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Following their EU accession, the new member countries from Central and Eastern Europe (CEE) must achieve sustainable price stability as one of the pre-conditions for joining the Economic and Monetary Union (EMU) and adopting the euro. This paper examines the distribution dynamics of inflation rates in ten EU members from CEE relative to the EMU accession benchmark inflation over the period 1990-2009. In contrast to previous studies, we use non-parametric 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 towards 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 towards 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 towards the EMU benchmark. In more recent years, 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.

Relative Inflation Dynamics in the EU Accession 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 pre-conditions for joining the Economic and Monetary Union (EMU) and adopting the euro. This paper examines the distribution dynamics of inflation rates in ten EU members from CEE relative to the EMU accession benchmark inflation over the period 1990-2009. In contrast to previous studies, we use non-parametric 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 towards the EMU benchmark along with intra-distributional convergence. However, this process is not uniform. In the early years, it was equally likely for CEE inflation rates to move towards 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 towards the EMU benchmark. In more recent years, 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.

JEL Classifications: C14; E31; E42; P22

Key words: Inflation; Convergence; EU Accession Countries; Distribution Dynamics

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 other structural reforms aimed at establishing a market economy. Although inflation was tamed by the second half of the 1990s, the start of accession negotiations between CEE countries and the European Union (EU), which coincided with the introduction of the euro in 1999, created new challenges. All new EU member states must eventually join the Economic and Monetary Union (EMU) and adopt the euro as their currency once they fulfill four convergence criteria stipulated in the Maastricht Treaty of 1992 and aimed at ensuring stability of the common European currency. 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 percentage points that of, at most, the three best-performing Member States in terms of price stability."[2]

Accordingly, as the CEE countries stood to join the EU, the prospect of accession to the EMU 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 two of the ten EU accession countries of CEE have managed to fulfill all four criteria and adopt the

[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 EMU was rejected although its inflation rate was just 0.1 percent point above the benchmark.

euro so far illustrates the enormity of the challenge faced by these countries.[4] One of the reasons for their failure to meet this criterion is that during the 2000s CEE countries recorded high growth rates, attracted foreign investment, and experienced a credit boom, all of which fueled inflation. The EMU inflation benchmark based on inflation in mature economies of Western Europe appeared to be too low and rigid for many fast-growing CEE countries. Furthermore, the requirement of nominal convergence between EMU members and accession countries makes it difficult for monetary authorities 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 can target inflation but expect a nominal exchange rate appreciation (Buiter, 2004). Finally, the global economic crisis of 2008-09 put the enlargement of the euro area on hold as budget deficits in CEE countries soared and inflation rates missed the EMU benchmark.[5]

The goal of this paper is to investigate the evolution of inflation rates in ten EU accession countries of CEE relative to the EMU benchmark over the period 1990-2009. In particular, we examine convergence of inflation in CEE towards the EMU benchmark. We also study the dynamics of relative inflation within the group of these accession 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 real interest rates and real wages, which in turn will influence the movements of capital and labor across borders. Previous studies on inflation 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

[4] Slovenia became the first CEE country to adopt the euro in 2007, followed by Slovakia in 2009.
[5] Estonia is set to introduce the euro in 2011 after managing to satisfy all four convergence criteria despite the fact that it has been one of the most adversely affected EU countries by the global economic crisis.

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; 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, the EMU accession of Slovenia and Slovakia, as well as the period of recent global economic crisis.

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. However, their sample period prevents them from investigating relative inflation in the two countries following the EU accession. In many studies on inflation convergence, the EU member countries from CEE are lumped together with other accession countries such as Malta and Cyprus (Kocenda *et al*., 2006; Siklos, 2010) or candidate countries such as Croatia and Turkey (Becker and Hall, 2009) which are either quite different in size than the CEE countries, are not transition economies or do not have the prospect of being admitted to the EU anytime soon. Our sample comprises all ten EU member states from CEE that are obliged to join the EMU and therefore must eventually conform to the price stability criterion.

A 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.[6] In contrast, we employ distribution dynamics, a non-parametric methodology that 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

[6] 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.

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 towards or away from the EMU benchmark.

