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Relative inflation dynamics in the new EU member countries of Central and Eastern Europe

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Abstract Following their EU accession, the new member countries from Central and Eastern Europe (CEE) must achieve sustainable price stability as one of the preconditions for joining the Economic and Monetary Union (EMU) and adopting the euro. This article examines the distribution dynamics of inflation rates in ten new EU members from CEE relative to the EMU accession benchmark inflation over the period 1990–2009. In contrast to previous studies, we use nonparametric methods to test for convergence in inflation rates between CEE and the EMU benchmark as well as within the CEE sample. Over the entire sample period, we detect a general shift in the CEE inflation distribution toward the EMU benchmark along with intradistributional convergence. However, this process is not uniform. In the early years, it was equally likely for CEE inflation rates to move toward or away from the benchmark. The resulting multimodal distribution gave way to a unimodal distribution in the years leading up to the EU accession, accompanied by a marked shift toward the EMU benchmark. In more recent years, emergence of a bimodal distribution signaled the stratification of relative inflation in CEE into two convergence clubs, which has intensified since the start of the global economic crisis.

Keywords Inflation · Convergence · New EU member countries · Distribution dynamics

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1 Introduction

Inflation has been one of the key issues of economic transition in Central and Eastern Europe (CEE) over the past two decades. The early period of transition was marked by galloping inflation triggered by price liberalization and structural reforms aimed at establishing a market economy. Although inflation was tamed by the second half of the 1990s, the onset of accession negotiations between CEE countries and the European Union (EU), which coincided with the introduction of the euro in 1999, posed new challenges. All new EU member countries must join the Economic and Monetary Union (EMU) and eventually adopt the euro as their currency once they fulfill four convergence criteria stipulated in the Maastricht Treaty of 1992.

One of these criteria requires the member state to achieve price stability by controlling the rate of inflation.[1] In particular, this criterion states that "a Member State has a price performance that is sustainable and an average rate of inflation, observed over a period of one year before the examination, that does not exceed by more than 1.5 % points that of, at most, the three best-performing Member countries in terms of price stability."[2] Accordingly, as the CEE countries stood to join the EU, the prospect of accession to the eurozone brought upon them the responsibility of achieving a low inflation not only in absolute terms but relative to the benchmark established by the Maastricht Treaty.[3] The fact that only three of the ten new EU member countries of CEE have managed to fulfill all four criteria and to adopt the euro so far illustrates the enormity of the challenge faced by these countries.[4]

The aim of this article is to investigate the evolution of inflation rates in ten new EU member countries of CEE relative to the EMU benchmark over the period 1990–2009.[5] In particular, we examine convergence of inflation in CEE toward the EMU benchmark.[6] We also study the dynamics of relative inflation within the group of these new EU member countries. This is important in itself because with greater economic integration under the umbrella of the EU, persistent differences in inflation among these countries will affect relative real interest rates and real wages, which in turn will influence the movements of capital and labor across borders. Previous studies on inflation

[1] The other criteria include: sustainable fiscal position, exchange rate stability, and low long-term interest rates.

[2] Article 109j(1) of the Maastricht Treaty lays down the protocol on convergence criteria for entering the EMU. See p. 85 of the treaty text at http://www.ecb.int/ecb/legal/pdf/maastricht_en.pdf.

[3] The importance of the price stability criterion and the stringency in its implementation became apparent in 2006 when Lithuania's bid to join the eurozone was rejected although its inflation rate was just 0.1 % point above the benchmark.

[4] Slovenia became the first CEE country to adopt the euro in 2007, followed by Slovakia in 2009 and Estonia in 2011.

[5] An earlier version of this article was published as a Bulgarian National Bank Discussion Paper (Nath and Tochkov 2011).

[6] However, as Camarero et al. (2000) discuss, "the notion of convergence behind the Maastricht Treaty is less restrictive… The Treaty states that the countries must be in the process of convergence but that this process does not have to be achieved completely" (p. 153).

convergence among CEE countries vary widely in terms of their scope and coverage. While the majority of these studies focus on the period from the mid-1990s to the EU enlargement in 2004 (Brada et al. 2005; Kocenda et al. 2006; Kutan and Yigit 2004), a few others also include the years up to the second enlargement in 2007 (Becker and Hall 2009; Palomba et al. 2009; Siklos 2010). Our sample period extends over the two decades since the beginning of transition in 1990 and thus allows us to study relative inflation in CEE during the early transition period of hyperinflation, the periods before and after the two EU enlargements, adoption of the euro by Slovenia and Slovakia, as well as the period of recent global economic crisis. Furthermore, the current study includes all ten CEE countries that formally joined the EU in 2004 and 2007.[7]

The most crucial difference between the present study and the existing literature is the choice of methodology. Previous studies often use unit root tests to investigate the stationarity of the inflation differential series and cointegration tests to detect a common stochastic trend between EMU and CEE inflation.[8] In contrast, we employ distribution dynamics, a nonparametric methodology, which allows us to explore the entire distribution of relative inflation rates rather than just the first two moments of the distribution, and its dynamics over time. We analyze the shape of the distribution and its evolution over time in discreet and continuous space. In particular, we use Markov transition matrices and stochastic kernels to estimate the probability of making a transition from an initial level of relative inflation toward or away from the EMU benchmark.

Furthermore, the benchmark against which CEE inflation rates are evaluated varies across studies. For those focusing on convergence toward European standards, the most popular choices are the inflation rates of Germany, the EU or EMU average, and the European Central Bank (ECB) target rate (Becker and Hall 2009; Brada et al. 2005; Siklos 2010) while those investigating convergence within the group of the new EU member countries opt for the CEE average or test for a common stochastic trend between different clusters of CEE countries (Becker and Hall 2009; Kutan and Yigit 2004). We adopt the EMU benchmark stipulated in the Maastricht Treaty as the only reference value of importance for the new EU member countries of CEE as the focus of our article is on the inflation dynamics in these countries with respect to fulfilling the convergence criterion of price stability that would facilitate the adoption of the euro.[9]

The few studies that focus on inflation convergence in CEE relative to the EMU price stability criterion largely concur in their findings. Kocenda et al. (2006) report convergence over the late 1990s but show that as inflation rates approached the EMU benchmark in the early to mid-2000s the downward movement came to a halt with very

[7] Most previous studies include the eight CEE countries that joined the EU in 2004. Only Becker and Hall (2009) and Kutan and Yigit (2004) include Bulgaria and Romania that joined the EU in 2007. In some other studies, the EU member countries from CEE are lumped together with other new member countries such as Malta and Cyprus (Kocenda et al. 2006; Siklos 2010) or other EU member countries (Palomba et al. 2009; Egert 2007) or candidate countries such as Croatia and Turkey (Becker and Hall 2009) which are either quite different in size than the CEE countries or are not transition economies or do not have the prospect of being admitted to the EU anytime soon.

[8] Kocenda et al. (2006) and Becker and Hall (2009) are notable exceptions as they use β-convergence and the principle component analysis, respectively, to study inflation convergence in CEE.

[9] Becker and Hall (2009), Kocenda et al. (2006), and Siklos (2010) also use the EMU benchmark based on the price stability criterion, but it represents only a relatively minor part of their convergence analysis.

few exceptions, such as Slovenia. Similarly, Becker and Hall (2009) find evidence of convergence over the period 1998–2002 and they show that this trend continued only for Slovakia and Slovenia during 2003–2007 while for most others inflation veered away from the benchmark. Palomba et al. (2009) show that over the period 1999–2006 the new EU member countries displayed a high degree of similarity in inflation dynamics both among each other and with eurozone countries. Siklos (2010) finds evidence of convergence over the period 1995–2007 only for a few of the CEE accession countries, but his results are not robust across different model specifications.

