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# INFLATION CONVERGENCE IN CENTRAL AND EASTERN EUROPEAN ECONOMIES

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Abstract

*In this study, the degree of convergence of inflation rates of Central and East European economies to a variety of measures of European norm inflation is assessed using a range of econometric techniques. These include unit root testing based upon time series and panels of data and – an innovation to the pertinent literature – tests of nonlinear convergence. The results suggest that while convergence can be revealed in a number of cases, there is some sensitivity associated with the testing framework, in particular whether time series or panel methods are used. Furthermore, the inflation convergence performance of the Central and Eastern European countries is conditional on the chosen inflation benchmark, the composition of the panel and the correlations among members. Moreover, by conducting a battery of linearity tests, it is found that nonlinear inflation convergence is virtually ubiquitous for the period that includes the accession of the Central and Eastern European former transition economies into the EU.*

Keywords: *inflation convergence, panel data, linearity tests*

## 1. Introduction

After joining the European Union, the main goal for Central and Eastern European (henceforth, CEE) countries is to prepare for monetary union membership. To ensure that participation of new member states contributes to the stability and viability of the system, their entry into EMU is conditional on the fulfilment of the Maastricht criteria for nominal convergence. These criteria impose a number of benchmark values for inflation, interest rates, government deficit and public debt.

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This paper conducts an empirical inquiry focused on one of the facets of nominal convergence, specifically the convergence of inflation. Compliance with this convergence criterion is intrinsically related to the effectiveness of monetary policy in achieving disinflation.

Eleven countries form the sample under scrutiny in this study. In terms of macroeconomic policy design, they have been characterised by a variety of experiences: ten of them joined the EU in May 2004, eight after successfully completing the transformation of their economies (Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic and Slovenia), two others (Cyprus and Malta) after years of experience as market economies. The eleventh country of the sample is Romania, which joined the EU in January 2007. The composition of the sample portends a challenging assessment that will combine elements of comparative analysis and country-specific coverage.

The prospects of these economies as candidates for monetary integration will depend strongly on the ability to align themselves with the institutions and macroeconomic policies of the existing EMU members. Although structural change and institutional adaptation to EMU norms are still in progress, convergence to EMU standards has gained momentum. Therefore, the analysis conducted in this paper represents a stock-taking empirical exercise, whose purpose is twofold. First, it examines the extent to which the candidate countries have been able to achieve a certain degree of convergence to EMU standards. Second, it sheds light on convergence to group averages, relevant to assessing a number of common features.

The Maastricht Treaty states an explicit target in terms of convergence of inflation rates: the inflation rate of a country that aims to join EMU should not exceed by more than 1.5% the average of the three lowest inflation rates in the Euro zone. Since the beginning of the 1980s until the introduction of the Euro in 2002, inflation rates have declined within the Euro area. After the inception of the single currency, however, a proliferating inflation divergence has been observable. The pertinent literature is yet to discern whether this divergence is only short natured or represents the manifestation of a more structural phenomenon. A forthcoming EMU enlargement, mostly with CEE countries, is likely to add new dimensions to this stylized fact. Two questions become relevant in this context. First, what is the degree of inflation convergence towards EMU benchmarks that currently characterises the future members of the monetary union? Second, what is the anticipated effect of the EMU enlargement on the inflation rates of the current members? The empirical analysis conducted in this paper endeavours to provide an answer to the first question, while highlighting some issues that may be relevant in tackling the second. To this end, the methodological framework employed here builds on the literature on growth convergence and brings together several econometric techniques to address the stationarity properties of inflation differentials. The main contribution of the analysis performed in this paper consists in employing an augmented framework, which features two classes of econometric techniques: time series and panel, while encompassing two modeling paradigms: linear and nonlinear. The use of the nonlinear approach in this context is novel and provides results that generate new insights into the inflation convergence process. Moreover, this study covers the period January 1993 to December 2004, which extends the time span used in other empirical analyses in this vein, in an attempt to draw more reliable inferences. In terms of country coverage, I include more countries and form more panels, in order to gain a better understanding of the impact of institutional and regional characteristics on convergence, while also paying attention to country-specific factors and cross-country differences.

The organisation of paper is as follows. After this introduction, a selective review of inflation convergence studies is presented in section 2, with an aim to integrate this study into the existing literature. Section 3 focuses on methodology. Section 4 presents the data and reports the empirical findings of the analysis, using conventional and more sophisticated approaches to the testing of order of integration. Section 5 discusses the results from a policy perspective. Section 6 concludes.

## 2. Empirical Studies on Inflation Convergence: A Review

The primary interest in this section is in reviewing the techniques employed to examine inflation convergence. From a methodological point of view, one can classify existing attempts into two broad categories: time series approaches and panel studies. While the first approach has dominated most of the early contributions, the second has started to gain popularity when the enhanced power of panel methods over their univariate time series counterparts was widely documented.