Furthermore, the benchmark against which CEE inflation rates are evaluated varies across studies. For those focusing on the convergence towards 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 CEE accession 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 mandated by the Maastricht Treaty as the only reference value of importance for the CEE accession countries as it is used by the ECB to evaluate their readiness to join the euro area.[7] However, while previous studies had to use multiple reference values to examine inflation convergence between CEE and EU/EMU and among CEE countries, our methodology enables us to simultaneously detect and analyze 1) shifts of the distribution of CEE inflation rates relative to the EMU benchmark, 2) intra-distributional convergence, and 3) the stratification into different convergence clubs within CEE.

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 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

[7] 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.

most others inflation veered away from the benchmark. 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 paper is organized as follows. The next section discusses the data and the methodology used in this paper. In section 3, we present the empirical results, and the concluding remarks are in section 4.

2. Data and Methodology

2.1 Data

We obtain annual data on consumer price index (CPI) inflation for the period 1990-2009 from the IMF's International Financial Statistics. The sample includes the eight CEE countries that joined the EU in 2004 as well as Bulgaria and Romania, which became EU members in 2007.[8] While assessing whether a member state is ready to join the Euro area, 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 states. 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.

[8] The eight countries that became EU members in 2004 are the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia.

Furthermore, the differences between the two measures have diminished over time as the national statistical agencies have adopted the HICP standards for their CPIs.[9]

Table 1 presents annual consumer price inflation rates in the ten accession countries during 1990 - 2009. We make the following observations. First, in the early stages of transition, almost all CEE countries experienced high and volatile inflation that reflects corrective price changes associated with sweeping price and trade liberalization as well as substantial exchange rate depreciation. Moreover, inflation rates varied widely across the sample. By 1995, all countries were able to reduce inflation to double-digit levels and the cross-country variations also declined substantially, mostly due to the success of structural reforms and stabilization policies.

Second, the moderate rates of inflation achieved by the mid 1990s were persistent in most countries. Negative demand shocks (e.g., lower external demand from the EU and Russia) and positive supply shocks (e.g., falling oil and food prices in the wake of the Asian financial crisis) contributed to the decline in inflation rates during the late 1990s. The downward spiral came to a halt and inflation picked up again in a number of transition countries in 2000. This is attributed to increased demand in the EU and Russia and increases in the price of oil (Backe *et al*., 2002). In contrast to the rest of CEE, Bulgaria and Romania were slow in implementing structural reforms and suffered from hyperinflation in the late 1990s. After experiencing a devastating financial and banking crisis in 1996-97, Bulgaria introduced a currency board and drastically reduced its rate of inflation. However, Romania did not succeed in reducing consumer price inflation to the single-digit level until 2005.

Third, the average inflation rate dropped immediately after the EU accession of the 8 CEE countries in 2004, followed by a gradual increase and a significant spike in 2008. This reflects a

[9] 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 paper to save space but are available from the authors upon request.

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 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.

2.2 Methodology

The focus of our analysis is on the dynamics of inflation in EU accession 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 natural logarithms of inflation in a given CEE country and of 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 states plus 1.5 percent.[10] Accordingly, a relative inflation rate that equals or is less than zero indicates that an 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 towards 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 1990s; however, since 1992 there was a clear downward trend in relative inflation which bottomed out in 2003 just before the accession of the first group of CEE

[10] As mentioned in the introduction, previous studies on relative inflation in CEE have often used 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.

countries. In fact, average relative inflation in 2003 was below zero, that is, 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 the deviation in CEE inflation from the benchmark remained relatively small. The global financial crisis appears to have caused the average CEE inflation rate to converge again towards the benchmark in 2009.

The existing literature addresses the issue of inflation convergence between CEE and EU countries 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).[11] 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 lack of power in univariate unit root tests. But panel test procedures have their own problems.[12] We, therefore, use a completely different method: a non-parametric technique to study inflation dynamics in EU accession countries of CEE relative to EU inflation.[13] Following Quah (1996b, 1997), we use kernel density estimates to examine the shape of the distribution of relative inflation in CEE and

[11] This literature on inflation convergence has its predecessor in the empirical growth literature. 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 became known as β-convergence (Barro and Sala-i-Martin, 1992). Kocenda *et al*. (2006) and Figuet and Nenovsky (2006) employ this methodology to study inflation convergence in CEE.