The rest of the article is organized as follows. The next section includes a brief discussion on various monetary regimes as a background for our analysis of inflation developments in the CEE countries. Section 3 describes the data and the methodology used in this article, while Sect. 4 presents the empirical results and their analysis. The concluding remarks are in Sect. 5.

2 Monetary policy regimes in CEE

Despite their shared legacy of central planning, CEE countries adopted different policies to deal with the macroeconomic imbalances they faced since the beginning of the transition in the early 1990s. In general, three broad monetary policy approaches emerged in CEE countries over the past two decades. The first approach uses an exchange rate peg as a nominal anchor, while the second adopts an inflation target combined with a floating exchange rate. The third approach is characterized by a floating exchange rate without a formal nominal anchor.

The introduction of market reforms in the early 1990s led to a rapid increase in inflation and exchange rate devaluation in transition economies. In response, the Czech Republic, Slovakia, Hungary, Poland, and Latvia pegged their respective currencies to the US dollar or to a basket of currencies, while Estonia and Lithuania, which had experienced triple-digit inflation, instituted currency boards. Although the exchange rate-based stabilization policies were highly successful in reducing inflation, they resulted in a real appreciation of the CEE currencies causing severe current-account deficits (Jonas and Mishkin 2004). Between 1997 and 2001, the Czech Republic, Hungary, and Poland abandoned their currency pegs and adopted inflation targets as a new nominal anchor (Orlowski 2005). As these countries were able to moderate their inflation rates, Bulgaria and Romania, which were relatively slow in implementing painful structural reforms, experienced a major financial crisis in 1996–1997, which led to triple-digit inflation.

By the end of the 1990s, as most major CEE countries were moving toward floating exchange rates, Bulgaria opted for a currency board to achieve price stability thereby joining Estonia and Lithuania. In contrast, Romania introduced inflation targeting in 2005. After giving up its currency peg, Slovakia joined Slovenia as the only CEE countries with a floating exchange rate but with no formal nominal anchor. However, as Frommel and Schobert (2006) discuss, while Slovakia followed implicit inflation targeting with a significant amount of discretion, Slovenia switched from monetary targeting to a two-pronged approach of adjusting interest rates and exchange rate interdependently to achieve price stability during the period around the EU accession.

The requirement of nominal convergence between EMU members and accession countries in the Maastricht Treaty makes it difficult for monetary authorities in CEE to fulfill the price stability and exchange rate stability criteria simultaneously. Consequently, monetary policy can either maintain a fixed exchange rate, risking a sustained inflation differential, or target inflation but expect a nominal exchange rate appreciation (Buiter 2005). De Grauwe and Schnabl (2005) show that CEE countries with flexible exchange rates and inflation targets could achieve a smoother entry into the eurozone because they can target the inflation level set by the Maastricht Treaty while allowing an appreciation of their currency within the Exchange Rate Mechanism II (ERM II) band. This could be further facilitated by adopting relative inflation-forecast targeting aimed at a dynamic reduction in inflation-forecast differentials between the accession countries and the eurozone and by setting a realistic ERM II reference exchange rate with a wide band (Orlowski 2008, 2010).

In contrast, countries with pegged currencies or currency boards would take much longer to converge to inflation levels required for entry into the eurozone and would have to follow policies of fiscal restriction, which are tighter than necessary (Lewis 2009). However, Estonia, which became the most recent member of the eurozone and the first with a currency board, demonstrated that this scenario is not impossible, even though the country was one of the most adversely affected by the global economic crisis. This resolve to join the eurozone is further resonated in the adjustments carried out by two other Baltic states, Latvia and Lithuania, in the face of the recent global economic crisis.[10]

Despite the differences in monetary policy approaches, the new EU member countries of CEE were unified in pursuing the objective of price stability in their attempts to join EU and adopt the euro for most part of the sample period we have considered here. It may be noted that in the wake of the recent global economic crisis, differences have appeared in their desire and resolve to join the eurozone. While some countries like Hungary are exploiting the flexibility of being outside the eurozone to cope with the crisis, others like Bulgaria, Latvia, and Lithuania, have chosen harder adjustments without compromising on their determination to join the eurozone. However, there has also been some reluctance among the current eurozone members for any further expansion.

3 Data and methodology

3.1 Data

We obtain annual data on consumer price index (CPI) inflation for the period 1990–2009 from the IMF's *International Financial Statistics*.[11] The sample includes the eight CEE countries that joined the EU in 2004: Czech Republic, Estonia, Hungary,

[10] For a detailed discussion, see Purfield and Rosenberg (2010).

[11] The choice of annual over monthly inflation rates is dictated by the fact that the ECB evaluates the progress toward inflation convergence of an EMU candidate country by examining the annual inflation rate over the previous year.

Latvia, Lithuania, Poland, Slovakia, and Slovenia, as well as Bulgaria and Romania, which became EU members in 2007. While assessing whether a member state is ready to join the eurozone, the ECB focuses on inflation measures based on the Harmonized Indices of Consumer Prices (HICP) rather than on CPI inflation. Eurostat, the statistical office of the EU, calculates HICP using a unified methodology applied to all EU member countries. In contrast, CPIs are reported by the respective national statistical agencies that might use slightly different definitions in certain instances. However, HICP data are available only since 1997 and, therefore, their use would significantly restrict our analysis of inflation dynamics, particularly during the early years of transition. Furthermore, the differences between the two measures have diminished over time as the national statistical agencies have adopted the HICP standards for their CPIs.[12]

3.2 Methodology

The focus of our analysis is on the dynamics of inflation in the new EU member countries of CEE relative to the EMU benchmark over the period 1990–2009. For this purpose, we define relative inflation as the difference between the inflation in a given CEE country and the benchmark inflation. Following the relevant EMU convergence criterion, we calculate the benchmark as the average of the annual nonnegative inflation rates of the three best performing (i.e., with lowest inflation) EU member countries plus 1.5 % points.[13] Accordingly, a relative inflation rate that equals or is less than zero indicates that the EMU accession country has fulfilled the inflation/price stability criterion set in the Maastricht Treaty. Convergence to the EMU accession standard is thus defined in our model as the movement of relative inflation in CEE countries toward zero over time.

Figure 1 displays the average of relative inflation rates in CEE countries over the sample period. There was a large gap between the average inflation rate in CEE and the EMU accession benchmark in the early 1990s that reflects corrective price changes associated with sweeping price and trade liberalization as well as substantial exchange rate depreciation. However, since 1992 there was a clear downward trend in relative inflation—mostly due to the success of structural reforms and stabilization policies—which bottomed out in 2003 just before the EU accession of the first group of CEE countries.[14] In fact, average relative inflation in 2003 was below zero, i.e., average inflation was below the benchmark, thanks to the extremely low inflation in the Czech Republic, Poland, and Estonia. However, this trend was reversed after 2004, although

[12] We replicate our analysis for the 1997–2009 period using HICP data and find that our results and conclusions remain robust across the two inflation measures. The results of the HICP analysis are not reported in the article to save space but are available from the authors upon request.

