics indicate **one (1)** cointegrating vector at both the 1% and the 5% significance level. The finding of one only cointegrating vector and subsequently of four common stochastic trends in a group of five countries forces us to reject the hypothesis of complete convergence of the market economies to EMU countries. The form of the cointegrating vector further supports the result of partial convergence, as it is clearly different from the [1, -1] form required by the complete convergence definition.

(b) Restriction Results:

Table 22 presents the cointegrating coefficients.

Table 22. Normalized Cointegrating Coefficients.*

Cyprus	Malta	Germany	France	Netherlands	Trend
1	-0.270169	-2.548598	0.602411	1.365283	-0.000274
	(0.24880)	(0.36472)	(0.31157)	(0.36716)	(0.00010)

* Standard Error in parentheses.

The corresponding adjustment coefficients are presented in Table 23.

Table 23. Adjustment Coefficients.

Country	A(i, j)
Cyprus	-0.317048 (0.09783)
Malta	0.072597 (0.07401)
Germany	0.067915 (0.03103)
France	0.007802 (0.02986)
Netherlands	-0.055188 (0.02616)

* Standard Error in parentheses.

We now test whether a country of this group participates in the relation and whether it adjusts to the deviations from the long-run equilibrium, by imposing restrictions on the parameters A(i,j) and B(j,i) under the assumption of one cointegrating relation. Next, we check the validity of these restrictions. The results are reported below.

Table 24. LR tests for restrictions on a and β matrices.

	Cointegration Restrictions Cyprus	Malta	Germany	France	Netherlands
	A(1,1)=0	**A(2,1)=0**	**A(3,1)=0**	**A(4,1)=0**	**A(5,1)=0**
χ^2**(1)** **Prob.**	11.10377 0.000862	0.755844 0.384632*	5.219219 0.022339	0.088842 0.765655*	5.290198 0.021446
	B(1,1)=0	**B(1,2)=0**	**B(1,3)=0**	**B(1,4)=0**	**B(1,5)=0**
χ^2**(1)** **Prob.**	18.89900 0.000014	0.766073 0.381435*	17.91665 0.000023	4.410377 0.035721	10.99164 0.000915

A(i,j), B(j,i), where i: the country and j: the cointegrating equation, i.e. 1.
* Acceptance of the hypothesis at the 5% level.

According to the previous results, the adjustment coefficients of Cyprus, Germany and Netherlands are significantly different from zero. Out of them, Cyprus (as expected) performs the greatest adjustment to deviations from the long-run equilibrium. Malta and France, on the other hand, are found to be weakly exogenous with respect to the β matrix. Bearing in mind, however, the fact that Malta is excluded from the cointegrating vector [B(1,2)=0], we conclude that the relation is dominated by France.

(c) Short-Run Dynamics:

In this section we carry out pairwise Granger causality tests, in order to decide about the direction of causality. Table 25 displays χ^2 (Wald) statistics for the individual and joint significance of each of the independent variables.

Table 25. VEC Pairwise Granger Causality / Block Exogeneity Wald Tests.

Variable: Δ(Inflation Rate)						
Independent Variable		**Dependent Variable**				
		Cyprus	**Malta**	**Germany**	**France**	**Netherlands**
Cyprus	$\chi^2(7)$	-	6.802132	2.223400	1.796185	10.16192
Malta	$\chi^2(7)$	8.45976	-	5.307092	9.337172	10.36318
Germany	$\chi^2(7)$	6.02828	8.056048	-	2.293216	19.49583*
France	$\chi^2(7)$	7.56311	13.40036	10.36469	-	14.11847*
Netherlands	$\chi^2(7)$	5.75236	5.702553	12.04325	4.531421	-
ALL	$\chi^2(28)$	23.6549	37.85671	41.04758	19.69883	58.60326*

* Rejection of the hypothesis at the 5% level.

According to the results reported in Table 25, only the inflation rates of the Netherlands cannot be treated as exogenous, as the coefficients of the lagged independent variables are significantly different from zero only in this case. That is, the changes in the inflation rate of the Netherlands are affected by the history of the changes in the inflation rates of the other countries. All the other countries do not seem to have short-run relations; the one is not affected by past changes in the other(s).

Except for the joint hypothesis of Granger non-causality, we also tested the statistical significance of the C's individually. Table 18 shows more clearly the results. The table is read horizontally, e.g. Germany Granger causes the Netherlands*, Malta does not Granger cause France*, etc.

Table 18. Direction of Causality.

	Cyprus*	**Malta***	**Germany***	**France***	**Netherlands***
Cyprus	-	No	No	No	No
Malta	No	-	No	No	No
Germany	No	No	-	No	Yes
France	No	No	No	-	Yes
Netherlands	No	No	No	No	-
All	No	No	No	No	Yes

Yes: Granger causes.
No: Does not Granger cause.

2. INTEREST RATES:

2.1. Baltic Countries

(a) Cointegration Results:

The number of lags indicated by the sequential modified LR test statistic for the two Baltic countries (excluding Lithuania) and the EMU members is 3.

Table 23. Lag selection.

Lag	LR	FPE	AIC	SC	HQ
0	N/A	7.86E-15*	-18.28730*	-18.14749*	-18.23095*
1	38.54470	8.68E-15	-18.18990	-17.35103	-17.85178
2	39.12586*	9.26E-15	-18.12971	-16.59179	-17.50982
3	17.73834	1.29E-14	-17.81091	-15.57393	-16.90925
4	26.47024	1.57E-14	-17.63838	-14.70235	-16.45495
5	31.24256	1.75E-14	-17.57249	-13.93741	-16.10730
6	24.40435	2.15E-14	-17.43146	-13.09732	-15.68449
7	34.79356	2.15E-14	-17.52615	-12.49295	-15.49741
8	16.67678	3.03E-14	-17.31178	-11.57953	-15.00127

We select the appropriate model based on the likelihood ratio tests, under the assumption of two cointegrating vectors. The log Likelihood by rank and model is reported in Table 24.

Table 24. Log Likelihood by Rank (rows) and Model (columns).

	Model				
Rank	1	2	3	4	5
0	909.2623	909.2623	914.1083	914.1083	915.0614
1	925.3528	925.7656	930.3867	933.0258	933.6969
2	936.1771	938.1654	942.7662	946.9448	947.5540
3	943.4424	946.1861	949.5169	956.1565	956.7233
4	946.5012	951.3976	953.2438	961.0879	961.4824
5	947.0803	954.4447	954.4447	962.6826	962.6826

The likelihood ratio tests suggest that the more suitable model is once more the fifth one. Specifically, in testing for model 4 in model 5 under the assumption of two cointegrating vectors, we reject the null hypothesis that model 4 is more suitable, as LR = 12.184 ~ $\chi^2(3)$ and Probability ≈ 0 < 0.05. Consistent with the previous indications, we estimate the 5th model, which assumes quadratic trend in the data and intercept and trend in the cointegrating equations. Table 25 reports the number of cointegrating vectors according to the Trace and Maximum Eigenvalue statistics.

Table 25. Unrestricted Cointegration Rank Test.

Hypothesized No. of CE(s)	Trace Statistic	Critical Value 5%	Critical Value 1%	Max-Eigen Statistic	Critical Value 5%	Critical Value 1%
None	95.24244**	77.74	85.78	37.27109*	36.41	41.58
At most 1	57.97134*	54.64	61.24	27.71426	30.33	35.68
At most 2	30.25708	34.55	40.49	18.33848	23.78	28.83
At most 3	11.91860	18.17	23.46	9.518282	16.87	21.47
At most 4	2.400319	3.74	6.40	2.400319	3.74	6.40

* Rejection of the hypothesis at the 5% level.
** Rejection of the hypothesis at the 1% level.