The time series-based strand of the literature examines inflation convergence by employing several techniques. For example, Koedijk and Kool (1992), who assess the degree of convergence in inflation rates of the EMS members, utilise a variant of the principal components method. Hall et al. (1992) and Holmes (1998) estimate models with time-varying coefficients. Other studies (Caporale and Pittis, 1993; Thom, 1995; Siklos and Wohar, 1997; Holmes, 1998; Westbrook, 1998; Amián and Zumaquero, 2002; Mentz and Sebastian, 2003) employ cointegration analysis to identify common stochastic trends in inflation rates. In these papers, the existence of a common stochastic trend is regarded as evidence of convergence. To examine inflation convergence among EMU countries, Busetti et al. (2006) use a sequence of univariate and multivariate unit root and stationarity tests that take into account correlations across countries.

A second strand of the literature uses panel unit root and cointegration tests (see, for example, Kočenda and Papell, 1997, Holmes, 2002, Beck and Weber, 2005). The main conclusion that can be drawn by examining the evidence on inflation convergence among the EU (or EMU) economies is that the results are sensitive to the time interval considered and institutional arrangements. It is widely agreed that participation in the Exchange Rate Mechanism (ERM) has fostered inflation convergence, while the introduction of a single currency and a common monetary policy generated a certain degree of divergence.

The eastward enlargement of the EU has generated a growing interest in the macroeconomic convergence of CEE economies. The extent of this convergence has been assessed from two angles: first, within their own groups, formed based on geographical and/or institutional criteria (Kočenda, 2001; Kutan and Yigit, 2002) and second, with respect to EU benchmarks (Brada and Kutan, 2002; Brada et al., 2002; Kutan and Yigit, 2002 and 2004; Kočenda et al., 2006). From a methodological standpoint, some of the above mentioned studies employ time series testing techniques, while others attempt to mediate the short time series dimension of the sample by applying panel methods. Moreover, nominal convergence is examined together with real convergence. The findings of these studies suggest that the CEE countries have surpassed the difficulties of the macrostabilisation process and started moving in the same direction as the EU economies. However, the results are sensitive to the methodology employed.

## 3. Methodology

The concept of convergence is inherently related to that of economic growth. Therefore, definitions and methodological approaches to convergence are rooted in the empirical growth literature, pioneered by Baumol (1986), Barro (1991) and Barro and Sala-i-Martin (1991, 1992). This literature defines two types of convergence: absolute and conditional. Absolute convergence implies that, independent of their characteristics, different economies will eventually converge to the same long-term level. With conditional convergence, all countries grow to their own steady state, which depends on underlying, country-specific, economic factors.

In two seminal contributions, Bernard and Durlauf (1995, 1996), drawing on Carlino and Mills (1993), develop the concept of "stochastic convergence". This entails that, in terms of economic variables, differences between countries will always have a transitory nature. Hence long-run forecasts of the differential between any pair of countries converge to zero, as the forecast interval increases (Oxley and Greasley, 1997).

Stochastic convergence can be present only if shocks to the disparity between two countries are temporary, in other words their effects dissipate over time. Hence, the stochastic approach to convergence is characterised by a testable inference: the differential series is stationary. Nonstationarity of the differential series implies that any shocks to this relative variable will have a long-lasting effect, accentuating the gap between countries. Evans and Karras (1996) show that in order to investigate the presence of stochastic convergence one can conduct standard unit root test for the differential series. If the null of a unit root cannot be rejected, then there is no convergence between the two countries involved in the calculation of the differential. Alternatively, if stationarity is supported by the results, then convergence is present.

Testing inflation convergence involves studying the dynamic properties of the inflation differential between two economies. If we let $\pi_{i,t}$ denote the inflation rate of country $i$ at time $t$, then the inflation differential ($d_t^{i,b}$) between country $i$ and a benchmark country $b$ can be calculated as:

$$d_t^{i,b} = \pi_{i,t} - \pi_{b,t} \qquad (1)$$

Stochastic convergence of country $i$'s inflation rate towards the benchmark value implies that:

$\lim$ E ($d_{t+\tau}^{i,b} \mid \Omega_t$) = $\alpha$ , $\forall t$ (2) $\tau \rightarrow \infty$

where $\Omega_t$ denotes the information set available at time $t$, comprising current and past observations on the differential series. For $\alpha = 0$, expression (2) mirrors the definition of absolute inflation convergence in a stochastic environment, in the spirit of Bernard and Durlauf (1996). This definition states that absolute convergence entails equality of long-term forecasts of the two inflation series at any fixed point in time. If, in (2) above, $\alpha$ is different from zero, then convergence is conditional or relative (Durlauf and Quah, 1999), implying that the two inflation series converge towards a time-invariant equilibrium differential.

Empirical test for stochastic inflation convergence can be implemented in a time series framework by examining the univariate properties of the inflation differential using a unit root test. Both absolute and conditional convergence require a stationary inflation differential. While absolute convergence implies that the auxiliary regression of the test does not include an intercept term, conditional convergence does not impose this restriction. As argued by Busetti et al. (2006), a simple time-series representation of conditional convergence is provided by a first-order autoregressive process:

$$d_t^{i,b} - \alpha = \rho\left(d_{t-1}^{i,b} - \alpha\right) + \varepsilon_{i,t} \qquad (3)$$

which, parameterised in first differences, has the following expression:

$$\Delta d_t^{i,b} = \gamma + (\rho - 1)\, d_{t-1}^{i,b} + \varepsilon_{it} \qquad (4)$$

where $\varepsilon_t^{'}$s are a sequence of martingale difference innovations, $\rho$ represents the speed of convergence and $\gamma = \alpha(2-\rho)$ (where $\alpha$ is defined in (2) above).