[13] As mentioned in the introduction, previous studies on relative inflation in CEE often use Germany as numeraire given its reputation for low inflation. However, for most of the 1990s Germany was not among the three EU member countries with the lowest rates of inflation. Austria, the Netherlands, and France often appeared to be among the lowest inflation countries.

[14] For a discussion on the events of the 1990s that contributed to inflation movements in CEE, see Backe et al. (2002).

Fig. 1 Average relative inflation of CEE accession countries, 1990–2009. The *line* at the origin represents the EU accession benchmark which is measured as the average of the inflation in the three EU member countries with the lowest inflation plus 1.5 %. A relative inflation of zero or less indicates that the CEE countries have on average fulfilled the EU accession criteria on inflation

the deviation in CEE inflation from the benchmark remained relatively small. This reflects a credit boom across CEE that peaked before the global financial crisis hit the region in late 2008 and early 2009. The inflation was also fueled by a surge in oil and food prices that affected almost all economies around the world. The trend was abruptly reversed in 2009 as the global financial crisis caused average inflation in CEE to drop to its lowest level since the beginning of the transition.

The existing literature addresses the issue of inflation convergence between CEE and EU countries using methods that have been extensively used in the empirical growth literature. For example, Kocenda et al. (2006) and Figuet and Nenovsky (2006) employ the concept and methodology of β-convergence to study inflation convergence in CEE.[15] Others address this issue by examining if the stochastic shocks that cause inflation differentials across countries are temporary in nature and would thus have no effect on inflation convergence in the long run (Kutan and Yigit 2004; Drine and Rault 2006; Siklos 2010). The presence of this stochastic convergence is usually investigated by testing for stationarity of the inflation differential series using unit root tests. Further, the use of cointegration tests helps detect a common stochastic trend which is interpreted as evidence of convergence. However, the power of the standard unit root/cointegration tests is often low in small samples and therefore the results obtained are suspect. Some studies resort to panel unit root/cointegration tests to make up for

[15] Early studies in the area of growth empirics tested for the existence of a negative relationship between the average income growth over a period of time and the initial level of income which came to be known as β-convergence (Barro and Sala-i-Martin 1992).

lack of power in univariate unit root tests. But panel test procedures have their own problems.[16]

In this article, we use a completely different method: a nonparametric technique to study inflation dynamics in the new EU member countries of CEE relative to EMU benchmark inflation. Following Quah (1996b, 1997), we use kernel density estimates to examine the shape of the distribution of relative inflation in CEE and transition probability functions to investigate distributional dynamics and intradistributional mobility. The main argument in favor of this approach to income/inflation convergence is that while the standard econometric techniques focus on the first (β-convergence) and second (σ-convergence) moments of the income/inflation distribution and thus describe the dynamics of a representative economy, the distribution dynamics approach characterizes the evolution of the entire income distribution over time.[17] This methodology enables us to simultaneously detect and analyze (1) shifts of the distribution of CEE inflation rates relative to the EMU benchmark, (2) intradistributional convergence, and (3) the stratification into different convergence clubs within CEE. Furthermore, this methodology is particularly suitable for the study of relative inflation convergence in CEE because of the heterogeneity across transition economies. To the best of our knowledge, Beck and Weber (2005) is the only article that has ever applied distribution dynamics to explore inflation convergence. They focus on inflation convergence across regional economies in six EMU member countries.

The first step of the analysis involves estimating a probability density function of relative inflation using a kernel function. Let $X_1, \ldots, X_n$ be a sample of n independent and identically distributed observations on a random variable X. The density value $f(x)$ at a given point x is estimated by the following kernel density estimator:

$$\hat{f}(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \tag{1}$$

where h denotes the bandwidth of the interval around x and K is the kernel function.[18] The kernel estimator assigns a weight to each observation in the interval around x with the weight being inversely proportional to the distance between the observation and x. The density estimate consists of the vertical sum of frequencies at each observation. The resulting smooth curve allows us to visualize the shape of the distribution of relative inflation and detect the presence of "convergence clubs" represented by modes.

The next step of the analysis is to study the dynamics of the inflation distribution and the intradistributional mobility of CEE countries by estimating a transition probability matrix. Let Q_t denote the distribution of relative inflation across CEE countries at time t. The distribution at time $t + 1$ is then described by:

[16] For a general discussion, see Baltagi (2005). Mark and Sul (2008) also discuss some issues related to the use of panel unit root test in the study of real exchange rate.

[17] For details, see Quah (1993a,b, 1996a,b,c, 1997).

[18] We use data-driven bandwidth selection and a Gaussian kernel.

$$Q_{t+1} = M \times Q_t \tag{2}$$

where M is a finite discrete first-order Markov transition matrix that contains a complete description of the distributional dynamics as it maps Q_t into Q_{t+1}. The transition matrix is given by

$$M = \begin{pmatrix} p_{11} & \cdots & p_{1N} \\ \vdots & \ddots & \vdots \\ p_{N1} & \cdots & p_{NN} \end{pmatrix} \tag{3}$$

where p_{ij} with $i, j = 1, .., N$ is the probability of a transition from an initial state i at time t to a state j at time $t + 1$. The main diagonal of the matrix consists of the probabilities that an observation remains in the same state in $t + 1$ as in t.

Assuming that the transition probabilities from t to $t + 1$ are time-invariant and independent of any previous transitions, the evolution of intradistributional mobility can be studied by iterating Eq. (2) k times. As $k \to \infty$, the iteration yields

$$\lim_{k\to\infty} M_j^k = \delta_j > 0, \sum_j \delta_j = 1 \tag{4}$$

The limiting probability distribution, δ_j, is the unconditional or ergodic distribution.[19] In other words, Eq. (4) describes the convergence to a steady-state distribution independent of the initial distribution. Accordingly, the ergodic distribution allows us to analyze the long run tendencies of inflation in CEE countries relative to the EMU accession benchmark assuming that the observed dynamics continue to hold.

The transition probability matrix approach has two major drawbacks that might distort the distributional dynamics. First, it uses continuous data on relative inflation to estimate a discrete model. Second, the discretization of the state space into states i and j, with $i, j = 1, \ldots, N$ is somewhat arbitrary. To avoid these potential issues and test for the robustness of the results, we focus—in the third step of our analysis—on transition probabilities in a continuous state space and, following Quah (1997), estimate a stochastic kernel that maps the distribution Q_t into $Q_{t+\tau}$ as follows:

$$Q_{t+\tau}(x_{t+\tau}) = \int g(x_{t+\tau}|x_t) Q_t(x_t) dx \tag{5}$$

where the conditional density function $g(x_{t+\tau}|x_t)$ describes the probability of the transition to a certain state in $t + \tau$ given the initial state in t. In line with Hyndman et al. (1996), the conditional density is estimated using a kernel estimator given by

$$\hat{g}(x_{t+\tau}|x_t) = \frac{\hat{z}(x_{t+\tau}, x_t)}{\hat{f}(x_t)} \tag{6}$$

[19] The ergodic distribution is unique if there is only one eigenvalue of M with modulus one.

where $f(x_t)$ is the marginal density from Eq. (1) and $z(x_{t+\tau}, x_t)$ is the joint density given by

$$\hat{z}(x_{t+\tau}, x_t) = \frac{1}{nhb} \sum_{i=1}^{n} K\left(\frac{x_{t+\tau} - X_{i,t+\tau}}{b}\right)\left(\frac{x_t - X_{it}}{h}\right) \tag{7}$$

with h and b denoting the bandwidth of the interval around x_t and $x_{t+\tau}$ respectively. The visual representation of the stochastic kernel produces three-dimensional graphs and two-dimensional contour plots. Like a Markov transition matrix, the main diagonal in these graphs indicate a lack of mobility across states.