At the 1% significance level, the Trace statistic indicates that the rank of the Π matrix is 1, while at the 5% level 2. On the other and, at the 1% level, the Maximum Eigenvalue statistic indicates that there is no cointegration (rank of the Π = 0), while at the 5% level that there is one cointegrating vector (rank of the Π = 1). We accept that there is **one (1)** cointegrating vector in this group of five countries. This result means that the specific countries share four common stochastic trends in their interest rates series and is equivalent to "partial" convergence. In this case, the interest rates series respond to the same long-run driving processes and face the same permanent shocks with different magnitude across countries, i.e. the interest rates of these countries move towards a long run equilibrium and do not drift too far apart over time.

(b) Restriction Results:

We impose restrictions on the α and β parameters and test their validity, under the assumption of one cointegrating vector.

Table 26. Normalized Cointegrating Coefficients.*

Estonia	Latvia	Germany	France	Netherlands
1	1.353806	8.498356	-1.769981	-7.786519
	(0.32196)	(1.87825)	(2.62367)	(3.21079)

* Standard Error in parentheses.

The corresponding adjustment coefficients are:

Table 27. Adjustment Coefficients

Country	A(*i, j*)
Estonia	0.035755 (0.04049)
Latvia	-0.168163 (0.06527)
Germany	-0.051450 (0.01088)
France	-0.033408 (0.01054)
Netherlands	-0.032638 (0.00924)

* Standard Error in parentheses.

Firstly, we test whether a country participates in and whether it adjusts to the long-run relationship, by imposing restrictions on the parameters A(*i*,*j*) and B(*j*,*i*) under the assumption of one cointegrating relation. Next, we check the validity of these restrictions. The results are reported below.

Table 28. LR tests for restrictions on *a* and *β* matrices.

	Cointegration Restrictions				
	Estonia	**Latvia**	**Germany**	**France**	**Netherlands**
	A(1,1)=0	**A(2,1)=0**	**A(3,1)=0**	**A(4,1)=0**	**A(5,1)=0**
χ^2**(1)**	0.329765	3.516179	9.378268	8.792579	9.465974
Prob.	0.565798*	0.060772*	0.002196	0.003025	0.002093
	B(1,1)=0	**B(1,2)=0**	**B(1,3)=0**	**B(1,4)=0**	**B(1,5)=0**
χ^2**(1)**	0.926856	5.305445	8.936155	0.362930	4.476580
Prob.	0.335681*	0.021259	0.002796	0.546883*	0.034362

A(*i*,*j*), B(*j*,*i*), where *i*: the country and *j*: the cointegrating equation, i.e. 1.
* Acceptance of the hypothesis at the 5% level.

As shown above, Estonia and France do not participate in the equilibrium relation, while the restrictions on the adjustment coefficients reveal that Latvia (and Estonia) is exogenous in respect with the β matrix, i.e. that it does not adjusts to its changes.

(c) Short-Run Dynamics:

Finally, we carry out pairwise Granger causality tests, in order to decide about the direction of causality. Table 29 displays χ^2 (Wald) statistics for the individual and joint significance of each of the independent variables.

Table 29. VEC Pairwise Granger Causality / Block Exogeneity Wald Tests

Variable: Δ[Log(Long-Term Interest Rate)]						
Independent Variable		Dependent Variable				
		Estonia	Latvia	Germany	France	Netherlands
Estonia	$\chi^2(2)$	-	0.330816	0.937323	0.901653	1.148784
Latvia	$\chi^2(2)$	1.85345	-	9.788776*	5.568228	6.511538*
Germany	$\chi^2(2)$	2.18114	1.552134	-	3.576017	2.881976
France	$\chi^2(2)$	4.90837	7.227556*	2.634601	-	2.754972
Netherlands	$\chi^2(2)$	0.40245	1.037156	1.721221	0.407142	-
ALL	$\chi^2(8)$	8.10268	10.01539	21.67513*	14.59649	16.74056*

* Rejection of the hypothesis at the 5% level.

We remind that rejection of the null hypothesis is equivalent to Granger causality. Hence, the interest rates of Estonia, Latvia and France can be treated as exogenous, as the coefficients of the lagged independent variables are found to be zero. That is, their interest rates are not affected by the history of the changes in the interest rates of the other countries. The interest rates of Germany and the Netherlands, on the other hand seem to be affected by the past changes in the interest rates of the remaining countries (of Latvia, as shown below). Except for the joint hypothesis of Granger non-causality, we also tested the statistical significance of the C's individually. Table 18 shows more clearly the results. The only short-run relations detected are the following: Latvia Granger causes Germany* and the Netherlands, while France Granger causes Latvia.

Table 30. Direction of Causality.

	Estonia*	Latvia*	Germany*	France*	Netherlands*
Estonia	-	No	No	No	No
Latvia	No	-	Yes	No	Yes
Germany	No	No	-	No	No
France	No	Yes	No	-	No
Netherlands	No	No	No	No	-
All	No	No	Yes	No	Yes

Yes: Granger causes.
No: Does not Granger cause.

2.2. CEFTA Members

(a) Cointegration Results:

The number of lags indicated by the sequential modified LR test statistic for the CEFTA members is 1.

Table 31. Lag selection.

Lag	LR	FPE	AIC	SC	HQ
0	N/A	8.86E-23*	-28.07470*	-27.76878*	-27.95821*
1	92.78006*	1.23E-22	-27.77763	-25.02432	-26.72915
2	69.72345	2.34E-22	-27.33046	-22.12976	-25.35001
3	67.33316	3.59E-22	-27.46379	-19.81570	-24.55135

We select the appropriate model based on the likelihood ratio tests, under the assumption of two cointegrating vectors. The log Likelihood by rank and model is reported below.

Table 32. Log Likelihood by Rank (rows) and Model (columns).

	Model				
Rank	1	2	3	4	5
0	797.6615	797.6615	802.0299	802.0299	806.0223
1	827.1114	835.5912	839.9310	839.9381	843.4478
2	845.3948	856.6561	860.5319	860.9795	864.4088
3	858.2567	869.9730	873.8414	875.8677	878.0791
4	867.6823	881.6857	885.1269	887.6873	889.8957
5	875.5733	890.9581	894.3902	897.9774	899.9746
6	879.6584	897.6691	900.5813	904.7821	906.7676
7	881.4819	901.4437	902.3948	910.3192	911.9653
8	883.0172	903.0037	903.0037	912.1107	912.1107

The likelihood ratio tests suggest that the more suitable model is the fifth. Specifically, in testing for model 4 in model 5, we reject the accept the null hypothesis that model 4 is more suitable, as LR = 68.586 ~ $\chi^2(6)$ and Probability ≈ 0 < 0.05. Following these results, we estimate the 5th model, which assumes quadratic trend in the data and intercept and trend in the cointegrating equations. Table 32 reports the number of cointegrating vectors according to the Trace and Maximum Eigenvalue statistics.

Table 33. Unrestricted Cointegration Rank Test.

Hypothesized No. of CE(s)	Trace Statistic	Critical Value 5%	Critical Value 1%	Max-Eigen Statistic	Critical Value 5%	Critical Value 1%
None	212.1767**	170.80	182.51	74.85105**	54.25	60.81
At most 1	137.3257*	136.61	146.99	41.92195	48.45	54.48
At most 2	95.40372	104.94	114.36	27.34067	42.48	48.17
At most 3	68.06305	77.74	85.78	23.63319	36.41	41.58
At most 4	44.42986	54.64	61.24	20.15768	30.33	35.68
At most 5	24.27218	34.55	40.49	13.58608	23.78	28.83
At most 6	10.68610	18.17	23.46	10.39539	16.87	21.47
At most 7	0.290709	3.74	6.40	0.290709	3.74	6.40

* Rejection of the hypothesis at the 5% level.
** Rejection of the hypothesis at the 1% level.