Representation (4) illustrates that the value of the growth rate of the inflation differential in the current period is a negative fraction of the inflation gap between two countries in the previous period, after allowing for a permanent difference $(\gamma)$.

Expression (4) above corresponds to the maintained regression of the standard DF unit root test. However, in empirical studies on inflation convergence, the ADF test, a generalisation of the DF test that accounts for serial correlation in the residuals, is a more suitable representation. Commonly applied in studies of inflation convergence, the auxiliary regression of the ADF test requires additional lagged values of the inflation differential $\Delta d^{i,b}$ in specification (4) above, having the following expression:

$$\Delta d_t^{i,b} = \gamma + (\rho - 1)\, d_{t-1}^{i,b} + \sum_{j=1}^{p_i} \varphi_{ij} \Delta d_{t-j}^{i,b} + \varepsilon_t \quad (5)$$

Using representation (5) above, inflation convergence can be examined by conducting a unit root test, which evaluates the null hypothesis $H_0 : \rho = 1$, against the alternative $H_A : \rho < 1$. Müller and Elliott (2003) argue that the power properties of this unit root test depend on an initial condition, that is how far $d_0^{i,b}$ is from α. If the hypothesis under scrutiny is that of absolute convergence and consequently α is assumed to be equal to zero, a test based on an ADF regression with no intercept term performs relatively well, with a high initial value of the differential leading to enhanced power properties of the test (see Harvey and Bates, 2003 and Müller and Elliott, 2003, for a formal demonstration and Busetti et al., 2006, for an empirical illustration). As a result, a specification that does not include a constant term is appropriate for testing the null of no convergence against the alternative hypothesis that two inflation series are converging in absolute terms, since it provides an improvement in power. However, testing absolute convergence is of interest when inflation differentials pertain to countries that are already members of a monetary union. In this study, I will employ the conditional variant of convergence, this being appropriate in view of CEE countries' inflation history since the beginning of transition.

As mentioned in Section 2, the methodological approach employed in empirical studies of convergence has gradually moved on from time series to panel data techniques. The latter provide more sophisticated devices. In a panel setting, the time series dimension is augmented with the information contained in the cross-sectional one. This implies that nonstationarity from the time series can be dealt with and combined with the increased data and power that the cross-sectional dimension brings to the analysis. As a result, the inference becomes more accurate. Such outcome is particularly important in the case of CEE economies, where time series data are available over a short span, but similar data may be obtained across a cross-section of countries.

Panel unit root tests not only mediate the time dimension problem that arises in small samples, but are also characterised by enhanced power properties in comparison with their univariate counterparts. It is now a widely documented fact that commonly applied standard unit root tests, such as ADF, have low power in distinguishing the unit root null from a stationarity alternative, tending to over-reject the alternative of stationarity. In a convergence testing framework, this is equivalent to offering more empirical support to divergence between countries.

In this study, two panel unit root tests are conducted to assess the extent of convergence of CEE inflation rates. The first is the test proposed by Im, Pesaran and Shin (IPS, 1997, 2003), a test that addresses the convergence properties of a panel as a whole. The second test employed here, developed by Breuer, McNown and Wallace (SURADF, 2002) sheds light on the convergence performance of each panel member. These two testing frameworks complement each other, enabling one to derive convergence results not only for the panel as a whole, but also for individual countries. Their features facilitate a comprehensive analysis, which can focus on country-specific aspects. Moreover, both tests allow for heterogeneity in convergence rates.

To conduct the IPS test, an ADF-type regression is specified and estimated for each inflation differential, as follows:

$$\Delta d_t^{i,b} = X_{it}^{'}\gamma_i + \phi_i d_{t-1}^{i,b} + \sum_{j=1}^{p_i} c_{i,j}\Delta d_{t-j}^{i,b} + u_{i,t} \quad (6)$$

where $i = 1,...,N$ and $t = 1,...,T$. N is the cross-sectional dimension of the panel, while T is the time dimension. $X_{it}$ is a vector of deterministic components. In the framework of equation (6), the null hypothesis of a unit root, $H_0 : \phi_i = 0$, $\forall i$, is tested against the alternative $H_A : \phi_i < 0$, for $i = 1,...,N_1$ and $\phi_i = 0$, for $i = N_1 + 1,...,N$. Here, $\phi_i = \rho_i - 1$, where $\rho_i$ is used as a measure of the speed of inflation convergence. The specification of the vector of deterministic components $(X_{it})$ is important in empirical applications. If no deterministic components are allowed in (6) above, then the IPS procedure tests absolute convergence between inflation rates, which is equivalent to assuming that the two inflation rates used in the calculation of the differential are characterised by identical steady states. When a constant term is included in (6), then one can distinguish two cases. In the first case, the constant is restricted to be equal across panel members ($X_{it} = 1$ and $\gamma_1 = \gamma_2 = ... = \gamma_N = \gamma$), which suggests that inflation rates are characterised by the same growth rate. The second case allows different constant terms, which is equivalent with a model with fixed effects, suitable for representing conditional convergence. If the vector of deterministic components includes a constant and a term trend, where the constant is not the same across panel members, then there is a time-changing disparity between inflation rates

The empirical analysis conducted here uses a constant term as the only deterministic component in the specification of (6), therefore adopting a model with fixed effects. This representation allows for idiosyncratic features and heterogeneity across countries.