4 Empirical results

The kernel density distribution of relative inflation for different years of the sample period is presented in Fig. 2. At the beginning of market transition in 1990, two distinctive modes are observed. The mode at lower levels of relative inflation (larger peak) represents those CEE countries (larger in number) that were yet to introduce price liberalization. In contrast, the larger mode (smaller peak) represents the few frontrunners in market reforms, such as Poland and Slovenia, which were already experiencing high inflation. By the mid 1990s, all CEE countries in the sample had liberalized their prices, leading to higher average relative inflation illustrated by the marked shift of the distribution to the right. While inflation was rising for most countries, it was already falling in case of the early reformers. The concentration of the probability mass around the mean value of 2.8 in 1995 indicates that there was convergence in relative inflation within a group of CEE countries. This process was reversed by 2000 as some countries, such as Bulgaria and Romania, experienced financial crises accompanied by hyperinflation, while others, including the Baltics and the Czech Republic, recorded their lowest relative inflation in a decade. This intradistributional divergence is reflected in a widening of the distribution for the year 2000.

The graphs for 2004 and 2005 in Fig. 2 show that in the year following the EU accession of the first eight CEE countries, there was a significant shift of the distribution to the left, indicating inflation convergence of the CEE toward the EMU accession benchmark. In fact, the 2005 distribution exhibits a single peak at the benchmark value, which also suggests that there was inflation convergence among CEE countries. However, this situation did not last long as the global financial crisis reached the region by the second half of 2008 and affected some economies, such as Hungary and Latvia, more severely than others. The divergence in inflation between those economies that weathered the crisis without serious implications and those devastated by it is illustrated in the widening of the 2009 distribution that resembles the situation in 2000.

While the graphs in Fig. 2 are snapshots of the kernel density distribution in a given year, the evolution of the distribution of relative inflation over the entire sample period is presented in Fig. 3. Two general trends are clearly visible. First, there is convergence in inflation within CEE, as indicated by the gradual transition from a multimodal distribution with a high variance in the early 1990s to a single peak in the

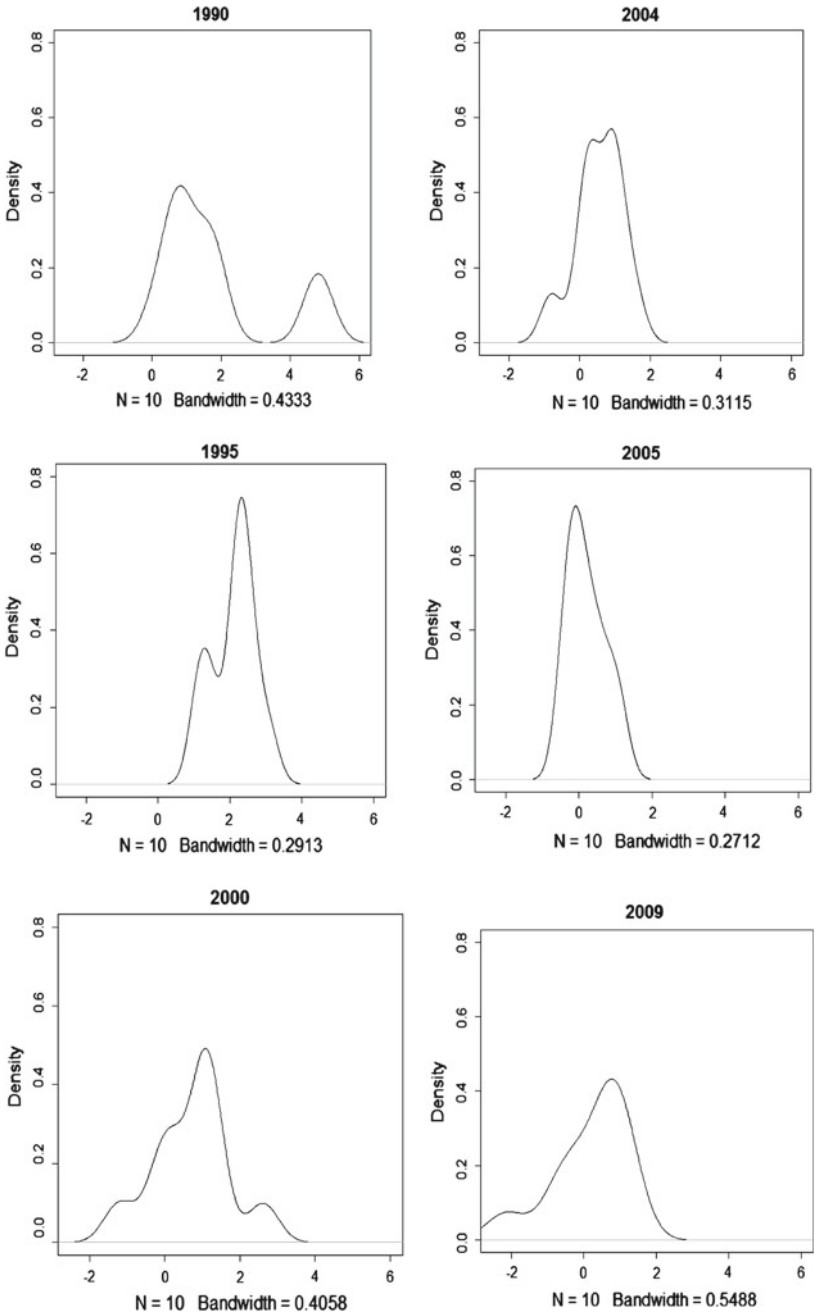

Fig. 2 Density probability distributions of relative inflation in CEE

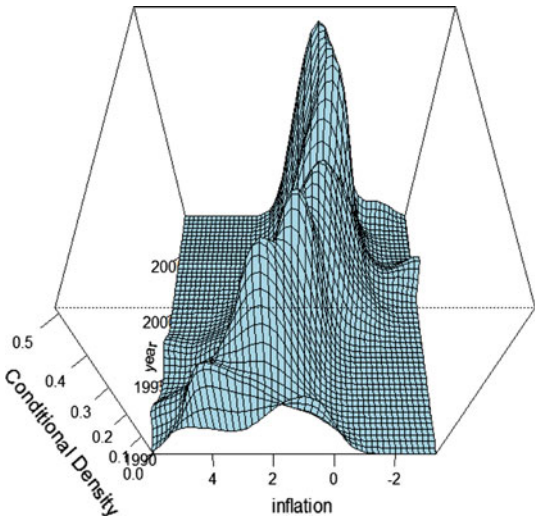

Fig. 3 Distribution dynamics of relative inflation, 1990–2009

mid 2000s. Second, the gradual shift of the distribution toward zero mean suggests that mean relative inflation has been declining over the sample period which is a sign of convergence in inflation between the new EU member countries of CEE and the EMU accession benchmark. Not surprisingly, this shift appears to have been more intense between the late-1990s when the EU accession negotiations began and the mid-2000s when actual accession took place.