The Trace statistic indicates one cointegrating equation at the 1% level and two cointegrating equations at the 5% level, while the Maximum Eigenvalue statistic indicates one cointegrating equation at both levels. Thereby, we accept the existence of **one (1)** cointegrating vector. The finding of one cointegrating vector means that the specific countries share seven common stochastic trends in their interest rates series, which refers to the case of "partial" convergence. That is the series respond to the same long-run driving processes and face the same permanent shocks with different magnitude across countries, i.e. the interest rates of these countries move towards a long run equilibrium and do not drift too far apart over time.

(b) Restriction Results:

As next step we impose restrictions on the α and β parameters and test the validity of the assumptions, under the assumption of one cointegrating vector. The cointegrating coefficients are presented in Table 34.

Table 34. Normalized Cointegrating Coefficients*

Czech	Hungary	Poland	Slovakia	Slovenia	Germany	France	Netherlands	Trend
1	-0.996421	-0.588660	-0.986650	2.611757	4.095600	-23.42942	20.63065	-0.996421
	(0.26828)	(0.25212)	(0.12271)	(0.68100)	(1.24377)	(3.00998)	(2.42126)	(0.26828)

* Standard Error in parentheses.

The corresponding adjustment coefficients are shown in Table 35.

Table 35. Adjustment Coefficients

Country	A(i, j)
Czech	-0.114831 (0.05113)
Hungary	0.092423 (0.04764)
Poland	0.043979 (0.04522)
Slovakia	0.362970 (0.15239)
Slovenia	-0.052934 (0.02638)
Germany	-0.047926 (0.02487)
France	-0.019585 (0.02215)
Netherlands	-0.039716 (0.01918)

* Standard Error in parentheses.

We now impose restrictions on the α matrix and test their statistical validity. Specifically, we test whether the parameter A(i,j) is significantly different from 0. Equivalently, we impose restrictions on the cointegrating coefficients B(i,j) and test their validity. Table 36 reports the results.

Table 36. LR tests for restrictions on α and β matrices.

	Cointegration Restrictions							
	Czech	**Hungary**	**Poland**	**Slovakia**	**Slovenia**	**Germany**	**France**	**Netherlands**
	A(1,1)=0	**A(2,1)=0**	**A(3,1)=0**	**A(4,1)=0**	**A(5,1)=0**	**A(6,1)=0**	**A(7,1)=0**	**A(8,1)=0**
$\chi^2(1)$	4.995864	3.934773	0.986649	4.765538	4.230937	3.853351	0.822024	4.523004
Prob.	0.025408	0.047298	0.320563*	0.029035	0.039694	0.049647	0.364589*	0.033442
	B(1,1)=0	**B(1,2)=0**	**B(1,3)=0**	**B(1,4)=0**	**B(1,5)=0**	**B(1,6)=0**	**B(1,7)=0**	**B(1,8)=0**
$\chi^2(1)$	8.898246	7.107133	2.353545	22.29246	7.663359	9.447518	25.99152	26.11212
Prob.	0.002854	0.007678	0.124998*	0.000002	0.005635	0.002114	0	0

A(i,j), B(j,i), where i: the country and j: the cointegrating equation, i.e. 1.
* Acceptance of the hypothesis at the 5% level.

According to the previous results, the only country that does not participate in the equilibrium relation is Poland. The restrictions on the adjustment coefficients reveal that the only country that does not adjust to the equilibrium is France (and Poland). That is, France is weakly exogenous with respect to the β parameters; it is not influenced by the deviations from the long-run relation. The Czech and Slovak Republics, as well as Slovenia perform the greatest adjustment to deviations from the long-run equilibrium.

(c) Short-Run Dynamics:

In this section we carry out pairwise Granger causality tests, in order to decide about the direction of causality. Table 37 displays χ^2 (Wald) statistics for the individual and joint significance of each of the independent variables.

Table 37. VEC Pairwise Granger Causality / Block Exogeneity Wald Tests

Variable: Δ[Log (Long-Term Interest Rate)]									
Independent Variable		Dependent Variable							
		Czech	Hungary	Poland	Slovakia	Slovenia	Germany	France	Netherlands
Czech	$\chi^2(1)$	-	0.556790	1.71946	0.270283	0.911368	5.613818*	5.85792*	8.709754*
Hungary	$\chi^2(1)$	4.03039*	-	6.06238*	2.101007	0.745041	1.219018	0.48566	0.813926
Poland	$\chi^2(1)$	0.26337	0.129513	-	0.533509	0.152738	7.083137*	6.227526*	7.212132*
Slovakia	$\chi^2(1)$	0.12217	0.737209	0.92553	-	0.621767	1.966405	0.477197	2.053987
Slovenia	$\chi^2(1)$	2.56748	1.978454	0.215759	0.059746	-	1.878622	3.296747	3.959508*
Germany	$\chi^2(1)$	3.28372	0.741375	1.880077	0.334626	3.163829	-	3.572948	5.080740*
France	$\chi^2(1)$	0.15930	0.722005	0.95904	0.574898	5.195069*	5.613818	-	2.401604
Netherlands	$\chi^2(1)$	0.91878	2.659021	2.52922	0.814669	0.546175	1.219018	0.308406	-
ALL	$\chi^2(7)$	15.7452*	7.349500	18.14916*	6.214319	8.734035	15.05352*	14.10672*	18.06821*

* Rejection of the hypothesis at the 5% level.

According to the results reported in Tables 37 and 38, only the interest rates of Hungary, the Slovak Republic and Slovenia can be treated as exogenous, as the coefficients of lagged independent variables are zero. In this case, the changes in their interest rates are not affected by the history of the changes in the interest rates of the other countries. The individual relations are of special interest as Czech and Poland Granger cause Slovenia and the three EMU countries, while they are both affected by the past changes in the interest rates of Hungary. In general, the results are equivalent to the ones reported in the case of inflation rates.

Table 38. Direction of Causality.

	Czech*	Hungary*	Poland*	Slovakia*	Slovenia*	Germany*	France*	Netherlands*
Czech	-	No	No	No	Yes	Yes	Yes	Yes
Hungary	Yes	-	Yes	No	No	No	No	No
Poland	No	No	-	No	Yes	Yes	Yes	Yes
Slovakia	No	No	No	-	No	No	No	No
Slovenia	No	No	No	No	-	No	No	Yes
Germany	No	No	No	No	No	-	No	Yes
France	No	No	No	No	Yes	No	-	No
Netherlands	No	No	No	No	No	No	No	-
All	Yes	No	Yes	No	Yes	Yes	Yes	Yes

Yes: Granger causes.
No: Does not Granger cause.

2.3. Market Economies

(a) Cointegration Results:

The number of lags indicated by the sequential modified LR test statistic for the market economies is 1.

Table 39. Lag selection.

Lag	LR	FPE	AIC	SC	HQ
0	N/A	1.60E-18	-26.78478	-26.61324*	-26.71743*
1	54.43239*	1.36E-18*	-26.95034*	-25.92108	-26.54623
2	24.46787	1.92E-18	-26.62365	-24.73667	-25.88277
3	34.53488	2.11E-18	-26.56795	-23.82327	-25.49032
4	20.52227	3.11E-18	-26.26205	-22.65964	-24.84765
5	36.48408	2.90E-18	-26.46904	-22.00892	-24.71789
6	18.36114	4.46E-18	-26.25488	-20.93705	-24.16697

We select the appropriate model based on the LR tests, under the assumption of three cointegrating vectors. The log Likelihood by rank and model is reported in Table 40.