[12] See Maddala and Wu (1999) for an early critique and see Baltagi (2005) for a general discussion,. Mark and Sul (2008) also discuss some issues related to the use of panel unit root test in the study of real exchange rate.

[13] In a series of seminal papers, Quah (1993a, b, 1996a, b, c, 1997) criticized the standard econometric approaches to income convergence arguing that their focus on the first (β-convergence) and second (σ-convergence) moments of the income distribution describe the dynamics of a representative economy but fail to characterize the evolution of the entire income distribution over time.

transition probability functions to investigate distributional dynamics and intra-distributional mobility. This methodology is particularly suitable for the study of relative inflation convergence in CEE because of the heterogeneity across transition economies.[14] To the best of our knowledge, Beck and Weber (2005) is the only paper that has ever applied distribution dynamics to explore inflation convergence. They focus on inflation convergence across regional economies in six EMU member states.

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:

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

where h denotes the bandwidth of the interval around x and K is the kernel function.[15] 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 intra-distributional mobility of CEE countries by estimating a transition probability matrix. Let

[14] Countries like the Czech Republic or Poland have always been at the forefront of economic reforms and received recognition by being among the first to be admitted in the EU. In contrast, Bulgaria and Romania were relatively slow in implementing painful structural reforms and their EU accession has proved tortuous. The global economic crisis in 2008-2010 further highlighted the differences across CEE. While Hungary, Latvia, and Romania had to be rescued by the IMF, the economy of Poland proved resilient amid the crisis.

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

Q_t denote the distribution of relative inflation across CEE countries at time *t*. The distribution at time *t+1* is then described by:

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

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

$$M = \begin{pmatrix} p_{ij} & \cdots & p_{iN} \\ \vdots & \ddots & \vdots \\ p_{Nj} & \cdots & p_{NN} \end{pmatrix} \tag{3}$$

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* and *t+1*.

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

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

The limiting probability distribution, δ_j, is the unconditional or ergodic distribution.[16] 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.

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

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,...,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

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

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.

3. Empirical Results

The kernel density distribution of relative inflation for different years of the sample period is presented in Figure 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, that 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 intra-distributional divergence is reflected in a widening of the distribution for the year 2000.

The graphs for 2004 and 2005 in Figure 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 towards 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 Figure 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 Figure 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 mid 2000s. Second, the gradual shift of the distribution towards zero mean suggests that mean relative inflation has been declining over the sample period which is a sign of convergence in inflation between the EU accession 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 EU accession countries vis-à-vis the EMU benchmark by examining the Markov transition matrix as shown in Table 2. 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 percent) exceeding the benchmark, and (4) far exceeding the benchmark, respectively. Each cell in a given row of the matrix in Table 2 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.

The probabilities for annual transition along the diagonal of the first matrix of Table 2 are higher than those off the diagonal. This is an indication of persistence in relative inflation among the EU accession countries during the sample period. Furthermore, that the two highest values occur in the upper left and the lower right cell suggest that the countries with inflation below the EMU accession benchmark and those with inflation far exceeding the benchmark were most likely to remain in these categories 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 percent 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 towards 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 2. The tendency for inflation

to converge towards the EMU benchmark over the 5-year horizon is stronger. There was only 20 percent chance that countries experiencing moderate or high inflation would remain in the same states. These countries had a 50-80 percent chance of moving towards the EMU benchmark inflation, while the ones that were initially below or at the EMU benchmark had a 50 percent chance of remaining at these levels. The ergodic distribution is again skewed to the right with two-thirds 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 sub-periods: 1990-1997, 1997-2004, and 2004-2009. These matrices are presented in Table 3. 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 intra-distributional 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 percent above the benchmark.

The transition matrix for the period 1997-2004 in Table 3 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 towards 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 percent probability of inflation being sufficiently close to fulfilling the EMU accession requirement. Thus this sub-period that coincides with the EU accession of the first group of CEE countries exhibits strong tendency for convergence towards 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, intra-distributional transitions exhibit different dynamics, as revealed by the third matrix of Table 3. 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.