We further investigate the dynamics of inflation in the CEE countries vis-à-vis the EMU benchmark by examining the Markov transition matrix as shown in Table 1. This matrix describes the transitions of countries from one state to another over the sample period(s) within the distribution of relative inflation. In line with the literature, we discretize the state space into four intervals chosen in such a way that each interval contains an approximately equal number of transitions. The four intervals can be interpreted as representing states in which inflation is (1) at or below the EMU accession benchmark, (2) slightly above the benchmark, (3) moderately (1–2 %) exceeding the benchmark, and (4) far exceeding the benchmark, respectively. Each cell in a given row of the matrix in Table 1 shows the probability of a transition from the initial state to one of the four states. The values along the diagonal represent the cases in which relative inflation remains in the same interval (state) from one period to the next, and are thus indicative of inflation persistence. Probabilities are estimated for transitions over 1- and 5-year horizons to test for robustness of the results.[20]

The probabilities for annual transition along the diagonal of the first matrix of Table 1 are higher than those off the diagonal. This is an indication of persistence in

[20] The fact that Bulgaria and Romania joined the EU in 2007 causes sample heterogeneity that may have consequences for the empirical analysis. We, therefore, re-generate the 1-year and 5-year transition matrices for the sample without these two countries. Although the estimated transition probabilities are not exactly the same, the differences are insignificant and they are qualitatively not different. This suggests that our results are robust to the sample heterogeneity caused by the late accession of Bulgaria and Romania.

Table 1 Markov transition matrices and ergodic distributions, 1990–2009

	[−3.34; 0.40)	[0.40; 1.10)	[1.10; 2.18)	[2.18; 5.96]	*q*
1-year transitions, 1990–2009					
[−3.34; 0.40)	0.75	0.23	0.00	0.02	48
[0.40; 1.10)	0.28	0.49	0.15	0.09	47
[1.10; 2.18)	0.06	0.27	0.60	0.06	48
[2.18; 5.96]	0.00	0.04	0.17	0.79	47
q	52	49	44	45	190
Ergodic	0.36	0.27	0.18	0.19	
	[−3.34; 0.70)	[0.70; 1.33)	[1.33; 2.39)	[2.39; 5.95]	*q*
5-year transitions, 1990–2009					
[−3.43; 0.70)	0.58	0.34	0.03	0.05	38
[0.70; 1.33)	0.63	0.32	0.05	0.00	38
[1.33; 2.39)	0.43	0.32	0.22	0.03	37
[2.39; 5.95]	0.16	0.30	0.35	0.19	37
q	68	48	24	9	150
Ergodic	0.57	0.33	0.06	0.04	

q represents the number of transitions that the countries have made from an initial state to a different state along the rows as well as the columns

relative inflation among the EU accession countries during the sample period. Furthermore, the fact that the two highest values occur in the upper-left and the lower-right cells suggests that the countries with inflation below the EMU accession benchmark and those with inflation far exceeding the benchmark were most likely to remain in those states from one year to the next. In the middle of the distribution, countries would not make a transition to a different state of relative inflation in more than half of all cases. There was a 28 % chance that CEE countries with inflation slightly above the benchmark would end up in a state with a lower inflation closer to the benchmark. The countries with inflation moderately above the benchmark were likely to make a transition to a level closer to the benchmark in one-third of the cases. In contrast, the probability of experiencing higher inflation than in the initial state (with slightly or moderately above benchmark inflation) was much lower. These results are indicative of a tendency among CEE countries, except for those with very high inflation, to converge in inflation toward the benchmark. The estimated ergodic distribution, shown at the bottom of the matrix, confirms this trend in the long run. It points to a right-skewed distribution, which means that in about two-thirds of cases CEE countries would tend to have relative inflation rates that are either below, exactly at, or slightly above the EMU benchmark.

To test for robustness of these findings and control for cyclical fluctuations, we also include a matrix for 5-year transitions over the entire sample period in Table 1. The tendency for inflation to converge toward the EMU benchmark over the 5-year horizon is stronger than for annual transitions. There was only a 20 % chance that countries experiencing moderate or high inflation would remain in the same states.

These countries had a 60–80 % chance of moving toward the EMU benchmark inflation, while the ones that were initially below or at the EMU benchmark had an almost 60 % chance of remaining at these levels. The ergodic distribution is again skewed to the right with 90 % of all cases achieving inflation very close to or below the accession benchmark.

The results for the ergodic distribution are based on the assumption that the distributional dynamics over the entire sample period remains the same in the long run, which could be misleading given the volatility associated with transition in CEE, especially in the early-1990s. To see if this assumption has any significant influence on the results, we construct separate Markov transition matrices for three subperiods: 1990–1997, 1997–2004, and 2004–2009. Additionally, we consider the period of recent global economic crisis, i.e., 2007–2009. The choice of these subperiods is not entirely ad hoc. For example, the first subperiod marks the initial years of transition when CEE countries were facing serious imbalances in the process of implementing structural changes and market reforms. The second subperiod coincides with the years when CEE countries applied for EU accession and eight out of ten countries formally joined the EU. During these years, there were important shifts in monetary policy regimes as discussed in Sect. 2 and the CEE countries were focused on adoption of and harmonization with EU standards. The third subperiod represents the years after the EU accession, when CEE countries were trying to satisfy the Maastricht criteria for euro adoption. Finally, the subperiod 2007–2009 is the period of global economic crisis that affected the CEE countries as well.

The matrices for these subperiods are presented in Table 2. The annual transitions over the period 1990–1997 reveal convergence tendencies within the distribution but away from the EMU accession benchmark. The countries with the lowest initial inflation were more likely to experience higher levels of inflation in the following year than to stay close to the benchmark. Those with highest levels of relative inflation exhibited a higher probability of persistence in the initial state and, to a lesser degree, were likely to transition to the next lower state which was still distant from the benchmark. The intradistributional mobility during this early period of transition in CEE results in an ergodic distribution that seems almost uniform. CEE countries were approximately as likely to experience inflation rates close to the benchmark as to inflation rates of 3–6 % above the benchmark.

The transition matrix for the period 1997–2004 in Table 2 presents a different picture. There is high persistence of relative inflation at both ends of the distribution. However, in the middle of the distribution, CEE countries were almost as likely to move to lower levels of inflation in the following year as to stay at the initial levels. This is an indication of convergence toward the lower end of the distribution that represents the interval around the EMU accession benchmark. The ergodic distribution lends further support to this finding as it is skewed to the right with almost 70 % probability of inflation being sufficiently close to fulfilling the EMU accession requirement. Thus, this subperiod that coincides with the EU accession of the first group of CEE countries exhibits strong tendency for convergence toward the EMU benchmark.

During the period between EU accession and the start of the global economic crisis, relative inflation remained low compared to previous periods; however, intradistributional transitions exhibit different dynamics, as revealed by the third matrix of Table 2.