Table 40. Log Likelihood by Rank (rows) and Model (columns).

	Model				
Rank	1	2	3	4	5
0	928.8961	928.8961	932.0575	932.0575	934.4244
1	944.5454	946.5232	949.6500	950.1624	952.4611
2	953.5338	956.9695	959.1151	964.5777	965.5162
3	960.0364	963.7306	964.8375	973.8231	974.7569
4	962.9479	969.2753	969.7437	978.9926	979.1783
6	963.3956	969.7477	969.7477	982.9537	982.9537

The LR tests suggest that the more suitable model is the fifth. Specifically, in testing for model 4 in model 5, we reject the null hypothesis that model 4 is more suitable, as LR = 18.676 ~ $\chi^2(3)$ and Probability ≈ 0 < 0.05. Following the previous indication, we estimate the 5th model, which assumes quadratic trend in the data, as well as intercept and trend in the cointegrating equations. Table 41 reports the number of cointegrating vectors according to the Trace and Maximum Eigenvalue statistics.

Table 41. Unrestricted Cointegration Rank Test.

Hypothesized No. of CE(s)	Trace Statistic	Critical Value		Max-Eigen Statistic	Critical Value	
		5%	1%		5%	1%
None	97.05864**	77.74	85.78	36.07336	36.41	41.58
At most 1	60.98527*	54.64	61.24	26.11008	30.33	35.68
At most 2	34.87519*	34.55	40.49	18.48155	23.78	28.83
At most 3	16.39364	18.17	23.46	8.842748	16.87	21.47
At most 4	7.550892	3.74	6.40	7.550892	3.74	6.40

* Rejection of the hypothesis at the 5% level.
** Rejection of the hypothesis at the 1% level.

The Trace statistic indicates one cointegrating equation at the 1% level and three cointegrating equations at the 5% level, while the Maximum Eigenvalue statistic indicates no cointegration at both levels. A close look at the eigenvalues shows that they are not evenly distributed; thereby we rely on the Maximum Eigenvalue statistic's indications. Moreover, the exogeneity tests advocate the existence of five exogenous variables in respect with the β matrix (we may have a maximum of $p - r$ exogenous variables). Bearing in mind all these, we conclude that there is no cointegration of the interest rates of the market economies and the EMU members. It is important to note, however, that the sample in this case is shorter than in the other groups of countries and the detection of a long-run relationship between them is much more improbable.

CONCLUDING REMARKS

This paper investigated the question of whether there exists evidence in support of inflation and interest rate convergence of the new EU members with EMU. In the first sections we reviewed the institutional relations between the EU and the new members, as well as the literature on nominal convergence. The countries under investigation were logically separated into four groups: the Baltic countries (Estonia, Latvia and Lithuania), the CEFTA members (Czech and Slovak Republics, Hungary, Poland and Slovenia), the market economies (Cyprus and Malta) and the EMU (proxied by Germany, France and the Netherlands). For the inflation convergence investigation we used the CPI based inflation rates for the period January 1994 – December 2003, while for the interest rates convergence analysis we used government bond yields for maturities varying from four to ten years, as well as interest rates on long-term loans (for the cases of Estonia, Latvia and Slovenia) for the period spanning from January 1995 to December 2003.

In order to ascertain the degree of convergence, we employed the cointegration tests introduced by Johansen (1988) and Johansen and Juselius (1990). Before testing for cointegration, we employed the ADF unit root test and concluded that all time series were non-stationary. Cointegration analysis is designed to find linear combinations (cointegrating relations) of non-stationary variables that remove unit roots. The cointegrating relations have the appealing economic interpretation of long run equilibrium relationships among the variables under study. In general, if there exist r cointegrating relations in a set of p variables, there must also exist $p - r$ common stochastic trends that move these variables around their equilibrium paths, and thus "drive" the cointegrating relations. To address the issue of convergence we adopted the definition of "complete" and "partial" convergence. "Complete" convergence refers to the case where the time series under consideration share one and only common stochastic trend (i.e. there are $r = p - 1$ cointegrating vectors). "Partial" convergence refers to the case where there are $0 < r < p - 1$ cointegrating vectors and thus more that one common stochastic trends.

Our empirical results support the view that the new members are only partially converging to EMU standards at the present:

- Specifically, in the case of **inflation rates** the Baltic countries and the EMU members we found the existence of two cointegrating relations, i.e. these countries share four common stochastic trends. The CEFTA and EMU members have five cointegrating relations and thus share three common stochastic trends and finally the market economies share four common stochastic trends with the EMU members. The existence of more than one common trend is indicative of "partial" convergence in the inflation rates of the new EU members with the three EMU members. In this case, we say that the inflation rates series of these countries respond to the same long-run driving processes and face the same permanent shocks with different magnitude across countries.

- The results concerning the **long-term interest rates** also force us to reject the hypothesis of complete convergence of the new EU members to EMU members. More specifically, in the case of the Baltic countries (excluding Lithuania) we detect only one cointegrating relation and thus four common stochastic trends, while in the case of the CEFTA members we detect one cointegrating relation and seven common stochastic trends. We may claim that there is evidence in support of "partial" convergence of the long-term interest rates of the Baltic countries with the EMU members, only. In this case, the interest rates of these countries move towards a long run equilibrium and do not drift too far apart over time. For the CEFTA members, however, the finding of just one cointegrating relation is not strongly supportive of the "partial" convergence hypothesis. Finally, we find no cointegration of the interest rates series of the market economies and the EMU members.

The Johansen procedure also permits hypothesis testing of the cointegrating relations and adjustment coefficients. At first, we tested whether a country participates in the equilibrium relation and, in the case that it does, whether it adjusts to the long-run relationship. If the country is found not to adjust to the long-run relation, we say that the country actually dominates the common trend. Finally, we examined the short-run dynamics of the relations between the countries and decided about the directions of causality.

The results concerning the **inflation rates** are the following:

- In the case of the Baltic countries with the EMU members, Latvia, Germany and the Netherlands do not participate in the equilibrium relation and thereby can be removed from the cointegrating equation. Moreover, the changes in the inflation rates of Germany and France are not explained by the history of changes in the other countries. We can then claim that the inflation rate of Germany is exogenous and that the effects on the inflation rates of Latvia and the Netherlands are short-term. Namely, short-run relations are developed between Estonia, Latvia and Lithuania in all directions, while the inflation rates of the Netherlands are affected by the past changes in the inflation rates of Germany and France. Of the countries that do participate in the equilibrium relation, France is the only one that is not adjusting towards the long-run relation, while the greatest rate of adjustment is observed in the case of Lithuania.

- In the case of the CEFTA members with the EMU members, only France does not participate in the equilibrium relation, while the inflation rate of Slovakia is the only one that is not affected by the history of changes in the other countries. Finally, the Czech Republic and Hungary are the only countries that adjust to the long-run relation and that are affected in the short-run by all the remaining countries, except for the Netherlands. The common trends seem to be dominated by Poland, Slovakia, Slovenia, Germany and the Netherlands. More probable is that the CEFTA members dominate the one common trend and EMU members the others. In the short-run, France has the greatest impact, as the history of changes of its inflation rate affects almost all the other countries.