The IPS $t$ -bar test statistic can be computed as an average of the *t*-statistics on the coefficients $\phi_i$ resulted from the estimation of ADF-type maintained regressions, illustrated in equation (6), for all countries in the panel.

An important drawback of the IPS testing technique is that it builds on the assumption that the error terms $u_{it}$ in (6) are individually and identically distributed, IID (0, $\sigma_{\varepsilon}^2$). If the residual terms are contemporaneously correlated, this assumption is no longer valid, and the IPS test is characterised by significant size distortions, as demonstrated by Maddala and Wu (1999) and Strauss and Yigit (2003). To account for cross dependencies across panel members, Im, Pesaran and Shin (op.cit.) suggest the following solution: introduce a common time effect by decomposing the error term in (6) into a common time effect and an idiosyncratic random effect that is independently distributed across groups. To remove the common time effect, one needs to subtract the cross sectional mean from each panel member. However, simple demeaning to account for the presence of contemporaneous cross correlations does not remedy the size distortions in a satisfactory way (Strauss and Yigit, 2003).

Taylor and Sarno (1998) argue that panel unit root tests that focus on the stationarity properties of the panel as a whole, like the IPS test, have an important drawback: the null of (joint) nonstationarity might be rejected due to strong stationarity of one panel member, which induces rejection of the unit root null. This critique pertains to the results delivered by the IPS test, in cases where the panel under scrutiny comprises a mixture of convergent and non-convergent inflation rates. When the results of the IPS test are interpreted, if the sample test statistic exceeds its critical value(s), it may not be the case that all members of the panel are stationary. The IPS testing framework does not allow one to distinguish how many and which members of the panel contain a unit root, which may constitute a serious drawback.

One of the objectives of the analysis conducted here is to shed light on the individual experiences, in terms of inflation convergence performance, of the selected countries, while exploiting the advantages of panel approaches over univariate ones. To this end, I complement the IPS testing framework with the series specific SURADF panel unit root test. By employing a SUR framework, this test offers an improvement in the power of univariate time series tests, without sacrificing much series-specific information.

To conduct the SURADF test, ADF-type regressions, illustrated in (6) above, are specified for each panel member (similar to IPS). In a subsequent step, these regressions are estimated using a seemingly unrelated regression (SUR) approach, and individual unit root tests are conducted for each member of the panel. The SUR framework allows taking into consideration contemporaneous cross correlations among panel members, circumventing one of the drawbacks of the IPS test. The trade relations and institutional arrangements that exist among the CEE countries considered in this paper suggest that a panel unit root test that accounts for cross correlations is required to ensure an accurate assessment. Since it accounts for cross correlations among panel members, which are specific to each panel, the SURADF test statistic is characterised by a nonstandard distribution, and so the critical values of this test must be generated by Monte Carlo simulations tailored to the panel under scrutiny.

## 4. Data and Empirical Results

The dataset comprises monthly observations on prices (represented by CPIs) for: Cyprus, the Czech Republic, Estonia, Germany, Greece, Hungary, Latvia. Lithuania, Malta, Poland, Romania, the Slovak Republic and Slovenia. The data are obtained from *International Financial Statistics* compiled by the IMF. The data cover the interval January 1993 to December 2004. The pre-1993 period is excluded from analysis for two reasons: first, in order to avoid the early years of transition and the instability that characterised them and second, for countries which have gained separate identities only recently (like the Czech Republic and Slovakia), data are available only since January 1993. Therefore, to construct balanced panels, in line with the requirements of the panel unit root tests conducted in this study, the beginning of the sample is fixed at January 1993.

Based on the monthly CPI observations, I calculate annualised[14] inflation rates as log differences:

$$\pi_t = \ln CPI_t - \ln CPI_{t-12} \qquad (7)$$

Six panels of countries are constructed as follows: *CEFTA*[15] (the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia), the extended

[14] Since I am using monthly observations on the consumer prices, annualisation is congruent to deseasonalisation

[15] CEFTA represents the acronym for the Central European Free Trade Agreement, signed by former Czechoslovakia, Hungary and Poland on December 21, 1992. On March 1st, 1993, CEFTA goes into effect. On January, 1st, 1996, Slovenia joins CEFTA as a full member. On July 1st, 1997, Romania also joins CEFTA.

CEFTA (*ECEFTA*: the Czech Republic, Hungary, Poland, Romania, the Slovak Republic and Slovenia), the Baltic States (*BALTICS*: Estonia, Latvia and Lithuania), the first wave group[16], comprising only former transition economies (*FIRST8*: the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the Slovak Republic and Slovenia), the complete first wave group (*FIRST10*: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, the Slovak Republic and Slovenia) and a panel that includes all former transition economies (*ALL9*: the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia). Therefore, I form panels based on both institutional and geographical criteria.