Table 2 Markov transition matrices and ergodic distributions by subperiod

State	[0.12; 1.70)	[1.70; 2.30)	[2.30; 3.30)	[3.30; 5.95]	*q*
1-year transitions, 1990–1997					
[0.12; 1.7)	0.44	0.17	0.11	0.28	18
[1.70; 2.30)	0.39	0.61	0.00	0.00	18
[2.30; 3.30)	0.12	0.24	0.47	0.18	17
[3.30; 5.95]	0.00	0.06	0.41	0.53	17
q	17	19	17	17	70
Ergodic	0.25	0.29	0.23	0.23	
State	[−3.35; 0.10)	[0.10; 0.80)	[0.80; 1.30)	[1.30; 5.95]	*q*
1-year transitions, 1997–2004					
[−3.35; 0.10)	0.59	0.24	0.17	0.00	17
[0.10; 0.80)	0.39	0.44	0.17	0.00	18
[0.80; 1.30)	0.00	0.44	0.44	0.12	18
[1.30; 5.95]	0.06	0.06	0.24	0.64	17
q	17	21	18	13	70
Ergodic	0.34	0.34	0.24	0.08	
State	[−2.14; 0.00)	[0.00; 0.40)	[0.40; 0.90)	[0.90; 1.55]	*q*
1-year transitions, 2004–2009					
[−2.14; 0.00)	0.50	0.33	0.17	0.00	12
[0.00; 0.40)	0.42	0.25	0.25	0.08	12
[0.40; 0.90)	0.15	0.00	0.38	0.47	13
[0.90; 1.55]	0.15	0.07	0.38	0.38	13
q	15	8	15	12	50
Ergodic	0.30	0.15	0.30	0.25	
State	[−2.14; 0.13)	[0.13; 0.60)	[0.60; 1.00)	[1.00; 1.33]	*q*
1-year transitions, 2007–2009					
[−2.14; 0.13)	0.60	0.20	0.20	0.00	5
[0.13; 0.60)	0.40	0.20	0.40	0.00	5
[0.60; 1.00)	0.17	0.17	0.49	0.17	6
[1.00; 1.33]	0.00	0.25	0.25	0.50	4
q	6	4	7	3	20
Ergodic	0.34	0.19	0.35	0.12	

At the low end of the distribution, there was an equal chance of staying at the initial level or moving to the higher levels. At the other end, the probability of staying at the same level and that of transitioning to the next lower interval were the same. In contrast, countries with inflation slightly higher than the benchmark were more likely to move downward, whereas those with inflation moderately higher than the benchmark

had a higher chance of moving upward. These trends are reflected in the bimodal ergodic distribution that indicates a divergence in relative inflation between two groups of CEE countries.

A closer look at the years 2007–2009 suggests that the global economic crisis has indeed magnified the polarization in inflation rates. The last matrix in Table 2 shows that countries at or below the benchmark have a high probability of moving toward higher levels of relative inflation. At the same time, those furthest away from the benchmark exhibit high probability of converging closer to it. However, in the middle of the distribution countries have almost equal probability of moving toward both ends of the distribution. Thus, the ergodic distribution is bimodal with one mode around the benchmark and a second one moderately above it.

As we discussed in the previous section, one of the concerns with Markov transition matrix is that the state space is divided into arbitrary discrete intervals. Given that inflation is a continuous variable, it would be useful to test for robustness of the results by estimating transition probabilities in a continuous state space. The resulting stochastic kernels of annual and 5-year transitions for the entire sample period are presented in Fig. 4. The vertical dimension of the three-dimensional graph measures the conditional probability of a country experiencing relative inflation of x % in $t+1$, given that it had a relative inflation rate of y % in year t. As with the Markov transition matrix, peaks along the main diagonal indicate high persistence of relative inflation and lack of intradistributional mobility. Figure 4 also includes contour plots that provide a two-dimensional view of the distributions, where the contours represent points of equal frequency.

The stochastic kernel of annual transitions in Fig. 4 indicates that a large portion of the probability mass in the middle of the distribution is clustered around the main diagonal. However, there are signs of mobility at both ends of the distribution. At lower levels of relative inflation, a peak above the main diagonal suggests that countries with initial inflation below the accession benchmark experienced higher inflation rates in the following year, but these were still clustered around the benchmark. At the high end of the distribution, a very pronounced mode can be observed below the main diagonal, indicating that countries with initial inflation far exceeding the benchmark were likely to achieve a slightly lower inflation in the following period, thus moving closer to the benchmark. Over a 5-year horizon, these convergence tendencies intensify as illustrated by the lack of concentration along the main diagonal of the contour plot. Countries with initial inflation levels below the benchmark have a very high probability of ending up clustered at or slightly above the benchmark. On the other hand, those with moderate to high initial relative inflation are also very likely to converge toward the same level close to the benchmark after a 5-year period.

The convergence tendencies toward the benchmark shown in Fig. 4 concur broadly with the results from the Markov transition matrices in Table 2, even though it is obvious that the stochastic kernels provide a more detailed picture of intradistributional mobility that is obscured by the somewhat arbitrary discretization of the state space in the transition matrix.[21]

[21] For instance, the Markov transition matrix in Table 2 treats relative inflation ranging from 2.18 to 5.96 % in a single interval and indicates persistence of almost 80 %. The stochastic kernel shows that countries

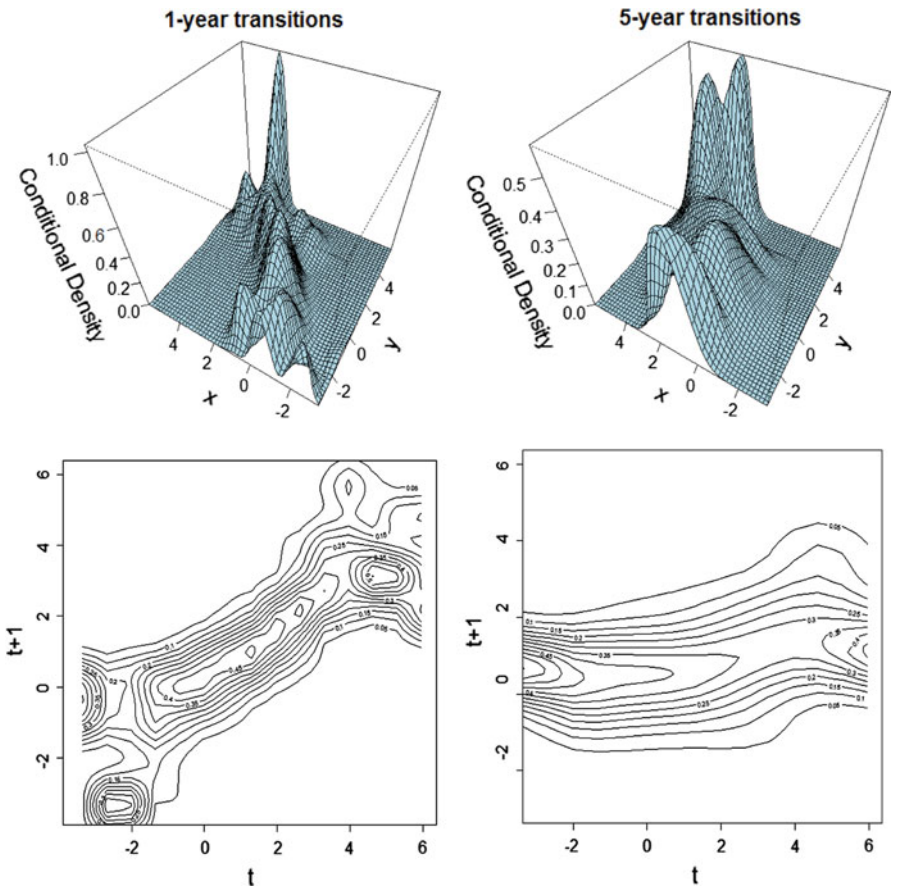

Fig. 4 The stochastic kernel of relative inflation dynamics, 1990–2009. x and y denote the relative inflation of CEE countries in year $t+1$ and t, respectively. The conditional density function $g(x_{t+1}|x_t) = g(y|x)$ is plotted on the *vertical axis*

The stochastic kernels for the four subperiods presented in Fig. 5 reflect very different dynamics. For the first period up to 1997, the probability mass is widely spread above and below the main diagonal. While a high probability density above the diagonal indicates a divergence away from the benchmark, clustering of probability mass below the diagonal reflects a tendency for convergence in relative inflation toward the benchmark. This is largely in line with the corresponding ergodic distribution in Table 2, which is almost uniform across the four states. Furthermore, the stochastic kernel reveals comparatively high persistence at the level of 2 % and a high probability of downward mobility at initial inflation levels above 5 %.