- The results concerning the market economies indicate that Malta is the only country excluded from the long-run relation. Furthermore, France does not adjust to the long-run relation, while Cyprus performs the greatest adjustment. Finally, the short-run relations are restricted among the EMU members. Specifically, the inflation rate of the Netherlands is affected by the history of changes in the inflation rates of Germany and France.

As far as the **long-term interest rates** are concerned, we have reached the following results:

- In the case of the Baltic countries and the EMU members, we see that Estonia and France do not participate in the equilibrium relation, while Latvia (and Estonia) is not adjusting to the long-run relation. In addition, Latvia (as well as Estonia and France) can be treated as exogenous, since its interest rates are not affected by the history of the changes in the interest rates of the other countries.

- At last, we showed that between the CEFTA and the EMU members, the only country that does not participate in the equilibrium relation is Poland. Of the remaining countries, the only country that does not adjust to the equilibrium (is not influenced by the deviations from the long-run relation) is France. The Czech and Slovak Republics, Slovenia as well as the Netherlands perform the greatest adjustment to deviations from the long-run equilibrium. The interest rates of Hungary, Slovakia and Slovenia can be treated as exogenous variables, as they are not affected by the history of the changes in the interest rates of the other countries. Finally, there exist short-run relations between Hungary, Poland, the Czech Republic Slovenia, Germany, France and the Netherlands but the causality is not towards all the directions.

The results presented in this paper are not surprising, given that the new EU members have not reached their steady state, and are still running a transitional period, while the EMU members (especially the chosen ones) are mature economies. As explicitly stated by Caporale and Pittis (1994) the methodology that we applied is very powerful to test whether convergence has been maintained after being achieved. And this is clearly not our case. Indeed, the deep structural reforms of the financial markets have been a gradual process and the results have only recently started to show up. For instance, Poland fulfilled the inflation, long-term interest rate and public debt criteria just in November 2003.

The greatest degree of inflation convergence (in contrast with the case of the interest rates) was also expected, given the inflation targeting policies adopted by most of the new members. For example, Czech adopted a system of direct inflation targeting (DIT) in 1998, Poland in 1999, while Hungary in 2001 (June), while the other countries impose price stability as a primary objective of their monetary policies. According to Orlowski (2001), this DIT allows focusing on disinflation as a primary goal, which makes it a viable starting point of monetary convergence to the euro area. Moreover, it may be expected that accession to the EU (and the euro area) will provide additional boost to convergence of the new EU members and the EMU members. The result of limited or non-existent degree of interest rate convergence, however, is really disappointing. We should note here that an important limitation of the analysis is the lack of equivalent long-term interest rates for all the countries.

In all cases, the research in the field of inflation and interest rates convergence of the new EU members is likely to be more reliable in the future, since the accession process has led to the construction of more appropriate indices, like the harmonised long-term interest rates series for convergence assessment purposes since 2001 and the harmonised index of consumer prices (HICP).