To examine convergence, I calculate inflation differentials of the selected countries with respect to the following four benchmarks: Germany, Greece, the Euro area and their group average, where the groups are those described above. Germany is chosen as a benchmark to represent the core EU standards, since it has a remarkable experience in terms of low inflation. Greece is chosen to represent the peripheral countries of the union. The third benchmark is a weighted average CPI for the Euro area, reported by Eurostat.

Table 1 provides some descriptive statistics for the inflation rates considered. The averages suggest that the lowest mean inflation rate prevailed in Germany, followed by the Euro zone. Not surprisingly, inflation tended, over this period, to be higher in the transition economies than elsewhere.

**Univariate Unit Root Test Results**

To test for mean-reverting behaviour (beta convergence), standard ADF unit root test are first conducted. They serve as benchmark for comparison for the results of subsequent panel unit root tests and assist in the selection of the lag order for these tests.

If we can reject the null hypothesis of a unit root and therefore detect stationarity (and convergence), any shock that causes deviations from equilibrium[17] has a temporary nature and its impact will eventually die out. The speed of this process can be derived using the estimated value of the speed of convergence ( $\hat{\rho}$ ). Given $\hat{\rho}$ , half-lives $(HL)$ can be calculated using the following formula:

[16] I adopt this terminology in order to distinguish between the first wave of new member states, which entered EU on 1 May 2004 (Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, the Slovak Republic and Slovenia) and the second wave, which comprises Bulgaria and Romania.

[17] Proxied, as mentioned above by the benchmark value of inflation.

$$HL = \frac{\ln(0.5)}{\ln(\hat{\rho})} \qquad (8)$$

The results of the ADF test suggest that, with only a few exceptions, the inflation differentials examined here are unit root processes. The only country which appears consistently not to have a unit root in the inflation differential is Romania; this is likely due to its particularly large average inflation differential. However, since this limited support for convergence may be due to the low power that characterises the ADF test, in what follows I present results derived from a panel framework.

**Panel Unit Root Test Results**

Table 3 reports the results of the IPS t-bar test for each inflation benchmark and panel of countries. After calculating the standardised version of this test statistic, its level of significance is determined using critical values drawn from a standard normal distribution.

**[insert Table 3 here]**

The null hypothesis of a unit root is rejected for all benchmarks and lag values for four panels: BALTICS, FIRST8, ALL9, FIRST10. However, for the CEFTA and ECEFTA panels, the results are conditional on the selected lag length and benchmark inflation rate. It may be the strong rejection of nonstationarity for the Baltic States that drives these results, if we look also at the CEFTA and ECEFTA results.

**[insert Table 4 here]**

Table 4 presents two measures of convergence: the speed of convergence ($\rho$) and the corresponding half-life (HL). The convergence coefficient ($\rho$) represents a measure of the speed of convergence. The closer $\rho$ is to 1, the slower the convergence of the inflation rate to the chosen benchmark value. Interpreted in terms of the half life of shocks, convergence is faster when the value of the half life is smaller, which implies that the impact of a shock causing a deviation from equilibrium (proxied by the benchmark value) will die out more rapidly. Table 4 illustrates that regardless of the inflation benchmark considered, convergence is faster in the case of the new EU members that had a longer history as fully-fledged market economies, Cyprus and Malta. They are followed by Slovakia, Slovenia and two of the Baltic States, Latvia and Lithuania. Convergence is definitely slower in the cases of Hungary, Poland, Czech Republic, Romania and Lithuania.

The second panel of Table 4 reports average values of the speed of convergence and half lives for the six panels examined in this study. They illustrate that when the benchmark inflation value is the German inflation, convergence is fastest for the panel that comprises the new EU members (FIRST10), followed by CEFTA. The Baltic panel is characterised by the slowest convergence. A change in the benchmark value of inflation to the Greek inflation changes the ranking, with CEFTA and ECEFTA panels showing the fastest convergence and the Baltics the slowest. If the benchmark is an average Euro zone inflation rate, then convergence is fastest for the new EU members (FIRST10), followed by CEFTA and ECEFTA.. The panel with the Baltic states is again characterised by the lowest speed of convergence.

In view of the sensitivity of some of the above results to lag length, and to look at the inflation convergence performance of each country, it is instructive to employ also the SURADF test, which allows a more flexible approach in terms of lag specification. In the representation of this test, I use different lag structures for each panel member, where the lags are the same as those used in the specification of the univariate ADF test. They are determined, as before, by employing the data dependent, top-down procedure devised by Campbell and Perron (1991). Table 5 displays the findings of the SURADF testing approach when inflation convergence is tested against a German inflation benchmark.

When the benchmark is Germany, convergence in inflation rates occurs consistently for Poland and Slovenia (in five out of six panels) and also for two Baltic economies, Estonia and Latvia (in four out of six panels). In the case of the new EU member states with tradition as market economies, convergence in inflation rates to the German benchmark occurs for Cyprus, while Malta is close to converging. The results indicate that the Slovak Republic is also close to converging, while the Czech Republic, Hungary and Romania do not exhibit convergence in any of the panels. Lithuania displays convergence only in the Baltics panel, which shows the greatest degree of homogeneity among all panels considered in this study, with all three members converging in their inflation rates to the German benchmark. These findings are, in general, in accord with those of Kutan and Yigit (2004), who study the inflation convergence performance of the ten new EU member states with respect to Germany using the SURADF test. However, they consider a shorter sample period, which ends in December 2003.