Footnote 21 continued
with initial inflation of between 4 and 6 % have a high probability of achieving inflation levels of around 3 % in the following year.

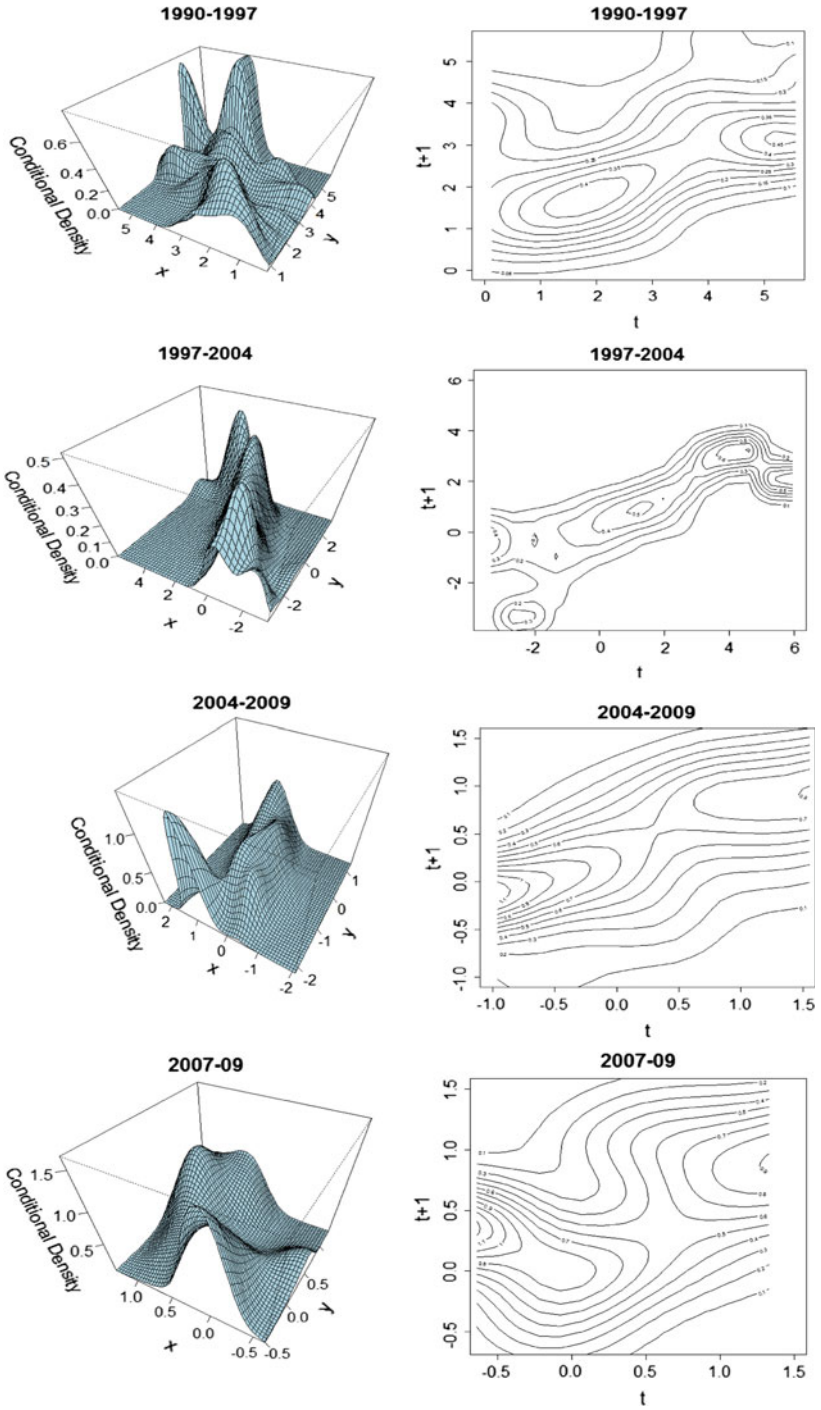

Fig. 5 Annual transitions of relative inflation by subperiod

In the subsequent period preceding the EU accession of 2004, the volatile intradistributional mobility largely disappeared and the probability mass is now clustered around the main diagonal. High persistence of relative inflation can be detected at around 1 % and to a smaller extent at 4 %. However, mobility is visible at both ends of the distribution. As we can see from the contour plot for 1997–2004, at initial levels of relative inflation above 5 %, there is a probability of more than 60 % that a country would move to a relative inflation of <2 %, indicating strong convergence toward the EMU benchmark. Furthermore, at initial levels lower than 0 %, there is a tendency to move closer to the benchmark with a probability of around 40 %.

After 2004, intradistributional mobility increased again, as illustrated by the spread of contour lines over the entire plot. It is obvious that the dynamics resulted in a thinning of the distribution in the middle and an accumulation at each of the tails. The emergence of two modes, one around the benchmark and the second at around 1.5 % of relative inflation, corresponds to the bimodal ergodic distribution for 2004–2009 reported in Table 2. The stochastic kernel and the contour plot for the years 2007–2009 illustrate that the two modes have come further apart indicating the increased polarization in relative inflation caused by the global economic crisis.[22]

In summary, the inflation dynamics in ten new EU member countries of CEE during the past two decades can be characterized by dividing this period into three phases. In the first phase spanning from 1990 to the late 1990s, these countries seemed to be clustered around two different levels of inflation that largely reflect differences in timing and speed of market reforms. The second phase that coincides with the process of EU accession witnessed a strong tendency for inflation convergence among these EU accession countries toward the EMU benchmark, This result is consistent with the findings of some previous studies (e.g., Becker and Hall 2009; Kocenda et al. 2006; Palomba et al. 2009) and seems to indicate that these countries made concerted efforts to meet the preconditions for accession. The third phase that covers the post-accession period is marked by a tendency among some countries to converge in inflation toward the EMU benchmark while the others diverging away from the benchmark but clustering among themselves. These tendencies seem to reflect the differences in economic performances and in adjustments to the global economic crisis among the CEE countries in recent times.