APPENDIX I – ABBREVIATIONS

ADF: Augmented Dickey-Fuller

AIC: Akaike Information Criterion

CEECs: Central and Eastern European Countries

CEFTA: Central European Free Trade Agreement

CPI: Consumer Price Index

ECB: European Central Bank

EMS: European Monetary System

EMU: Economic and Monetary Union

ERM: Exchange Rate Mechanism

EU: European Union

FPE: Final Prediction Error

HICP: Harmonized Index of Consumer Prices

I(b): Integrated of order b

LR: Likelihood Ratio

OCA: Optimum Currency Area

SC: Schwartz Information Criterion

VAR(k): Vector Auto-Regressive model of order k

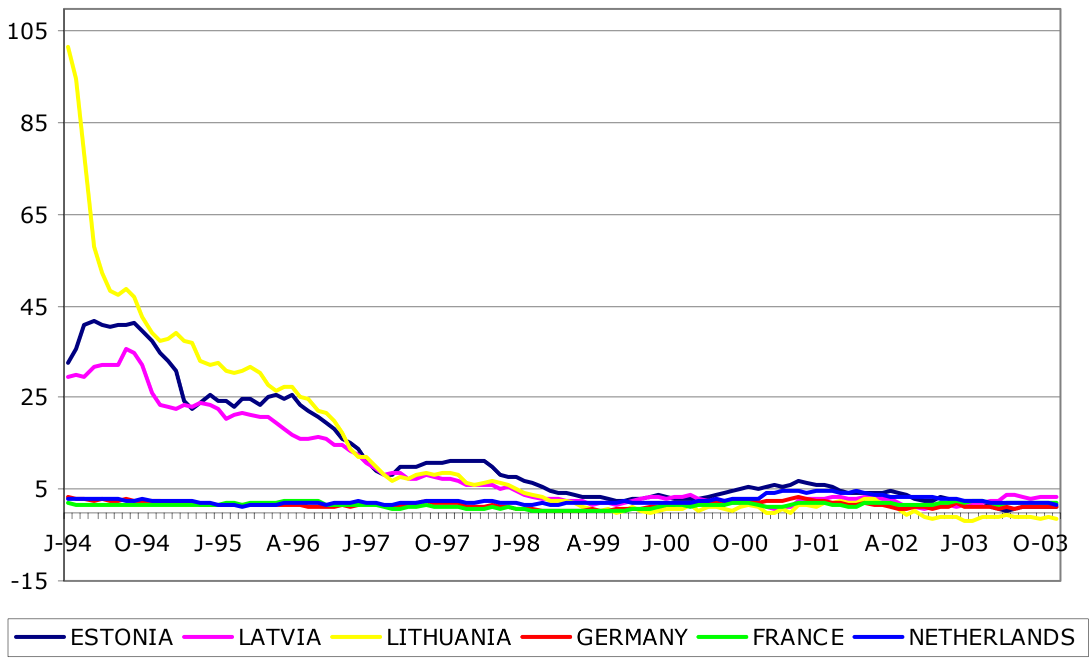
VECM: Vector Error-Correction Model

HQ: Hannan-Quinn Information Criterion

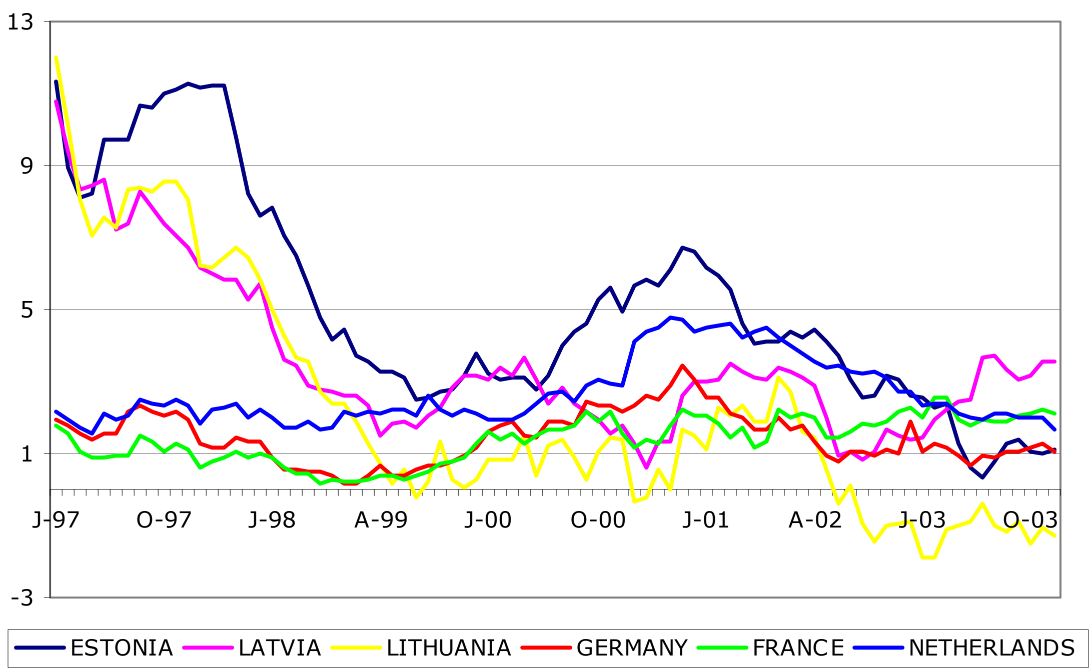
APPENDIX II – GRAPHS

1. INFLATION

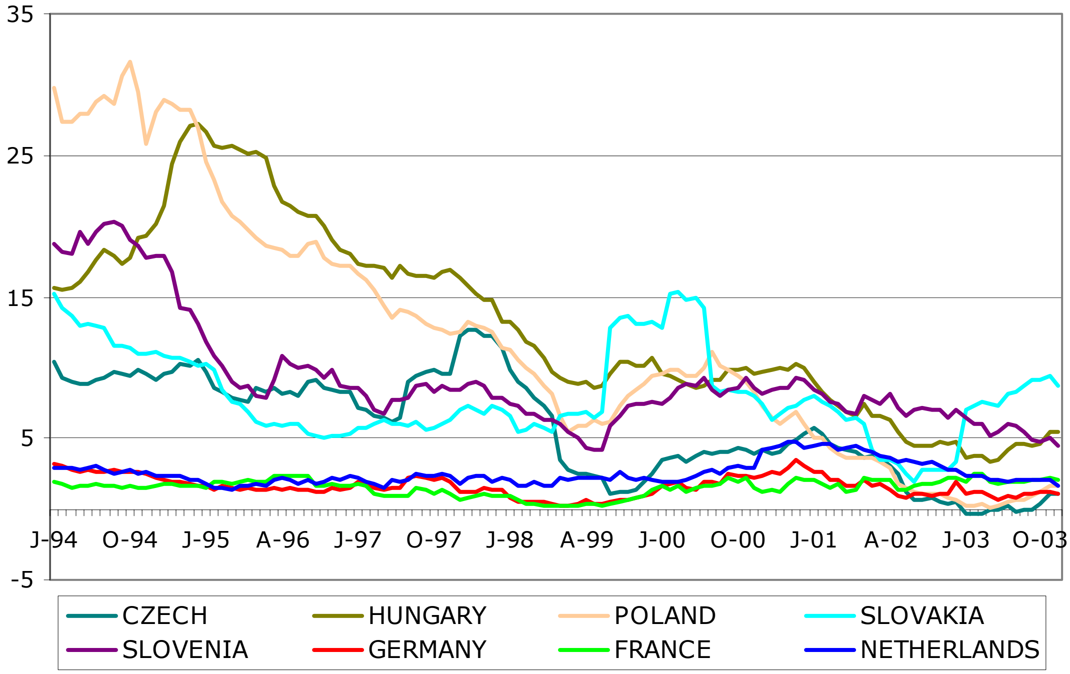
Graph 1. Inflation Rates of the Baltic Countries, 1994-2003.



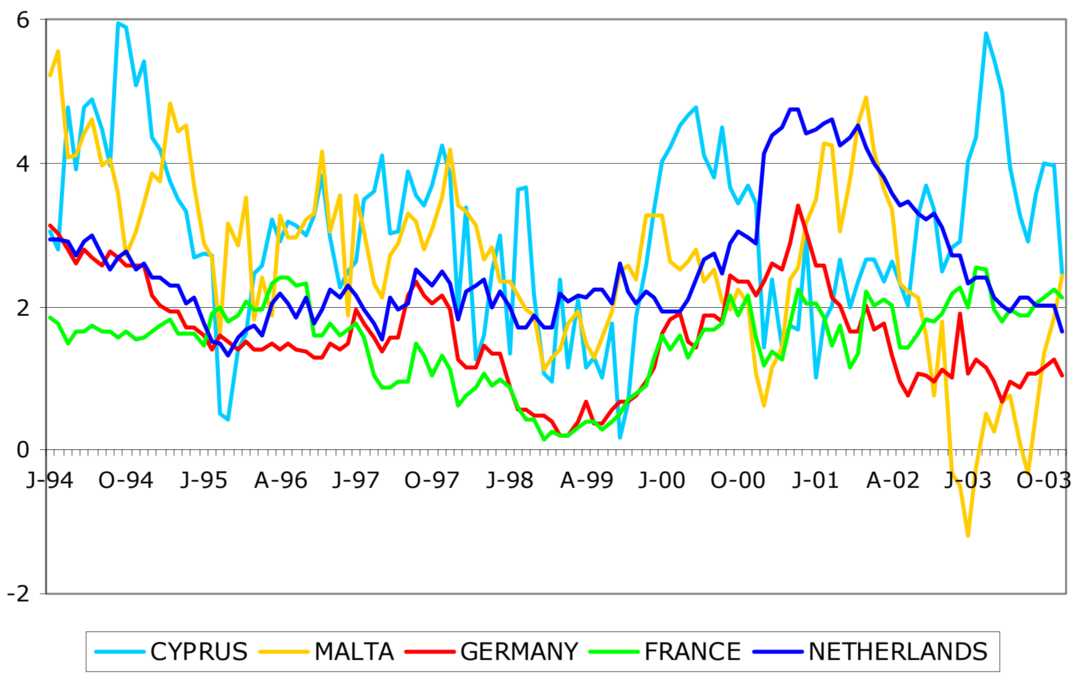
Graph 2. Inflation Rates (%) of the Baltic Countries, 1997-2003.



Graph 3. Inflation Rates (%) of the CEFTA Members, 1994-2003.

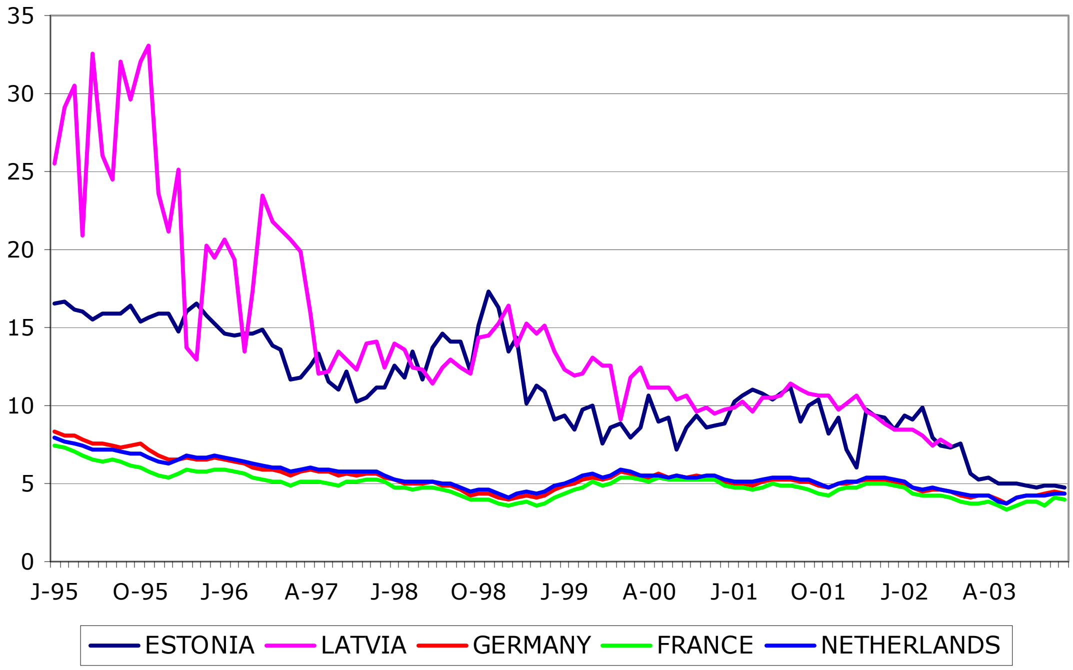


Graph 4. Inflation Rates (%) of the Market Economies, 1994-2003.