Table 6 illustrates the inflation convergence performance of the countries included in this study when the benchmark economy is represented by Greece, the last country to join the EMU structures. In comparison with Germany, Greece exhibited higher inflation rates throughout the interval under scrutiny. In various empirical assessments, Greece is generally viewed as a peripheral EMU economy.

This being so, the macroeconomic performance of the Central and Eastern European EMU candidates is often compared to that of Greece.

When the benchmark is Greece, convergence in inflation rates occurs consistently for Estonia and Latvia (in all panels that include them). Poland also exhibits convergence, while Slovenia is close to converging. Similar to the case when Germany is selected as benchmark, the Baltic panel displays the highest degree of homogeneity, with all three Baltic States converging. However, when other countries are included, Lithuania ceases to exhibit convergence. The change in benchmark does not alter, in qualitative terms, the results obtained in the cases of the Czech Republic, Hungary and Romania. Slovakia is, in all panels, closer to converging than these three economies. The inflation rates of Cyprus and Malta do not exhibit convergence to the Greek one, which shows that, in their cases, a change in the benchmark matters for the inflation convergence performance.

When a Euro area average inflation is the benchmark value, convergence occurs in the cases of Cyprus, Estonia, Latvia, Poland and Slovenia. The Baltic panel exhibits again the highest degree of homogeneity, in that all three inflation rates converge to the Euro area benchmark. Slovenia converges, albeit at 10%. Lithuania is close to convergence. Negative results in terms of convergence are uncovered for the Czech Republic, Hungary, Malta and Romania.

To summarise the results reported so far, the empirical evidence consistently shows that a number of countries, namely Estonia, Latvia and Poland display inflation convergence regardless of the Euro area inflation benchmark considered. At the other end of the convergence spectrum, the Czech Republic, Hungary and Romania do not exhibit convergence in inflation rates to any of these benchmarks. The evolution of inflation in Romania, with values that peaked several times as a result of several unsuccessful stabilization attempts and remained in the double-digit range until 2004, may justify its poor performance in terms of inflation convergence. In the cases of Czech Republic and Hungary, an explanation is more difficult to find. The Czech inflation rates have constantly been below those recorded by Estonia, which displayed a consistent inflation convergence. Therefore, in the light of this argument, an explanation may be sought in the way inflation convergence is defined from the viewpoint of an applied econometrics approach, as a process of lessening of differentials. This may be complemented with insights offered by a look at patterns in the evolution of inflation over the sample under scrutiny, which reveals a rather volatile evolution of Czech inflation over the period analysed, with values that have been much below the benchmark in some years and much above them in others. For Hungary, a possible explanation also lies in the inflation patterns during the interval under scrutiny, with several reversions in trend and a rather disappointing inflation performance over the past few years. Compared with the other countries considered in this analysis, Lithuania has represented an outlier in terms of inflation performance. In spite of this, the results indicate that in a panel which also includes the other two

Baltic States, Estonia and Latvia, Lithuania exhibits convergence in terms of inflation to all three benchmarks considered. This may be due to the strong correlations that exist among the three Baltic economies, correlations that have been accounted for by the testing methodology applied in this study.

A fourth benchmark employed in this study is represented by the average inflation of the groups considered. The results of inflation convergence to the group average illustrate that the strongest convergence occurs in the case of the Baltic States (Estonia, Latvia and Lithuania), which form the most homogeneous panel, a finding that reinforces previous results. At the other extreme are situated the CEFTA and ECEFTA panels, where, with the exception of Poland, the member countries do not converge in their inflation rates to the group average. The panel that comprises the eight CEE economies which joined the EU in May 2004 also evinces a high degree of homogeneity, in that convergence to the group's average inflation occurs for five countries (the Czech Republic, Estonia, Hungary, Poland and the Slovak Republic), while the other three (Latvia, Lithuania and Slovenia) are characterised by divergence. This result supports, to some extent, their admittance into EU as a group. However, one can notice that countries that exhibit convergence to this group's inflation average are, with the exception of the Slovak Republic, those who formed the initial first wave of accession economies. Latvia and Lithuania were initially members of the second wave. Their upgrading to the first wave of accession was decided based on their macroeconomic performance. However, their performance in terms of convergence to the average inflation of the group may suggest that their inflation experiences may have been different from those of the other first wave CEE economies.

Adding Romania to the group that comprises the other eight former transition countries does not significantly change the results, except for one rather puzzling outcome: convergence in inflation rate to the group's average also occurs in the case of Romania, besides the Czech Republic, Estonia, Hungary and Poland. As it is evident that Romania represents more of an outlier within this group, the impact of its high inflation rates on the group's average may solve the puzzle.

The panel that comprises the ten new EU members is also characterised by homogeneity, with most of its members (the Czech Republic, Estonia, Hungary, Lithuania, Malta, Poland and Slovenia) converging to the group's average inflation. This result tends to support their EU accession as a group.