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 kernel of annual transitions for the entire sample period is presented in Figure 4. The vertical dimension of the three-dimensional graph measures the conditional probability of a country experiencing relative inflation of x percent in t+1, given that it had a

relative inflation rate of *y* percent in year *t*. As with the Markov transition matrix, peaks along the main diagonal indicate high persistence of relative inflation and lack of intra-distributional mobility. Figure 4 also includes a contour plot that provides a two-dimensional view of the distribution, where the contours represent points of equal frequency.

The stochastic kernel in Figure 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. These convergence tendencies towards the benchmark concur broadly with the results from the Markov transition matrix in Table 2, even though it is obvious that the stochastic kernel provides a more detailed picture of intra-distributional mobility that is obscured by the somewhat arbitrary discretization of the state space in the transition matrix.[17]

The stochastic kernels for the three sub-periods presented in Figure 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 towards the benchmark. This is largely in line with the

[17] For instance, the Markov transition matrix in Table 2 treats relative inflation ranging from 2.18 to 5.96 percent in a single interval and indicates persistence of almost 80 percent. The stochastic kernel shows that countries with initial inflation of between 4 and 6 percent have a high probability of achieving inflation levels of around 3 percent in the following year.

corresponding ergodic distribution in Table 3, which is almost uniform across the four states. Furthermore, the stochastic kernel reveals comparatively high persistence at the level of 2 percent and a high probability of downward mobility at initial inflation levels above 5 percent.

In the subsequent period preceding the EU accession of 2004, the volatile intra-distributional 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 percent and to a smaller extent at 4 percent. 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 percent, there is a probability of more than 60 percent that a country would move to a relative inflation of less than 2 percent, indicating strong convergence towards the EMU benchmark. Furthermore, at initial levels lower than zero percent, there is a tendency to move closer to the benchmark with a probability of around 40 percent.

After 2004, intra-distributional 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 in the middle of the distribution and an accumulation at each of the tails. The emergence of two modes, one around the benchmark and the second at around 1.5 percent of relative inflation, corresponds to the bimodal ergodic distribution for 2004-2009 reported in Table 3.

In summary, the inflation dynamics in ten EU accession 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 towards the EMU benchmark, This result is consistent with the findings of some previous studies (for example, Becker and Hall 2009 and Kocenda et al. 2006) and seems to indicate that these countries made concerted efforts to meet the pre-conditions for accession. The third phase that covers the post-accession period is marked by a tendency among some countries to converge in inflation towards 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 among the CEE countries in recent times.

4. Concluding Remarks

Following a tumultuous transition, ten CEE countries succeeded in becoming EU members and must meet the Maastricht convergence criteria before joining EMU and adopting the euro. This paper focused on the price stability criterion and examined the inflation dynamics in the ten CEE accession countries from the beginning of transition in 1990 to the recent global economic crisis. We employ non-parametric methods to investigate convergence toward the EMU accession benchmark as well as inflation convergence among the CEE accession countries. Our findings suggest that, over the past two decades, there was, in general, a decisive shift of the distribution of CEE inflation rates towards the EMU reference level, which was accompanied by intra-distributional 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 goal 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 towards 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. The global economic crisis only strengthened their resolve to join the EMU. However, increasing difficulties associated with simultaneously sustaining fiscal discipline and achieving price and exchange rate stability have dashed any hope of a quick accession. In addition, 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.

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TABLE 1
Rates of Inflation in CEE Countries: 1990-2009 (average annual percentage changes in CPI)