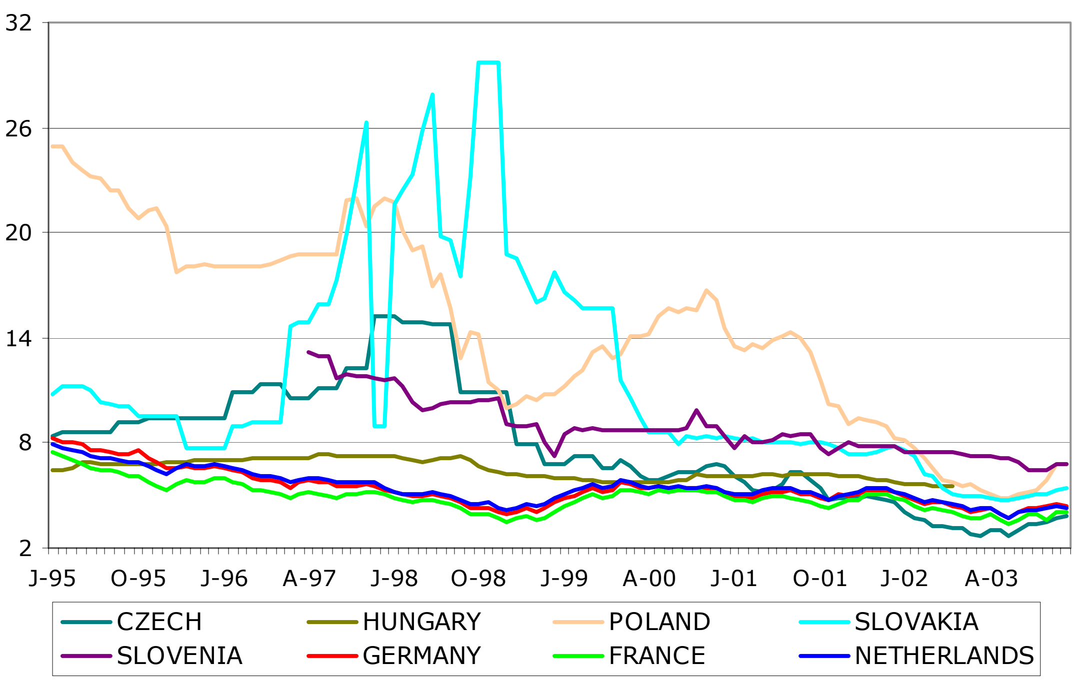


2. INTEREST RATES

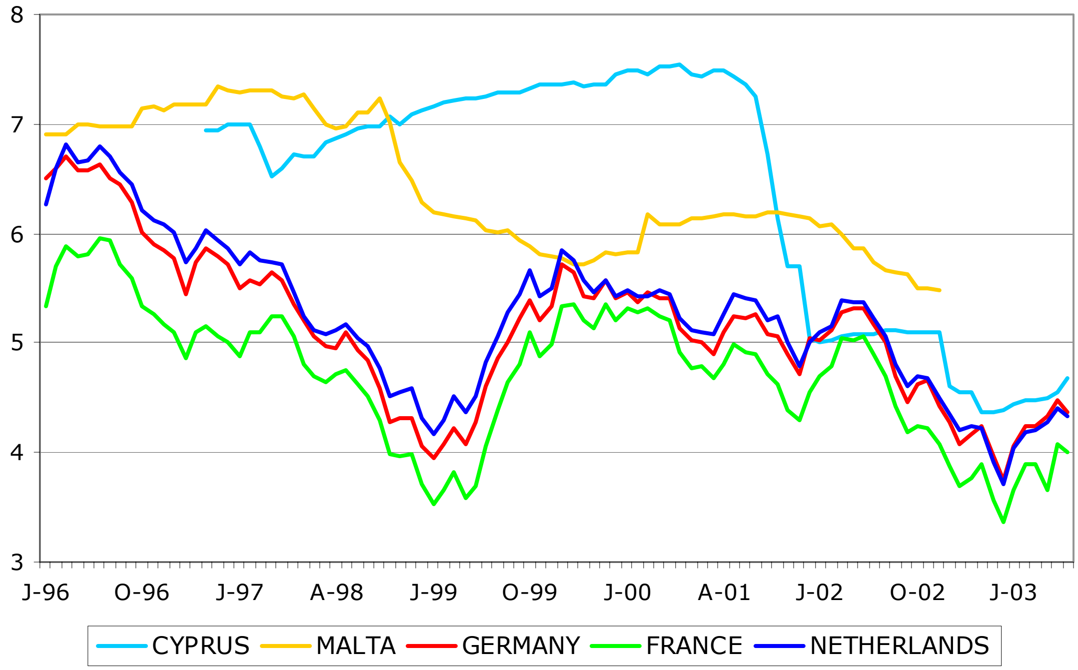
Graph 5. Interest Rates (%) of the Baltic Countries, 1995-2003.



Graph 6. Interest Rates (%) of the CEFTA Members, 1995-2003.



Graph 7. Interest Rates (%) of the Market Economies, 1996-2003.



REFERENCES

1. Amian, C. G., Zumaquero, A. M. (2002), *Complete or Partial Inflation Convergence in the EU?*, Fundacion Centro de Estudios Andaluces, Economic Working Paper, No. E2002/09.

2. Bank of Slovenia (2004), *Monthly Bulletin*, Vol. 13, No. 4, April 2004.

3. Barassi, M. R., Caporale, G. M., Hall S. G. (2000), *Interest Rate Linkages: Identifying Structural Relations*, Centre for International Macroeconomics (CIM), Discussion Papers, No. 2002.02, May 2000.

4. Barkoulas, J. T., Baum, C. F., Oguz, G. S. (1996), *Fractional Dynamics in a System of Long Term International Interest Rates*, International Journal of Finance, Vol. 9, No. 2, pp. 586-606.

5. Bernard, A.B. and Durlauf, S. N., (1995), Convergence in International Output. Journal of Applied Econometrics, Vol. 10, No. 1, pp. 97-108.

6. Bernard, A. B., Durlauf, S. N. (1996), *Interpreting Tests of the Convergence Hypothesis*, Journal of Econometrics, Vol. 71, pp. 161-173.

7. Boreiko, D. (2003), *EMU and Accession Countries: Fuzzy Cluster Analysis of Membership*, International Journal of Finance and Economics, Vol. 8, pp. 309-325.

8. Brada, J, C., Kutan, A. M. (2001), *The Convergence of Monetary Policy between Candidate Countries and the EU*, Social Science Research Network (SSRN), Electronic Paper Collection, id. 243561, January 2001.

9. Brada, J. C., Kutan, A. M., Zhou, S. (2002), *Real and Monetary Convergence within the EU and between the EU and Candidate Countries: A Rolling Cointegration Approach*, Centre for European Integration Studies (ZEI), Working Paper B05.