### The Case for Nonlinear Inflation Convergence

To complement the results based on linear representations reported so far, a new dimension is added to the empirical analysis performed. Specifically, the potential presence of nonlinear features in the inflation convergence process is investigated. A nonlinear adjustment is characterised by changes in the speed of convergence. Panel methods, which belong to the family of linear modelling frameworks, cannot account for this feature. In the applied econometrics literature, nonlinear representations have mainly been used to illustrate the dynamic adjustment of the real exchange rates to equilibrium or the dynamics of macroeconomic variables over the business cycle. However, their main features make them suitable for assessing potential changes in the speed of inflation convergence.

Intuitively, a nonlinear adjustment makes sense if one considers the EU accession of the CEE economies. Nonlinearities may have been induced by policy actions, when more effective disinflationary measures have been implemented by monetary authorities to ensure compliance with EU benchmarks. Such policy interventions are likely to increase the speed of convergence, as their main objective is to bring inflation down when it surpasses a certain threshold. Moreover, the nonlinear adjustment induced by policy actions may also be characterised by asymmetry, as policy makers are more concerned about increases in inflation than declines. Furthermore, as suggested by Killian and Taylor (2001) for the case of exchange rates, heterogeneity of economic agents' beliefs and expectations could induce nonlinearity. A similar argument may apply also in the case of inflation rates, given the crucial role played by inflation expectations, especially in the case of the European former transition economies. The potential for nonlinear convergence of CEE countries' inflation rates towards EU benchmarks is examined here in an attempt to shed more light on the results delivered by linear modelling frameworks used so far in this paper.

The investigation of nonlinear features in the inflation convergence of the case study countries considered in this paper is carried out for the inflation differentials calculated with respect to Germany. This choice is motivated by the arguments in favour of nonlinearity presented above, which suggest that German inflation is more likely to be viewed as a benchmark by the monetary authorities of the countries that aspire to become EMU members.

To examine the presence of nonlinearities, I apply a battery of linearity tests, developed by Luukkonen et al. (1988), Teräsvirta (1994) and Escribano and Jorda (1998, 2001). These tests are conducted to investigate a potential nonlinear adjustment of a Smooth Transition Auto Regressive (STAR) type. A linear specification, similar to those used by the univariate and panel unit root tests carried out in this paper, is assessed against the alternative of STAR-type nonlinearity. To avoid a spurious finding of nonlinearity that may be due to the presence of outliers, quite likely to exist given the inflation experiences of the CEE economies, I perform both the standard and the outlier-robust versions of these tests. For a thorough investigation, heteroscedasticity robust linearity tests are also conducted. The detailed results of this sequence of tests, not reported here due to space constraints, are available upon request.

The results of the battery of linearity tests conducted provide evidence in support of a nonlinear convergence in inflation rates for eight out of eleven countries included in the sample under scrutiny. Exceptions are the Czech Republic, Poland and Slovakia. In analysing the outcome of these tests, I place more emphasis on their outlier-robust versions, given the patterns in the evolution of inflation rates in CEE countries over the decade 1993-2004. An asymmetric, LSTAR-type nonlinear adjustment may provide an adequate description of the inflation convergence process in the cases of Hungary, Latvia, Malta and Romania. ESTAR models are suitable for Cyprus, Estonia, Lithuania, Romania and Slovenia. In the case of Hungary, the outcome of the linearity tests may explain why convergence was not unveiled by the univariate and panel unit root tests that adopted a linear specification. Furthermore, the case of Romania highlights the importance of performing outlier-robust linearity tests in order to avoid a spurious finding of nonlinearity. In terms of inflation experience, among the countries considered in this analysis, Romania stands out, with high and volatile inflation rates. However, the outlier-robust linearity tests performed here suggest that there is potential for nonlinear convergence in the case of the Romanian inflation rate.

## 5. The Inflation Convergence Record: a Look at Potential Explanatory Factors

The main finding of the empirical analysis performed above is that convergence in inflation rates of CEE countries to EU benchmarks occurs only in a limited number of cases. Moreover, the results are country-specific and benchmark-specific. An interpretation of the whole picture is difficult. This is not surprising, given the inflation experiences of the CEE economies during the period 1993 to 2004. While the established market economies of Cyprus and Malta make better candidates for convergence, the former transition economies from Central and Eastern Europe offer a rather mixed picture. To explain the results, I will evaluate a number of factors that may exert an impact on the convergence process.

First, the experience of current EMU members provides a very useful arena for examining the factors that underlie inflation convergence. In particular, the experience of the peripheral countries may help in drawing lessons for the CEE countries that aspire to join the monetary union.

In recent European economic history, two landmarks stand out. The first one corresponds to the establishment of the EMS in 1979, with the intention of stabilising exchange rate volatility among members. The second marks the adoption of a single currency and the introduction of a common monetary policy, in 1999, marking the last stage in the creation of the economic and monetary union.