Year\Countries	Bulgaria	Czech Republic	Estonia	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia	Average	Standard deviation
	1	2	3	4	5	6	7	8	9	10		
1990	23.8	9.7	23.1	29.0	10.5	8.4	555.4	5.1	10.8	551.6	122.7	227.2
1991	338.5	56.6	210.5	34.2	172.2	224.7	76.7	170.2	61.2	115.0	146.0	95.5
1992	91.3	11.1	1,076.0	23.0	243.3	1,020.5	45.3	211.2	10.0	207.3	293.9	407.3
1993	72.9	20.8	89.8	22.5	108.8	410.2	36.9	255.2	23.2	32.9	107.3	128.0
1994	96.1	10.0	47.7	18.9	35.9	72.2	33.3	136.8	13.4	21.0	48.5	41.3
1995	62.1	9.2	28.8	28.3	25.0	39.7	28.1	32.2	9.9	13.5	27.7	15.7
1996	121.6	8.8	23.1	23.6	17.6	24.6	19.8	38.8	5.8	9.8	29.4	33.8
1997	1,058.4	8.6	10.6	18.3	8.4	8.9	15.1	154.8	6.1	8.4	129.7	329.4
1998	18.7	10.6	8.2	14.2	4.7	5.1	11.7	59.1	6.7	7.9	14.7	16.2
1999	2.6	2.1	3.3	10.0	2.4	0.8	7.3	45.8	10.6	6.2	9.1	13.3
2000	10.3	3.9	4.0	9.8	2.7	1.0	10.1	45.7	12.0	8.9	10.8	12.8
2001	7.4	4.7	5.7	9.2	2.5	1.4	5.5	34.5	7.3	8.4	8.7	9.4
2002	5.8	1.8	3.6	5.3	1.9	0.3	1.9	22.5	3.3	7.5	5.4	6.4
2003	2.2	0.1	1.3	4.6	3.0	-1.1	0.8	15.3	8.6	5.6	4.0	4.9
2004	6.4	2.8	3.1	6.8	6.2	1.1	3.6	11.9	7.6	3.6	5.3	3.1
2005	5.0	1.9	4.1	3.6	6.7	2.7	2.1	9.0	2.7	2.5	4.0	2.3
2006	7.3	2.5	4.4	3.9	6.5	3.8	1.1	6.6	4.5	2.5	4.3	2.0
2007	8.4	2.9	6.6	7.9	10.1	5.7	2.4	4.8	2.8	3.6	5.5	2.7
2008	12.4	6.4	10.4	6.1	15.4	10.9	4.4	7.9	4.6	5.7	8.4	3.7
2009	2.8	1.0	0.2	4.2	3.5	4.5	3.9	5.6	1.6	0.9	2.8	1.8
Average	97.7	8.8	78.2	14.2	34.4	92.3	43.3	63.6	10.6	51.1		
Standard dev	239.2	12.3	239.8	9.7	64.9	240.4	122.1	77.1	12.9	127.8		
Average (post-accession period)	7.9	2.9	4.8	4.8	8.1	4.8	2.9	6.1	4.0	3.1		
Std. dev. (post-accession period)	4.8	1.8	3.4	1.8	4.2	4.2	1.2	1.2	2.1	1.6		

Source: International Monetary Fund

Figure 1: Average relative inflation of CEE accession countries, 1990-2009

Note: The line at the origin represents the EU accession benchmark which is measured as the average of the inflation in the three EU member states 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.