10. Caporale, G. M., Pittis, N. (1995), *Interest Rate Linkages Within the European Monetary System: An Alternative Interpretation*, Applied Economics Letters, Vol. 2, pp. 45-47.

11. Dolado, J. J., Gonzalo, J., Marmol, F. (1999), *Cointegration*, in Baltagi, B. H. (editor), *A Companion to Econometric Theory*, Blackwell Publishers, 2000, pp. 283-290.

12. Engle, R. F., Granger, C. W. J. (1987), *Co-integration and Error Correction: Representation, Estimation, and Testing*, Econometrica, Vol. 55, No. 2, March 1987, pp. 251-276.

13. EUROSTAT (2003), *Panorama of the European Union, Statistical Yearbook on Candidate Countries, Data 1997-2001*.

14. EUROSTAT (2004), *Long-Term Interest Rates for Acceding Countries*, Statistics in Focus, Theme 2 – 21/2004.

15. Fidrmuc, J., Korhonen, I. (2001), *Similarity of Supply and Demand Shocks between the Euro Area and the CEECs*, Bank of Finland Institute for Economies in Transition (BOFIT), Discussion Papers, No. 14.

16. Fidrmuc, J., Korhonen, I. (2003), *The Euro goes East: Implications of the 200-2002 Economic Slowdown for Synchronisation of Business Cycles between the Euro Area and CEECs*, Bank of Finland Institute for Economies in Transition (BOFIT), Discussion Papers, No.6.

17. Gaspar, P., *Real and Nominal Convergence of Pre-Accession Economies and the Choice of Exchange Rate* Regime, International Centre for Economic Growth (ICEG) and Budapest University of Economics.

18. Hafer, R. W., Kutan, A. M (1994), *A Long-Run View of German Dominance and the Degree of Policy Convergence in the EMS*, Economic Inquiry, Vol. 22, pp. 684-695.

19. Hafer, R. W., Kutan, A. M., Zhou, S. (1997), *Linkage in EMS Term Structures: Evidence from Common Trends and Transitory Components*, Journal of International Money and Finance, Vol. 16, No. 4, pp. 595-607.

20. Hall, S. G., Robertson, D., Wickens, M, R. (1997), *Measuring Economic Convergence*, International Journal of Financial Economics, Vol. 2, pp. 131-143.

21. Haug, A. A., MacKinnon, J. G., Michelis, L. (2000), *European Monetary Union: A Cointegration Analysis*, Journal of International Money and Finance, Vol. 19, pp. 419-432.

22. Hendry, D. F., Juselius, K. (1999), *Explaining Cointegration Analysis: Part I* (draft), September 1999, pp. 1-28. Published in The Energy Journal, Vol. 21, No. 1, 2000, pp. 1-52.

23. Hendry, D. and Juselius, K. (2000), *Explaining cointegration analysis: Part II*, University of Copenhagen, Institute of Economics, Discussion Papers, No. 00-20, pp. 1-34. Published in The Energy Journal, Vol. 22, No. 1, 2001, pp. 75-101.

24. Holmes, M. J. (2002), *Panel Data Evidence on Inflation Convergence in the European Union*, Applied Economics Letters, Vol. 9, pp. 155-158.

25. IMF (2000), *World Economic and Financial Surveys, World Economic Outlook, Focus on Transition Economies (CHAPTER IV Accession to Transition Economies to the European Union: Prospects and Pressures)*, October 2000.

26. Islam, N. (2003), *What Have we Learned form the Convergence Debate?*, Journal of Economic Surveys, Vol. 17, No. 3, pp. 309-362.

27. Johansen, S. (1988), *Statistical Analysis of Cointegration Vectors*, Journal of Economic Dynamics and Control, Vol. 12, No. 2/3, June/September 1988, pp. 231-254.

28. Johansen, S. (1991), *Estimation and Hypothesis Testing of Cointegration vectors in Gaussian Vectors Autoregressive Models*, Econometrica, Vol. 59, No. 6, November 1991, pp. 1551-1580.

29. Johansen, S., Juselius, K. (1990), *Maximum Likelihood Estimation and Inference on Cointegration – With Applications to the Demand for Money*, Oxford Bulletin of Economics and Statistics, Vol. 52, No. 2, May 1990, pp. 169-210.

30. Karfakis, C. & Moshos, D. (1990), *Interest Rate Linkages within the European Monetary System: a Time Series Analysis*, Journal of Money, Credit and Banking, Vol. 22, August 1990.

31. Kasa, K. (1992), *Common Stochastic Trends in International Stock Markets*, Journal of Monetary Economics, Vol. 29, pp. 95-124.

32. Kočenda, E., Papell, D. H. (1997), *Inflation Convergence within the EU: A Panel Data Analysis*, International Journal of Finance and Economics, Vol. 2, pp. 189-198.

33. Kočenda, E. (2001), *Macroeconomic Convergence in Transition Countries*, Journal of Comparative Economics, Vol. 29, pp. 1-23.

34. Koukouritakis, M. I., Michelis, L. (2003), *EU Enlargement: Are the New Countries Ready to Join the EMU?*, August 2003.

35. Kutan, A. M., Yigit, T. M. (2002), *Nominal and Real Stochastic Convergence within the Transition Economies and to the EU: Evidence from Panel Data*, Centre for European Integration Studies (ZEI), Working Paper B21.

36. Meister, I. S. (2002), *Is Eastern Europe Ready for the Euro? A Cointegration Analysis for the Maastricht Criteria*, Research Memorandum, De Nederlandsche Bank, Research Department, WO No. 699, September 2002.

37. Mentz, M., Sebastian, S. P. (2003), *Inflation Convergence after the Introduction of the Euro*, Center for Financial Studies, CFS Working Papers, No. 2003/30, October 2003.

38. Michelis, L., *Prospects of a Monetary Union in North America: An Empirical Investigation*, Ryerson University, Canada, M5B 2K3.

39. Monadjemi, S. M. (1997), *International Interest Rates Linkages: Evidence from OECD Countries*, International Review of Financial Analysis, Vol. 6, No. 3, pp. 229-240.

40. National bank of Poland (2004), *A Report on the Costs and Benefits of Poland's Adoption of the Euro* [Preliminary Draft], February 2004.

41. Orlowski, L. T. (2001), *Monetary Convergence of the EU Candidates to the Euro: A Theoretical Framework and Policy Implications*, Centre for European Integration Studies (ZEI), Working Paper B25.

42. Rogers, J. H. (2001), *Price Level Convergence, Relative prices, and Inflation in Europe*, Board of Governors of the Federal Reserve System, International Finance Discussion Papers, No. 699, March 2001.

43. Rutkowski, W. (2002), *When the Prospective Central and Eastern European Members of the EU will be Able to Join the Euro's Zone?*, Higher School of Economics &Arts in Skierniewice, June 2002.

44. Siklos, P. L., Wohar, M. E. (1997), *Convergence in Interest Rates and Inflation Rates across Countries and over Time*, Review of International Economics, Vol. 5, No. 1, pp. 129-141.

45. Sosvilla-Rivero, S., Olloqui, I. (1999), *Instability in Cointegration Regressions: Evidence from Inflation Rate Convergence in EU Countries*, FEDEA, EEE 53, July 1999.

46. Sosvilla-Rivero, S., Gil-Pareja, S. (2002), *Price Convergence in the EU*, Documento de Trabajo, FEDEA, No. 12, May 2002.

47. Temprano-Arroyo, H., Feldman, R. A. (1999), *Selected Transition and Mediterranean Countries: An Institutional Primer on EMU and EU Accession*, Economics of Transition, Vol. 7, No. 3, pp. 741-806.