5 Concluding remarks

Following a tumultuous transition, ten CEE countries succeeded in becoming EU members and must meet the Maastricht convergence criteria before adopting the euro. This article focuses on the price stability criterion and examines the inflation dynamics in the ten new EU member countries of CEE from the beginning of transition in 1990 to the recent global economic crisis. We employ nonparametric methods to investigate

[22] To verify if the shifts in the distributions over time as revealed in our analysis are statistically significant, we conduct a formal test of the equality of distributions for various pairs of years over the sample period. In particular, we use the test procedure proposed by Li et al. (2009). The test results are consistent with our findings. In the interest of saving space, we do not report the test results in the article. Interested reader may obtain these results from the authors.

convergence toward the EMU accession benchmark as well as inflation convergence among these new EU member countries of CEE. Our findings suggest that, over the past two decades, there was, in general, a decisive shift of the distribution of CEE inflation rates toward the EMU reference level, which was accompanied by intradistributional convergence within the CEE sample. However, these convergence tendencies were not uniform. In the early period of transition when the speed and composition of economic reforms differed across CEE, inflation rates were almost as likely to move closer to the benchmark as they were to diverge from it, resulting in a multimodal distribution. In the years leading up to the EU membership, increasing economic stability and the common objective of EU accession in CEE were reflected in the emergence of a unimodal distribution of inflation rates, which shifted closer to the EMU benchmark. In more recent years, differences in the economic performance across CEE became apparent and were magnified by the global economic crisis causing a stratification of inflation rates into two convergence clubs. In addition, the divergence in inflation rates within CEE occurred simultaneously with convergence of certain countries toward the EMU inflation benchmark, which is an indication that only a select few will be successful in their bid to join the EMU in the near future.

Following their EU accession, most CEE countries established target dates for their adoption of the euro. However, the global economic crisis has put the EMU accession on hold. The ballooning budget deficits and currency fluctuations in most of these countries have made it harder to fulfill the Maastricht criteria. As a strategy to cope with the crisis, some of these countries like Hungary have exploited the flexibility of fiscal and monetary policy outside the eurozone, thus deliberately postponing their accession. In contrast, countries with currency boards such as Bulgaria, Lithuania, and Latvia (and Estonia before joining the euro) have chosen to implement brutal internal devaluations with the sole objective that they would not lose their peg to the euro and stray too far away from the Maastricht criteria.[23] They have postponed their entry into the eurozone only reluctantly and only after a strong resistance from the eurozone countries against any further expansion. The debt crisis in Greece and other eurozone countries has made the EMU more reluctant to admit new members, and it is likely to be more stringent about accession countries fulfilling the Maastricht convergence criteria before they could be admitted. It is in this context that it would be interesting to see how inflation dynamics evolve in these new EU member countries of CEE, particularly the ones that are yet to join the eurozone, over the next few years. The results from our analysis of the crisis years are only indicative. We will have to wait until sufficient time elapses before we can attempt to conduct a more meaningful analysis of the recent developments that will have significant policy implications for future. Furthermore, it will be interesting to examine the factors underlying the inflation dynamics in these countries so that we can discuss appropriate policy options for sustainable price stability as envisaged in the Maastricht Treaty.[24]

[23] For a detailed discussion on the adjustments in the Baltic states of Estonia, Latvia, and Lithuania, in response to the global economic crisis, see Purfield and Rosenberg (2010).

[24] Egert (2007) discusses some of these underlying factors (including the Balassa–Samuelson effect) for price movements across the EU during the period 1997–2006.

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References

Backe P, Fidrmuc J, Reininger T, Schardax F (2002) Price dynamics in Central and Eastern European EU accession countries. Oesterreichische National Bank Working Paper 61

Baltagi BH (2005) Econometric analysis of panel data, 3rd edn. Wiley, West Sussex

Barro RJ, Sala-i-Martin X (1992) Convergence. J Political Econ 100:223–251

Beck G, Weber A (2005) Price stability, inflation convergence and diversity in EMU: does one size fit all? Center for Financial Studies Working Paper 30

Becker B, Hall S (2009) How far from the Euro Area? Measuring convergence of inflation rates in Eastern Europe. Econ Modell 26:788–798

Brada JC, Kutan A, Zhou S (2005) Real and monetary convergence between the European Union's core and recent member countries: a rolling cointegration approach. J Banking Finance 29:249–270

Buiter W (2005) To purgatory and beyond: When and how should the accession countries from Central and Eastern Europe become full members of the EMU? In: Breuss F, Hochreiter E (eds) Challenges for Central Banks in an enlarged EMU. Springer, New York, pp 145–186

Camarero M, Esteve V, Tamarit C (2000) Price convergence of peripheral European countries on the way to the EMU: A time series approach. Empir Econ 25:149–168

De Grauwe P, Schnabl G (2005) Nominal versus real convergence: EMU entry scenarios for the new member countries. Kyklos 58(4):537–555

Drine I, Rault C (2006) Testing for inflation convergence between the Eurozone and its CEE partners. Appl Econ Lett 13:235–240

Egert B (2007) Real convergence, price level convergence and inflation differentials in Europe. CESifo Working Paper No. 2127

Figuet JM, Nenovsky N (2006) Convergence and shocks in the road to EU: Empirical investigations for Bulgaria and Romania. William Davidson Institute Working Paper 810

Frommel M, Schobert F (2006) Exchange rate regimes in Central and East European countries: deeds vs. words. J Comp Econ 34:467–483

Hyndman R, Bashtannyk D, Grunwald G (1996) Estimating and visualizing conditional densities. J Comput Graph Stat 5:315–336

Jonas J, Mishkin FS (2004) Inflation targeting in transition economies: experience and prospects. In: Bernanke B, Woodford M (eds) The inflation targeting debate. National Bureau of Economic Research, Cambridge

Kocenda E, Kutan A, Yigit T (2006) Pilgrims to the Eurozone: how far, how fast. Econ Syst 30:311–327

Kutan A, Yigit T (2004) Nominal and real stochastic convergence of transition economies. J Comp Econ 32:23–36

Lewis J (2009) Hitting or hoping? Meeting the exchange rate and inflation criteria during a period of nominal convergence. Eur J Political Econ 25(4):508–524

Li Q, Maasoumi E, Racine JS (2009) A Nonparametric test for equality of distributions with mixed categorical and continuous data. J Econom 148:186–200

Mark NC, Sul D (2008) PPP strikes out: the effect of common factor shocks on the real exchange rate. Mimeo. University of Notre Dame

Nath HK, Tochkov, K (2011) Relative inflation dynamics in the EU Accession Countries of Central and Eastern Europe. Bulgarian National Bank Discussion Papers, DP/84/2011

Orlowski LT (2005) Monetary convergence of the EU accession countries to the eurozone: a theoretical framework and policy implications. J Bank Finance 29:203–225

Orlowski LT (2008) Relative inflation-forecast as monetary policy target for convergence to the euro. J Policy Model 30:1061–1081

Orlowski LT (2010) Monetary policy rules for convergence to the Euro. Econ Syst 34:148–159

Palomba G, Sarno E, Zazzaro A (2009) Testing similarities of short-run inflation dynamics among EU-25 countries after the Euro. Empir Econ 37:231–270
Purfield C, Rosenberg CB (2010) Adjustment under a currency peg: Estonia, Latvia and Lithuania during the Global Financial Crisis 2008–09. IMF Working Paper (WP/10/213)
Quah DT (1993a) Galton's fallacy and the convergence hypothesis. Scand J Econ 95:427–443
Quah DT (1993b) Empirical cross-section dynamics in economic growth. Eur Econ Rev 37:426–434
Quah DT (1996a) Convergence empirics across economies with (some) capital mobility. J Econ Growth 1:95–124
Quah DT (1996b) Empirics for economic growth and convergence. Eur Econ Rev 40:1353–1375
Quah DT (1996c) Twin Peaks: growth and convergence in models of distribution dynamics. Econ J 106:1045–1055
Quah DT (1997) Empirics for growth and distribution: stratification, polarization and convergence clubs. J Econ Growth 2:27–59
Siklos P (2010) Meeting Maastricht: nominal convergence of the new member countries toward EMU. Econ Modell 27:507–515