Figure 2: Density probability distributions of relative inflation in CEE

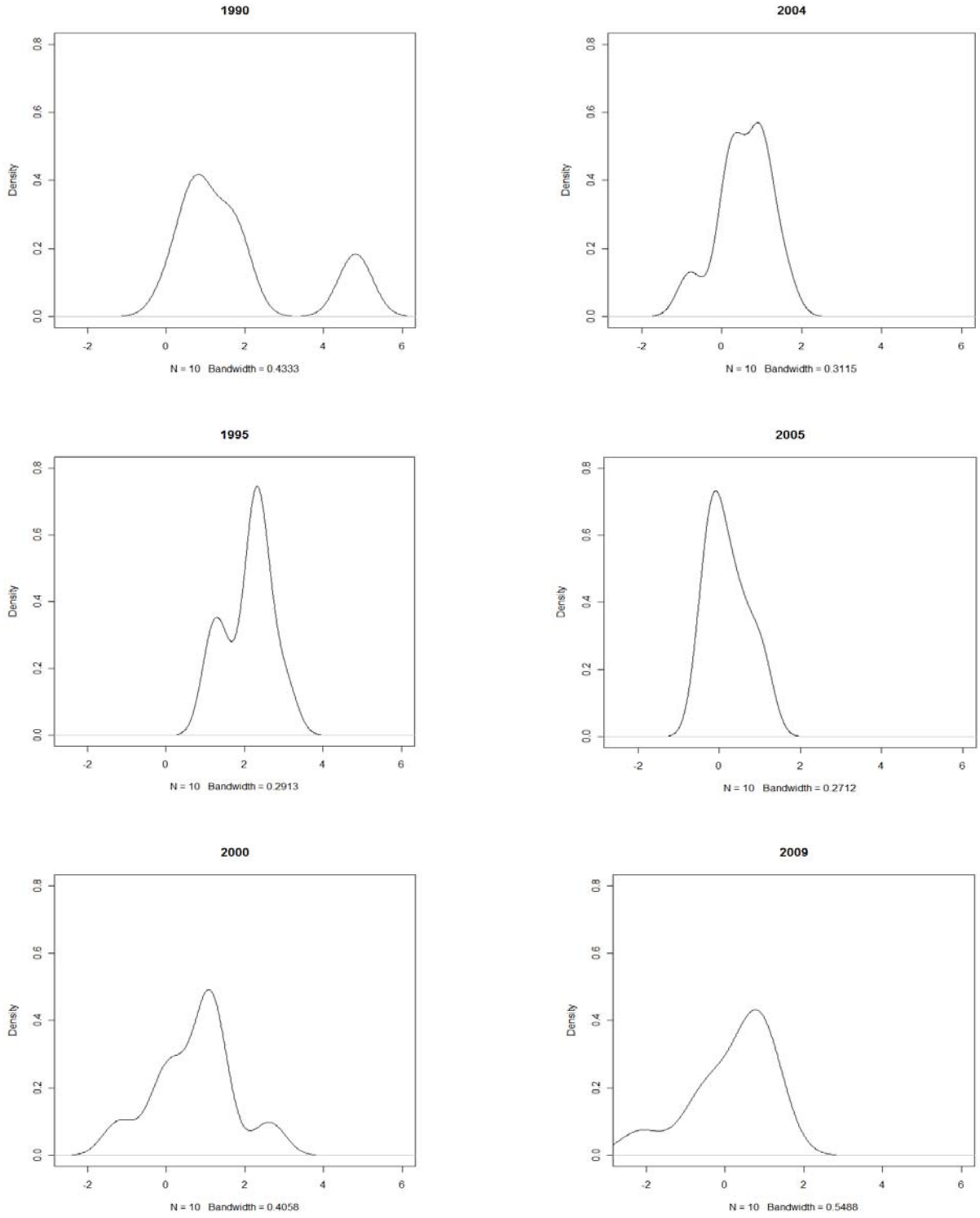


Figure 3: Distribution dynamics of relative inflation, 1990-2009

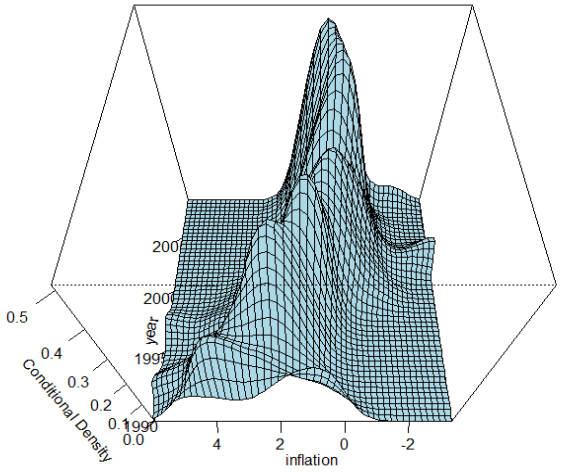


TABLE 2

Markov transition matrices and ergodic distributions, 1990-2009

1-year transitions, 1990-2009

State	[-3.34; 0.40)	[0.40; 1.10)	[1.10; 2.18)	[2.18; 5.96]	n
[-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
n	52	49	44	45	190
Ergodic	0.36	0.27	0.18	0.19	