The prospect of introducing a single currency within EU has required synchronisation of monetary decisions taken by the member states. This has provided the impetus for the establishment of a regulatory framework, which ranged from the EMS of 1979, with its own exchange rate mechanism (ERM I), to the Maastricht Treaty of 1992. Among other nominal convergence criteria, the Maastricht Treaty has defined explicit convergence goals for inflation rates. However, after the commencement of the Euro, a proliferating inflation divergence has been documented and significant cross-country differences have emerged. A large body of studies have addressed this topic, trying to shed light on the nature of the observed divergence (short or long lasting) and the factors that caused it. To explain this change in trend, it has been emphasised that inflation rates experienced a firm decrease as countries endeavoured to comply with the Maastricht inflation criterion. After that, the inception of a single monetary policy generated divergence in inflation rates, as a one size policy could not fit all experiences. If one looks at the developments discussed above in the light of the future EMU accession of the new EU member states, then more divergence can be expected to occur, as these countries will contribute to an increase in the already existing heterogeneity among member states.

Secondly, within the confines of the EMU, increased goods market integration and greater price transparency, generated by the Internal Market Programme and, ultimately, by the introduction of a single currency, aimed at stimulating price convergence. However, as documented by Maier and Cavelaars (2003), Euro area countries have adopted a common currency, but are still characterised by different price levels for similar products. The large body of literature that focuses on testing the validity of PPP offers an explanation for this, showing that price levels between countries tend to equalise, but the adjustment process is very slow[18] (see, for instance, Froot and Rogoff, 1995).

Within a monetary union, if prices expressed in a common currency reveal initial differences across countries, then convergence to a similar level entails higher inflation in countries with lower prices. Therefore, price level convergence, also labeled as "inflation catching up" may hinder the inflation convergence process by generating cross-country differences in inflation rates (Rogers et al., 2001; Rogers, 2002).

The differences in price levels between the euro area and the countries that aspire to join it are more pronounced than price differentials within the euro area. This suggests that the phenomenon of price convergence may constitute an important source of inflation differentials between current EMU members and aspiring countries.

[18] Price differences between countries tend to equalise, where these differences reflect certain costs.

Thirdly, an important aspect of the price convergence process concerns adjustments in the area of nontradable goods prices. The well-known Balassa Samuelson (BS) effect is often put forward in attempts to explain why prices of nontradable goods might increase faster in poorer members of a monetary union, therefore generating inflation differentials with respect to richer members. The process of economic integration witnessed by CEECs has created pressure for European-wide convergence of productivity levels in the tradable goods sector. In addition, productivity levels in the nontradable goods sector have converged at a much slower rate. Therefore, productivity increases in the tradable goods sector have outpaced those in the nontradables sector. Due to wage equalisation (an important assumption of the BS effect), the rise in wages in the tradables sector has determined an increase in wages, and hence prices, in the nontradables sector of CEECs, compared to the old EU members. The rise in inflation that has occurred due to high nontradable goods inflation explains, partly, the divergence in inflation between CEECs and old EU members.

Fourthly, the features of the monetary regime pursued by a country may be relevant for the inflation convergence process. This conjecture stems from the main tenet of the monetarist paradigm, which, in the words of Milton Friedman, upholds that inflation is always and everywhere a monetary phenomenon.

A fifth aspect that may shed some light on the inflation convergence performance of EMU accession countries is the design of fiscal policy. Kutan and Yigit (2004) argue that when CPI is used to calculate inflation rates, the stance of fiscal policy becomes relevant in interpreting inflation convergence results, since the CPI accounts for fiscal shocks.

## 6 Concluding Remarks

In this paper I have reported on a comprehensive econometric assessment of inflation convergence of CEE countries towards EU benchmarks and their group averages. After gaining the status of fully fledged market economies, these countries have been accepted as members of EU and intend eventually to subscribe to EMU, legitimating an assessment of their inflation performance. However, their participation in the monetary union is conditional upon complying with a strict inflation criterion. To meet this criterion, the CEE countries have strived to build the appropriate institutions and implement consistent, sound and coordinated monetary and fiscal policies. Containing inflation and maintaining price stability has become increasingly important for these countries. In this context, convergence of inflation becomes a topic of key importance.

The results reported in this paper suggest that while convergence can be revealed in a number of cases, there is some sensitivity associated with the testing framework, in particular whether time series or panel methods are used. Furthermore, the inflation convergence performance of the CEE countries is conditional on the chosen inflation benchmark, the composition of the panel and the correlations among members. The highest degree of homogeneity was recorded for the panel comprising the three Baltic States. Poland and Slovenia were the other CEE countries with a good performance in terms of inflation convergence.

To complement the results derived from univariate and panel unit root tests, I have conducted a set of linearity tests on the inflation differentials with respect to Germany, chosen to represent EMU core. In this regard, the analysis performed in this paper was characterised by an element of novelty, compared with other existing studies. While accounting for the interplay between linearity and outliers, the findings of the linearity tests highlighted a potential nonlinear convergence process in all but one case, which may have been induced not only by policy interventions, but also by heterogeneity of inflation expectations among economic agents. This finding opens an interesting line of inquiry, suggesting that the process of inflation convergence in the CEE countries is characterised by nonlinear features, which cannot be captured by standard linear models. The results suggest that nonlinear convergence, which allows for more flexibility in comparison with linear specifications, is almost ubiquitous. Therefore, an accurate representation of the convergence process of the CEE economies towards EMU norms needs to accommodate the presence of nonlinear features.

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