5-year transitions, 1990-2009

State	[-2.15; 0.20)	[0.20; 1.10)	[1.10; 2.15)	[2.15; 4.82]	n
[-2.15; 0.20)	0.50	0.40	0.00	0.10	10
[0.20; 1.10)	0.20	0.40	0.30	0.10	10
[1.10; 2.15)	0.30	0.20	0.20	0.30	10
[2.15; 4.82]	0.30	0.10	0.40	0.20	10
n	13	11	9	7	40
Ergodic	0.34	0.32	0.20	0.14	

TABLE 3

Markov transition matrices and ergodic distributions by sub-period

1-year transitions, 1990-1997

State	[0.12; 1.70)	[1.70; 2.30)	[2.30; 3.30)	[3.30; 5.95]	n
[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
n	17	19	17	17	70
Ergodic	0.25	0.29	0.23	0.23	

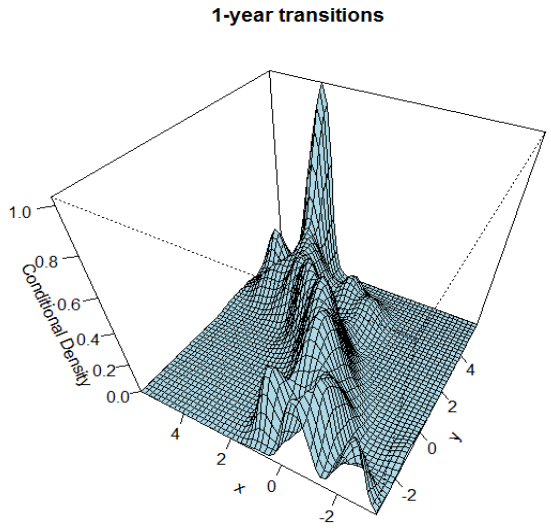
1-year transitions, 1997-2004

State	[-3.35; 0.10)	[0.10; 0.80)	[0.80; 1.30)	[1.30; 5.95]	n
[-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
n	17	21	18	13	70
Ergodic	0.34	0.34	0.24	0.08	

1-year transitions, 2004-2009

State	[-2.14; 0.00)	[0.00; 0.40)	[0.40; 0.90)	[0.90; 1.55]	n
[-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
n	15	8	15	12	50
Ergodic	0.30	0.15	0.30	0.25	

Figure 4: The stochastic kernel of relative inflation dynamics, 1990-2009



Note: 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.

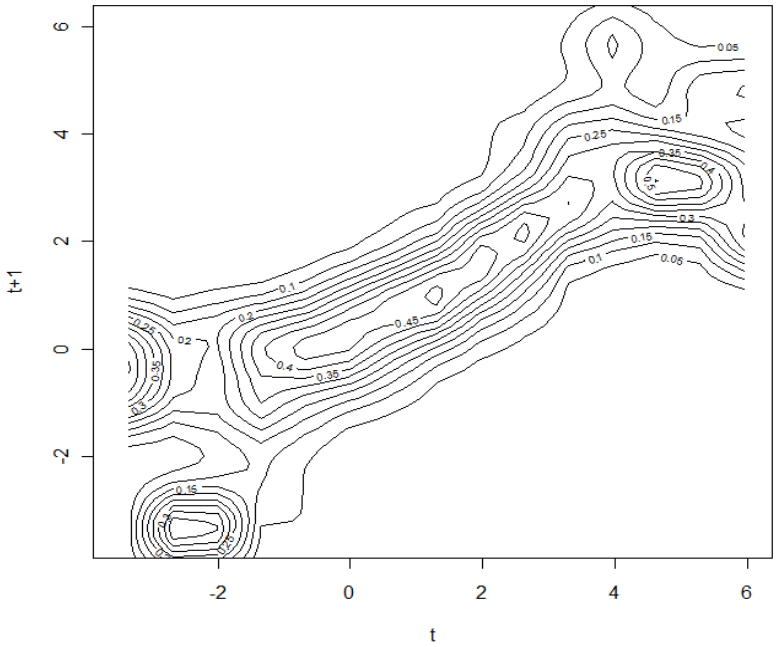


Figure 5: Annual transitions of relative inflation by sub-period